Teaching Scheme and Syllabus

For

Bachelor of Technology

In Mechanical Engineering

Honors in Mechanical Engineering

Department of Mechanical Engineering

Sardar Vallabhbhai National Institute of Technology

Honors in Mechanical Engineering

Sr. No.	Semester	Subject	Code	Scheme	Credit
1.	IV	Experimental Stress Analysis	MEHD1	3-1-0	4
2.	IV	Advanced Fluid Dynamics	MEHT1	3-1-0	4
3.	IV	Smart Materials	MFHM1	3-1-0	4
4.	IV	Solar and Biomass Energy	MEHE1	3-1-0	4
5.	V	Analysis and Synthesis of Mechanisms	MEHD2	3-1-0	4
6.	V	Advanced Heat Transfer	MEHT2	3-1-0	4
7.	V	Industry 5.0	MEHM2	3-1-0	4
8.	V	Electric Vehicles and Energy Storage Systems	MEHE2	3-1-0	4
9.	VI	Machinery Fault Diagnosis and Signal Processing	MEHD3	3-1-0	4
10.	VI	Design and Optimization of Thermal Systems	MEHT3	3-1-0	4
11.	VI	Micro and Nano Manufacturing	MEHM3	3-1-0	4
12.	VI	Hydro and Wind Energy	MEHE3	3-1-0	4
13.	VII	Advanced Vibration	MEHD4	3-1-0	4
14.	VII	Design And Analysis of Rotodynamic Machines	MEHT4	3-1-0	4
15.	VII	Metal Additive Manufacturing	MEHM4	3-1-0	4
16.	VII	Energy Conservation, Management and Audit	MEHE4	3-1-0	4

B.Tech. II (DoME) Semester – 4 EXPERIMENTAL STRESS ANALYSIS (HONORS) MEHD1	Scheme	L	T	P	Credit
		3	1	0	04

1. **Course Outcomes (COs):** **At the end of the course, students will be able to**	
CO1	Describe the basic principles of Elasticity.
CO2	Analyse the fixed and continuous beams.
CO3	Analyse Statically Indeterminate Structures and Estimate the stresses in rotating elements
CO4	Evaluate stress and strain of mechanical systems using electrical resistance strain gauges.
CO5	Apply the photo elastic technique for principal stress measurement on 2-D and 3-D objects.
CO6	Analyze various brittle coating techniques and Moire Fringes Technique

2.	**Syllabus**	
	ELEMENTARY ELASTICITY	**(08 Hours)**
	Introduction, Stress Tensor, Stress at a Point, Plane Stress Condition, Strain Tensor, Plane Strain Condition, Deformations, Generalized Hooke's Law, Equilibrium Equations, Pure Bending.	
	BEAMS	**(08 Hours)**
	Fixed Beams: Introduction, Fixed Beam-bending Moment Diagram, Fixed Beam-support Moments, Fixed Beam with a Concentrated Load at Centre, Fixed Beam with Uniformly Distributed Load Throughout Its Length, Fixed Beam with an Eccentric Load, Effect of Sinking of a Support in a Fixed Beam, Effect of Rotation of a Support in a Fixed Beam Continuous Beams: Introduction, Clapeyron's Theorem of Three Moments, Theorem of Three Moments—Any Type of Loading, Continuous Beam with Fixed End.	
	STATICALLY INDETERMINATE STRUCTURES & ROTATIONAL STRESSES	**(08 Hours)**
	Statically Indeterminate Structures: Introduction, Analysis of Redundant Frames with Strain Compatibility Condition, Degree of Redundancy, Analysis of Statically Indeterminate Trusses Rotational Stresses: Introduction, Rotating Ring, Stresses in a Thin Rotating Disc, Disc of	

	Uniform Strength, Stresses in Rotating Long Cylinders, Temperature Stresses in a Thin Disc	
	STRAIN GAUGES	**(08 Hours)**
	Strain Gauges: Introduction**,** Electrical Resistance Strain Gauge**,** Gauge Sensitivities and Gauge Factor**,** Temperature Compensation**,** Parameters Influencing the Behaviour of Strain Gauge**,** Rosette Analyses**,** Electrical Circuits**,** Semiconductor Strain Gauges**,** Stress Gauge.	
	PHOTOELASTICITY	**(08 Hours)**
	Photoelasticity: Introduction, Stress Optic Law, Properties of Light, Plane Polariscope, Properties of Isoclinic Fringes, Circular Polariscope, Compensation Techniques Fringe Sharpening by Partial Mirrors, Fringe Multiplication by Partial Mirrors, Separation Techniques, Stresses in Prototype, Three Dimensional Photoelasticity.	
	BRITTLE COATING TECHNIQUES	**(05 Hours)**
	Brittle Coating Technique: Introduction, Coating Stresses, Failure Theories, Crack Patterns in Brittle Coating, Refrigeration Technique, Load Relaxation Technique, Crack Detection, Types of Brittle Coating, Equipment for Brittle Coating Method, Preparation of Specimen, Testing Procedure, Calibration of Brittle Coating Moire Fringes Technique: Introduction, Strain Analysis Through Moire Fringes, Geometrical Approach, Displacement Approach	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	U. C. Jindal, Experimental Stress Analysis, Pearson Education India, 2012.
2	A. W. Hendry, Elements of Experimental Stress Analysis Structures and Solid, Elsevier Science, 2013.
3	J. Srinivas, Stress Analysis and Experimental Techniques, Alpha Science International Limited, 2012.
4	K. Ramesh, Digital Photoelasticity Advanced Techniques and Applications, Springer Berlin Heidelberg], 2012.
5	C. A. Sciammarella, F. M. Sciammarella, Experimental Mechanics of Solids, Wiley, 2012.

B.Tech. II (DoME) Semester – 4 ADVANCED FLUID DYNAMICS (HONORS) MEHT1	Scheme	L	T	P	Credit
		3	1	0	04

1. **Course Outcomes (COs):** **At the end of the course, students will be able to**	
CO1	Model fluid flow through Cartesian and Cylindrical domain.
CO2	Develop exact solution of Navier-Stokes equations for simplified flows.
CO3	Elaborate the Concept of lift and drag using Potential flow theory.
CO4	Evaluate the drag due to the boundary layer shear
CO5	Develop models for turbulent flows.
CO6	Comprehend the concepts of rotating and swirling flows

2.	**Syllabus**	
	MODELLING OF FLUID MOTION	**(10 Hours)**
	Lagrangian and Eulerian description for fluids, Reynolds transport theorem, Integral and differential forms of model transport equations: mass, momentum and energy Conservation equations, Cartesian Tensors, Stokes hypothesis for stress tensor, Navier-Stokes equations in Cartesian and cylindrical frame.	
	EXACT SOLUTIONS OF NAVIER-STOKES EQUATIONS	**(06 Hours)**
	Fully developed flow between parallel plates in Cartesian domain, fully developed flow through cylindrical pipes, Flow between concentric rotating cylinders, Parallel flow of a power law fluids, Stratified flow of two fluids.	
	POTENTIAL FLOWS	**(06 Hours)**
	Potential function, Circulation, Line vortex, Basic plane potential flows: Uniform stream; Source and Sink; Vortex flow, Doublet, Superposition of basic plane potential flows, Flow past a circular cylinder, concept of lift and drag.	
	BOUNDARY LAYER FLOWS	**(06 Hours)**
	Boundary layer behaviour and device performance, boundary layer equations for plane and curved surfaces, Von-Karman Momentum Integral Equation, Blasius solution, Boundary	

	Layers with non-zero pressure gradient, separation and vortex shedding.	
	TURBULENT FLOW MODELLING	**(10 Hours)**
	Mechanism of turbulence, Kolmogorov scale, Kinetic energy of the mean flow and fluctuations, turbulent intensity, Reynolds Averaged Navier-Stokes (RANS) equations, turbulent stresses, Eddy viscosity, Prandtl mixing length model, K-Epsilon model of turbulence, Universal velocity distribution law and friction factor, Concept of Large Eddy Simulations (LES) and Direct Numerical simulations (DNS).	
	FLOW IN ROTATING PASSAGES AND SWIRLING FLOWS	**(07 Hours)**
	Rotating coordinate systems and Coriolis accelerations, Conserved quantities in a steady rotating flow, Phenomena in flows where rotation dominates, Swirling flows in radial equilibrium flows, steady vortex core flows	
	(Total Contact Time: = 45 Hours)	

3.	Books Recommended
1	Muralidhar K and Biswas G, Advanced Engineering Fluid Mechanics, Narosa Publication, New Delhi, 2013.
2	Greitzer, E. M., Tan, C. S., Graf, M. B. “Internal Flow Concepts and Applications”. Cambridge University Press, Cambridge, United Kingdom, 2007
3	Schlichting H., “Boundary layer Theory”, McGraw Hill, NY, USA, 2016
4	White, Frank M., and Joseph Majdalani. Viscous fluid flow. Vol. 3. New York: McGraw-Hill, 2006
5	Anderson Jr. John D., “Fundamentals of Aerodynamics”, McGraw-Hill, NY, USA, 2010

B.Tech. II (DoME) Semester – 4 SMART MATERIALS (HONORS) MEHM1	Scheme	L	T	P	Credit
		3	1	0	04

1. **Course Outcomes (COs):** **At the end of the course, students will be able to**	
CO1	Describe the basic definition and classification of smart materials.
CO2	Explain Principle and Mechanisms of various smart materials.
CO3	Analyse, interpret and study the processing of smart materials.
CO4	Illustrate the Characterisation techniques of smart materials.
CO5	Describe the utilization of smart materials in engineering applications.
CO6	Apply fundamentals of smart materials and solve the existing problem in various applications using smart materials

2.	**Syllabus**	
	INTRODUCTION:	**(05 Hours)**
	Introduction to materials, Fundamentals on mechanics and electrostatics: Basic mechanics of materials: stress and strain, Basic electrostatics Introduction to smart materials and structures: Types of structures, Types of smart structures, Traditional v/s Smart systems, Classification of smart materials, Active and Passive smart Materials, Current applications of smart materials and challenges	
	PIEZOELECTRIC MATERIALS:	**(12 Hours)**
	Piezoelectric ceramic materials: Introduction, background, Piezoelectric theory, Piezoelectric Effects: Direct and Inverse Piezoelectric Effect, Mechanism, Manufacturing of Piezoelectric materials, Constitutive Relationships, Ferroelectric Properties and Its Contribution to Piezoelectricity, hysteresis loop, Typical Properties of Common Piezoelectric Materials: Coupling factor, Piezoelectric constants and coefficients, Challenges in Measuring Piezoelectric Properties, Measurement of Direct Piezoelectric Coefficient Using the Berlincourt Method, Measurement of Converse Piezoelectric Coefficient by Laser Interferometer, Resonance and Anti-resonance Method. **Piezoelectric Polymeric materials:** Introduction, background, Mechanism of Piezoelectric Polymer, Classification of piezoelectric polymers, Structure and piezoelectric properties of	

	different piezoelectric polymer, The effect of materials processing on properties of polymers, Characterisations of Piezoelectric materials, Comparison the typical Properties between piezoelectric ceramics and polymers, Problems with piezoelectric materials, Characterisation of piezoelectric Ceramics and polymers, Current applications of piezoelectric ceramic and polymeric materials as sensors and actuators.	
	MAGNETO STRICTIVE AND ELECTRO STRICTIVE MATERIALS:	**(04 Hours)**
	Introduction, Mechanism, Joule effect, Villari effect, Wiedemann Effect, Matteuci effect, Nagaoka–Honda effect, Magnetovolume effect, Properties of Magnetostrictive and Electrostrictive Materials, Magnetostrictive models, Synthesis of Magnetostrictive Materials: Directional Solidification Methods, Rapid Quenching Method, and others, Characterisation techniques, Methods of Magnetostrictive Property Measurement: Direct and Indirect Methods, Applications of Magneto strictive and Electro strictive materials as a sensors and actuators.	
	SHAPE MEMORY MATERIALS:	**(13 Hours)**
	Shape memory alloys: Introduction, Background on phase transition, The shape-memory effect, Mechanism, one–way SME, Pseudo elasticity, two–way SME, Super elasticity, Constitutive equations, Role of Transition temperature and hysteresis on application of SMA's, Applications of SMA, Nitinol, Copper-based SMA's, and Iron-based SMA's. magnetic shape memory alloys, Composite Materials, Hybrid Composite, Other SMA materials. Materials processing and Manufacturing of SMA. Shape memory polymers: Introduction, Mechanism, Materials processing and Manufacturing Methods, Comparison the typical Properties between shape memory alloys and polymers, Challenges with shape memory alloys and polymers, Characterisation of shape memory alloys and polymers. Applications (e.g., aerospace, biomedical, industrial, sensing, etc.) Single crystals and Polycrystalline, Manufacturing methods of single crystal, Applications. Electro-active materials, Dielectric Elastomer, Electronic materials, Electro-active polymers, Ionic polymer matrix composite (IPMC), Self-healing materials, Characterisation techniques, Applications.	
	ELECTRO RHEOLOGICAL AND MAGNETO RHEOLOGICAL FLUIDS:	**(06 Hours)**
	Introduction, Mechanisms and Properties, Characteristics, Fluid composition and behaviour, Discovery and Early developments, Summary of material properties. Models of ER/MR Fluid behavior & device performance, Characterisation techniques, Applications of ER and MR fluids (Clutches, Dampers, others). Chromic materials – thermochromic, photochromic, piezochromic, materials and their applications.	
	CASE STUDIES:	**(5 Hours)**

	Performance of different smart materials in biomedical device, energy harvesting, aerospace, and robotics applications, etc.
	(Total Contact Time: = 45 Hours)

3.	**Books Recommended**
1	A.V. Srinivasan, Smart Structures –Analysis and Design, 1st Edition, Cambridge University Press, New York, 2001
2	M. V. Gandhi and B. S. Thompson, Smart Materials and Structures, Chapman & Hall, London, 1992.
3	C. Brian, Smart Structures and Materials, Artech House, 2000.
4	P. Gauenzi, Smart Structures, Wiley, 2009.
5	W. G. Cady, Piezoelectricity, Dover Publication, New York, 2014.

B.Tech. II (DoME) Semester – 4 SOLAR AND BIOMASS ENERGY (HONORS) MEHE1	Scheme	L	T	P	Credit
		3	1	0	04

1. **Course Outcomes (COs):** **At the end of the course, students will be able to**	
CO1	Explain the principles of solar radiations and its geometry.
CO2	Compare the performance of solar collectors.
CO3	Comprehend the solar energy storage systems along with its applications.
CO4	Characterize different biomass feed stocks based on its constituents and properties.
CO5	Evaluate various biomass pretreatment and processing techniques in terms of their applicability for different biomass type for biomass conversion processes.
CO6	Understand basics of biofuels, their production technologies and applications in various energy utility routes.

2.	**Syllabus**	
	SOLAR RADIATION	**(08 Hours)**
	Introduction, Extra-terrestrial and terrestrial, Solar radiation measuring instruments, Estimation of Solar Radiation, Various earth-sun angles, Solar radiation data, Solar radiation geometry, Predicting the availability of solar radiation, solar radiation on tilted surface	
	SOLAR COLLECTORS	**(08 Hours)**
	General aspects, Collectors in various ranges and its applications, Collection systems, Characteristic features of a collector system, Factors affecting collector systems efficiency, Types of collectors, Performance evaluation of Concentrating Flat plate Collectors and Concentrating Collectors	
	SOLAR ENERGY STORAGE AND APPLICATIONS	**(07 Hours)**
	Energy storage system, Classification of solar energy storage systems, Solar pond, Solar pond electric power plant. Solar energy application, Solar water heating: Natural and forced circulation solar water heater, Space heating and cooling, Solar distillation, Solar pumping, Solar air heaters and	

	drying, Solar cooking, Solar furnace, Solar greenhouses, Solar power plants, Solar photovoltaic systems (SPV), Solar photovoltaic cells, SPV Lighting systems.	
	BIOMASS	**(07 Hours)**
	Biogas System: Anaerobic digestion, biogas production, Types of digesters, installation, operation and maintenance of biogas plants, Biogas plant manure utilisation and manure values, factors affecting biogas production, Biogas utilisation and storage, Compressed Biogas (CBG) production from agro waste; biogas for motive power generation, design calculations for biogas plants, Govt. policies	
	BIOENERGY	**(10 Hours)**
	Biogas System: Anaerobic digestion, biogas production, Types of digesters, installation, operation and maintenance of biogas plants, Biogas plant manure utilisation and manure values, factors affecting biogas production, Biogas utilisation and storage, Compressed Biogas (CBG) production from agro waste; biogas for motive power generation, design calculations for biogas plants, Govt. policies	
	BIODIESEL AND ETHANOL	**(05 Hours)**
	Liquid Biofuels: Biodiesel – The mechanism of transesterification, fuel characteristics of biodiesel, technical aspects of biodiesel/Ethanol and other liquid fuels utilization in engine.	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	J. A. Duffie and W.A. Beckman, Solar Engineering and Thermal Processes, John Wiley and Sons., 2013
2	Sukhatme S., Nayak J: Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 3rd edition, 2008
3	H. S. Mukunda, Understanding Clean Energy and fuels from biomass. Wiley India Pvt. Ltd, 2011
4	K. M. Mital, Biogas Systems, Principle and Applications. New Age International Ltd, 1996
5	G. D. Rai, Non-Conventional Energy Sources, Khanna Publication, 1988

B.Tech. III (DoME) Semester – 5 ANALYSIS AND SYNTHESIS OF MECHANICS (HONORS) MEHD2	Scheme	L	T	P	Credit
		3	1	0	04

2. Course Outcomes (COs): At the end of the course, students will be able to	
CO1	Illustrate the fundamentals of kinematics of different mechanisms.
CO2	Analyze the kinematics of planar and spatial mechanisms containing different number of links.
CO3	Apply the principles of path curvature theory to design different mechanisms.
CO4	Synthesize and evaluate different mechanisms using graphical and analytical methods.
CO5	Analyze the dynamics of different mechanisms and use simulation software packages.
CO6	Understand the different softwares for dynamic analysis.

2.	Syllabus	
	INTRODUCTION	**(08 Hours)**
	Review of fundamentals of kinematics; Classifications of mechanisms; Components of mechanisms; Mobility analysis; Formation of one degree-of-freedom (DOF) multi-loop kinematic chains; multi-DOF planar linkages; Network formula; Gross motion concepts; Basic kinematic structures of serial and parallel robot manipulators; Compliant mechanisms; Equivalent mechanisms	
	KINEMATIC ANALYSIS OF MECHANISMS	**(08 Hours)**
	Position Analysis; Vector loop equations for four bar, slider-crank, inverted slider-crank, geared five bar, and six bar linkages; Analytical methods for velocity and acceleration analysis of simple mechanisms; Analysis of planar complex mechanisms; Spatial RSSR mechanisms; D-H parameters; Forward and inverse kinematics of robot manipulators	
	PATH CURVATURE THEORY	**(07 Hours)**
	Fixed and moving centrodes; Inflection points and inflection circle; Euler-Savary equation; Graphical constructions – cubic of stationary curvature; Four bar coupler point curves; Cusp-crunode-coupler driven six-bar mechanisms	
	SYNTHESIS OF MECHANISMS	**(15 Hours)**
	Type synthesis; Number synthesis; Associated linkage concept; Dimensional synthesis; Function generation; Path generation; Motion generation; Graphical methods; Pole	

	technique; Inversion technique; 2-, 3-, and 4- position synthesis of four bar mechanisms; Analytical methods- Freudenstein's equation; Cognate linkages; Parallel motion linkages; Design of six bar mechanisms with single and multi-dwells; Geared five bar mechanism with multi-dwell; Determination of optimum size of cams.	
	DYNAMICS OF MECHANISMS	**(07 Hours)**
	Combined static and inertia force analysis; Kinetostatic analysis of planar mechanisms; Force and moment balancing of linkages; Study of different mechanism simulation software packages	
		(Total Contact Time: = 45 Hours)

3.	**Tutorials**
1	Mobility analysis
2	Formation of multi-DOF planar linkages
3	Kinematic structures of serial and parallel robot manipulators
4	Compliant mechanisms
5	Analytical methods for velocity and acceleration analysis of planar mechanisms
6	Analysis of planar complex mechanisms
7	Forward and inverse kinematics of robot manipulators
8	Graphical construction – four bar coupler point curves
9	Graphical construction – cubic of stationary curvature
10	Graphical methods of synthesis of mechanisms
11	Analytical methods of synthesis of mechanisms
12	Combined static and inertia force analysis

4.	**Books Recommended**
1	K. J. Waldron, G. L. Kinzel, and S. K. Agrawal. Kinematics, Dynamics and Design of Machinery, 3rd Edition, John Wiley, 2016
2	J. J. Uicker, G. R. Pennock, and J. E. Shigley. Theory of Machines and Mechanisms, 4th Edition, Oxford University Press, London, 2014
3	D. H. Myszka. Machines and Mechansims: Applied Kinematic Analysis, 4th Edition, Pearson Education India, New Delhi, 2015
4	A. Ghosh and A. K. Mallik. Theory of Mechanisms and Machines, Affiliated East West Press, New Delhi, 2008
5	E. Constans and K. B. Dyer. Introduction to Mechanism Design with Computer Applications, 1st Edition, CRC Press, Boca Raton, 2019

B.Tech. III (DoME) Semester – 5 ADVANCED HEAT TRANSFER (HONORS) MEHT2	Scheme	L	T	P	Credit
		3	1	0	04

2. Course Outcomes (COs): At the end of the course, students will be able to	
CO1	Model heat transport phenomena in Cartesian and Cylindrical domain
CO2	Develop analytical solutions for hat conduction with heat generation
CO3	Elaborate the concept of bulk radiation and radiative transport equation
CO4	Analyse flows with free for forced convective heat transfer
CO5	Develop analogy between momentum and heat transfer
CO6	Comprehend the concepts of boiling and condensation

2.	Syllabus	
	CONDUCTION HEAT TRANSPORT	**(10 Hours)**
	Control volume approach, constitutive relations, Energy equation in terms of temperature, Implication of Fourier's law: principles of local action and determinism, Tensor and scalar conductivities, second law analysis of Fourier's law of heat conduction, Expanded form of heat conduction equation in various coordinate systems. Non-dimensional form and dimensionless parameters, Initial and boundary conditions: Dirichlet, Neumann and Robin boundary conditions, radiation BC, treatment of interfaces.	
	ANALYTICAL SOLUTION OF THE HEAT CONDUCTION EQUATION	**(07 Hours)**
	Analytical solution of the steady heat conduction equation: two dimensional regions (Cartesian and cylindrical), Separation of Variables approach, Steady and unsteady heat conduction in a slab of finite thickness; effect of heat generation; non-zero initial condition; constant flux and convective boundary conditions, Analytical solution of the unsteady heat conduction equation, Solution by similarity variables and Laplace transforms.	
	RADIATION HEAT TRANSPORT	**(10 Hours)**
	Radiation Heat Exchange between surfaces —Gas Radiation —Equivalent beam length, Enclosure theory in the presence of a radiating gas, Radiative Transfer Equation, General and Exact solution of RTE, Isothermal gas enclosures, Well-stirred furnace model, Gas radiation in complex enclosures, Interaction between radiation and other modes of heat transfer.	

	CONVECTIVE HEAT TRANSFER	**(10 Hours)**
	Free and Forced convection; Similarity and Simulation of convection heat transfer, use of Boundary layer theory; Laminar internal and external flow heat transfer, Turbulent flow heat transfer; Analogy between momentum and heat transfer. Heat transfer in high velocity flow; Natural convection under different Engineering applications	
	CONVECTIVE HEAT TRANSFER WITH PHASE CHANGE	**(08 Hours)**
	Condensation: Laminar film on a vertical surface, turbulent film on a vertical surface, Film condensation in other configurations, dropwise condensation, effect of non-condensable gases in condensing equipment's; Boiling: Pool boiling regimes, Nucleate boiling and peak heat flux, Film boiling and minimum heat flux, Flow boiling	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	Muralidhar K and Banerjee Jyotirmay, Conduction and Radiation, Narosa Publication New Delhi, 2010.
2	Incropera and Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley, USA, 2011.
3	Greg F. Naterer, Advanced Heat Transfer, 3rd Edition, CRC Press, 2021
4	Amir Faghri, Yuwen Zhang, John Howell, Advanced Heat and Mass Transfer, Global Digital Press, 2010
5	Biswas G, Dalal Amaresh, Dhir V K, Fundamentals of Convective Heat Transfer, CRC Press, 2019.

B.Tech. III (DoME) Semester – 5 INDUSTRY 5.0 (HONORS) MEHM2	Scheme	L	T	P	Credit
		3	1	0	04

2. Course Outcomes (COs): At the end of the course, students will be able to	
CO1	Explain the important technological innovations of industrial revolutions 1.0 to 4.0.
CO2	Describe the characteristics, essence, and added features of Industry 4.0
CO3	Describe the characteristics, essence, and added features of Industry 5.0
CO4	Apply the enabling technologies of Industry 5.0
CO5	Analyse the challenges of Industry 5.0
CO6	Illustrate the applications of Industry 5.0

2.	Syllabus	
	TECHNOLOGICAL INNOVATIONS OF INDUSTRIAL REVOLUTIONS 1.0 TO 4.0	**(08 Hours)**
	First and second industrial revolutions; Third industrial revolution, programmable logic controllers, SCADA, industrial robots; Fourth industrial revolution, internet of things (IoT), industrial internet of things (IIoT), 3D printing, virtual reality (VR), augmented reality (AR), big data analytics, simulation; Review of existing maturity models for Industry 4.0	
	CHARACTERISTICS, ESSENCE, AND ADDED FEATURES OF INDUSTRY 5.0	**(12 Hours)**
	Motivations behind the evolution of Industry 5.0; Definition of Industry 5.0; Characteristics of Industry 5.0, human centricity, sustainability, resilience; Essence of Industry 5.0, collaborative intelligence, multi-objective interweaving, multi-technology restructuring, multi-discipline integration, multi-sector symbiosis, multi-systems heterogeneity; Added features of Industry 5.0: smart additive manufacturing, predictive maintenance, hyper customization, cyber-physical cognitive systems, waste management through industrial upcycling, collaborative robots, artificial intelligence; Benefits of industry 5.0.	
	ENABLING TECHNOLOGIES AND CHALLENGES OF INDUSTRY 5.0	**(16 Hours)**
	Cloud computing; Edge computing; Digital twins and metaverse; Collaborative robots (Cobots); Internet of everything (IoE); Blockchain and decentralized computing; 6G and beyond; Network slicing (NS); Extended reality (XR) and holography; Private mobile network	

	(PMN); Advanced sensors; Drones; Machine-to-machine interaction; Ergonomics and bionics; Human-centric AI architecture, mutual-cognitive human-robot collaboration in factory, skilled workforce, cognitive computing skills with human intelligence and resourcefulness; Implementation challenges and limitations of Industry 5.0, social barriers, transformation challenges, technological challenges, challenges related to data storage, security, and privacy, additive manufacturing scalability, chaos in human-robot collaboration, and regulatory compliance	
	APPLICATIONS OF INDUSTRY 5.0	**(09 Hours)**
	Automotive sector; Hi-tech electronics industrial sector; Processing and industrial manufacturing sectors; Energy sector; Education sector; Supply chain management, Intelligent healthcare, Disaster management; Future directions of Industry 5.0	
		(Total Contact Time: = 45 Hours)

3.	**Books Recommended**
1	U. Elangovan. Industry 5.0: The Future of the Industrial Economy, CRC Press, Boca Raton, 2022.
2	M. N. Bakkar and E. McKay. Advanced Research and Real-World Applications of Industry 5.0, IGI Global, Pennsylvania, 2023.
3	P. Sharma, India Automated: How the Fourth Industrial Revolution is Transforming India. Macmillan, Mumbai, 2019.
4	K. Kotecha, S. Kumar, A. Bongale, and R. Suresh. Industry 4.0 in Small and Medium-Sized Enterprises (SMEs), CRC Press, Boca Raton, 2022.
5	H. Allam, H. Arezou, B. Ameena, A. Pallavi, and A. Hala. From Industry 4.0 to Industry 5.0: Mapping the Transitions, Springer, Singapore, 2023.

B.Tech. III (DoME) Semester – 5 ELECTRIC VEHICLES AND ENERGY STORAGE SYSTEMS (HONORS) MEHE2	Scheme	L	T	P	Credit
		3	1	0	04

2. Course Outcomes (COs): At the end of the course, students will be able to	
CO1	Get acquainted with the types of EVs, their comparison with ICE Vehicles and general aspects of major components of EV including architecture design.
CO2	Apply basic know how of electric, electronic and battery fundamentals to solve related problems linked with EV.
CO3	Evaluate performance of Li Ion batteries and work out problems pertaining to various aspects of EV Batteries.
CO4	Explain the performance of electric motors, control units, BMS systems and calculate the sizing requirement.
CO5	Explain the mechanical aspects and EV charging related aspects of EV.
CO6	Work out prospects of EVs taking into account economics, various Policies safety aspects of EVs.

2.	Syllabus	
	INTRODUCTION TO ELECTRIC VEHICLES	**(08 Hours)**
	Historical Developments in Hybrid Electric Vehicles and Electric Vehicles. Prospects and Challenges of EVs, Comparison of EVs with I C Engines vehicles, Advantages and disadvantages of electric vehicles, Major components of Electric Vehicles. Types of Electric Vehicle and components, Electric Vehicle Architecture Design, Electrical protection and system requirement, Photovoltaic solar based EV design, Battery Electric vehicle (BEV), Hybrid electric vehicle (HEV), Plug-in hybrid vehicle (PHEV), Fuel cell electric vehicle (FCEV), Electrification Level of EV.	
	EV POWER TRAIN	**(08 Hours)**
	Basic components like Battery, DC-AC Converters, Electric Motors, DC-DC Converters, Transmissions and ECUs. Battery and Motor Selection, Calculations for Motor and battery sizing for EV for Two, Three and Four Wheeler Applications, Thermal Management of Battery, Initial acceleration, rated vehicle velocity, maximum velocity and maximum gradeability of EV, Basic architecture of EV Drive Train	
	BATTERY FUNDAMENTALS	**(08 Hours)**
	Dry Cell, Wet Cell, Vehicle Batteries, Functions of Batteries, Construction of Lead Acid Battery, Battery Grids, Electrolyte, Container, Cell Cover, Vent Plug, Cell and Battery Arrangement, Electrochemical Action, Charging and Discharging, Basics of Alkaline Battery, Nickel Cadmium Battery, Nickel Metal Hydride Battery, Sodium Sulphur Battery, Aluminium Air Battery,	

	Battery selection criteria. Jump starting, Boost charging, Maintenance Free Battery, Good practices for battery extended life.	
	LITHIUM-ION BATTERY FOR EV	**(08 Hours)**
	Why Li-Ion Battery, Advantages over other conventional Batteries, Charging and Discharging reactions, Battery Performance Assessment, Battery Characteristics, Battery Terminology - Battery Ratings and Capacity, Cyclic Life, Thermal Run Away, Battery Efficiency, Battery Testing, Battery charging and discharging calculation, Cell Selection and sizing, Battery lay outing design, Battery Pack Configuration, Battery Pack material and design consideration, Construction, Battery Pack Sizing, Thermal Design of Battery Pack, Heat Load Determination and Thermal Management of Battery. Alternative energy storage devices	
	EV CHARGING TECHNOLOGY	**(08 Hours)**
	Classification of different charging technology for EV charging station, introduction to Grid-to-Vehicle, Vehicle to Grid (V2G) or Vehicle to Buildings (V2B) or Vehicle to Home (V2H) operations, bi-directional EV charging systems, energy management strategies used in hybrid and electric vehicle, Wireless power transfer (WPT) technique for EV charging, Type of Charging station, Selection and Sizing of charging station, Components of charging station, Single line diagram of charging station, Charging and Energy Infrastructure Planning, Depot Infrastructure and Equipment Planning, Charging and Swapping Infrastructure	
	MECHANICAL ASPECTS OF EV	**(05 Hours)**
	Calculating the Rolling Resistance, calculating the grade resistance, Calculating the Acceleration Force, Finding The Total Tractive Effort, Torque Required on the Drive Wheel, Drive Cycle and Energy requirement per km calculations, Chassis and body considerations for EV and HEV, Steering System for EV and HEV, Suspension system for EV and HEV, Braking Systems for EV, Tyres for EVs, Material and Manufacturing considerations in EV/HEV. EV in Bus and Truck segment	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004
2	Babu A K, Electric and Hybrid Vehicles, Khanna Book Publishing, 2023.
3	Babu A K, Automotive Electrical and Electronics, Khanna Book Publishing, 2024
4	Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2010.
5	James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

B.Tech. III (DoME) Semester – 6 MACHINERY FAULT DIAGNOSIS AND SIGNAL PROCESSING (HONORS) MEHD3	Scheme	L	T	P	Credit
		3	1	0	04

1. **Course Outcomes (COs):** **At the end of the course, students will be able to**	
CO1	Apply condition monitoring methods for fault diagnosis in machines.
CO2	Study the vibration signals from rotating machines.
CO3	Illustrate the vibration signals from reciprocating machines.
CO4	Analyse the signals from rotating and reciprocating machines.
CO5	Apply fault detection techniques for fault diagnosis in rotating machines.
CO6	Illustrate the instrumentation in fault diagnosis of machines.

2.	**Syllabus**	
	INTRODUCTION	**(20 Hours)**
	Introduction to condition based monitoring, fault diagnosis and prognosis, machine learning in fault diagnosis. Condition Monitoring Techniques: Vibration and noise monitoring, wear debris and oil analysis, thermography, acoustic emission, ultrasonic, Eddy current. Vibration Analysis: Basics of vibration, free and forced response, vibration control, random vibration, statistical parameters i.e. RMS value, peak value, crest factor, kurtosis, standard deviation of vibration signals. Vibration Signals from Rotating Machines: Signal classification, signals generated by rotating machines, low shaft orders and subharmonics, vibrations from gears, rolling element bearings and electrical machines. Vibration Signals from Reciprocating Machines: Signals generated by reciprocating machines time-frequency diagrams, torsional vibrations.	
	SIGNAL PROCESSING	**(10 Hours)**

	Sample rate and aliasing, filtering, time domain signal analysis, frequency domain signal analysis, non-stationery signal analysis, Fourier series, Fast Fourier Transform, wavelet transform, Hilbert transform, modulation and sidebands, orbit and order analysis, cepstrum analysis.	
	FAULTS IN ROTATING MACHINES	**(15 Hours)**
	Faults in Rotating Machines: Unbalance, misalignment, crack, spalling, loosening, fault in electrical machines. Failure analysis of rotating machines, bearings and gears, fans, blowers, pumps, IC Engines. Instrumentation: Data recording, data acquisition, errors in measurements, transducers, accelerometer, sound level meter.	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	A. R. Mohanty, Machinery Condition Monitoring: Principles and Practices, CRC Press, 2014.
2	J. S. Rao, Vibration Condition Monitoring, Narosa Publishing House, 2nd Edition, 2000.
3	K. K. Choudary, Instrumentation, Measurement and Analysis, Tata McGraw Hill, 2012.
4	R. B. Randall, Vibration-based Condition Monitoring: Industrial, Automotive and Aerospace Applications, Wiley, 2021.
5	B. K. N. Rao and A. Davies, Handbook of Condition Monitoring: Techniques and Methodology, Springer Netherlands, 1998.

B.Tech. III (DoME) Semester – 6 DESIGN AND OPTIMIZATION OF THERMAL SYSTEMS (HONORS) MEHT3	Scheme	L	T	P	Credit
		3	1	0	04

1. **Course Outcomes (COs):** **At the end of the course, students will be able to**	
CO1	Understand the simulation of thermal systems with more than one component involving linear or non-linear equations.
CO2	Apply various methods for both exact and best fits to fit the data.
CO3	Analyse mathematical formulation of optimization problems as applicable to thermal systems.
CO4	Evaluate non-linear optimization problems with both equality and inequality constraints using Lagrange multipliers.
CO5	Evaluate Search methods for solving unconstrained and constrained optimization problems.
CO6	Apply stochastic optimization techniques to thermal system design.

2.	**Syllabus**	
	DESIGN OF THERMAL SYSTEMS	**(08 Hours)**
	Introduction to thermal systems, Design analysis of thermal systems through the flow chart, Identifying the need, Market research, Procedure of Thermal Analysis and Design, Constraints in Design, Workable system and optimum system, Optimum Design.	
	THERMAL SYSTEMS SIMULATION	**(10 Hours)**
	Introduction and uses of simulations, Classes of simulation, Information flow diagrams, Techniques for thermal system simulation: Successive substitution method (Example of heater, Fans, Duct Systems etc.), Newton Raphson method for single and multiple unknowns (Examples of Steam boiler, Feed water heater etc.), System of linear equations: Gauss-Seidal method (Examples from Oil cooler, Chemical reactors etc.).	
	REGRESSION AND CURVE FITTING FOR THERMAL SYSTEMS SIMULATION	**(12 Hours)**
	Need for regression in thermal systems simulation and optimization, Concept of best fit and exact fit, Exact fit and its types: Lagrange interpolation (Example of Heat Transfer from wall), Newton's divided difference (Example of Viscosity as function of temperature), Strategies for	

	best fit, Least Square Regression (Example of Turbulent flow in a pipe, cooling of ball bearing etc.), Linear regression with one and more unknowns, Non-linear least squares: Gauss-Newton Algorithm (Example of Lumped capacitance method etc.)	
	OPTIMIZATION OF THERMAL SYSTEMS	**(15 Hours)**
	Formulation of optimization problems (Example of Refinery plant), Representation of optimization problems, Optimization techniques: Calculus methods and search methods, Ex: Solar collector, Steam power plant, Calculus method: Lagrange multiplier (Example of Shell and Tube Heat Exchanger, Constrained and unconstrained optimization problems (Examples on energy systems), Tests for maxima/minima (Examples of Solar water heater problems, Flow in pipe network etc.), Handling in equality constraints, Kuhn-Tucker condition Search methods: Unimodal function, Exhaustive search method (Example of Solar water heater problem), Dichotomous search method, Fibonacci series search method (Example of Water heater storage), Golden section method (Example of Heat dissipation problem), Multivariable unconstrained problem. Linear programming and dynamic programming (Example of Refining plant, Steam turbine etc.) Non-traditional optimization techniques: Genetic algorithms, Simulated annealing (Example of Cylindrical storage heater)	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	Essentials of Thermal System Design and Optimization, Prof. C.Balaji, Ane Books, New Delhi in India and CRC Press in the rest of the world.
2	Design and optimization of thermal systems,Y.Jaluria, Mc Graw Hill, 1998.
3	Elements of thermal fluid system design, L.C.Burmeister, Prentice Hall, 1998.
4	Design of thermal systems, W.F.Stoecker, Mc Graw Hill, 1989.
5	Introduction to optimum design, J.S.Arora, Mc Graw Hill, 1989.

B.Tech. III (DoME) Semester – 6 MICRO AND NANO MANUFACTURING (HONORS) MEHM3	Scheme	L	T	P	Credit
		3	1	0	04

1. <u>Course Outcomes (COs):</u> **At the end of the course, students will be able to**	
CO1	Classify and describe micro and nano manufacturing processes based on applications
CO2	Explain and select suitable micro machining/ micro forming/ MEMS processes based on given parameters and constraints
CO3	Explain and select suitable MEMS/NEMS technique for identified application.
CO4	Distinguish between the requirements for micro and nano manufacturing processes
CO5	Recommend a suitable nano- manufacturing process for a given application.
CO6	Propose suitable metrological technique for measuring micro and nano features.

2.	**Syllabus**	
	INTRODUCTION	**(03 Hours)**
	Introduction to miniaturization and its needs, scaling laws, micro products and design considerations, classification, selection of micro machining processes, applications.	
	MICRO MACHINING PROCESSES	**(14 Hours)**
	Evolution and Principle of micromachining, micro turning, micro milling, micro grinding, ultrasonic micro machining, abrasive jet micro machining, micro electro discharge machining, micro electro chemical machining, laser micro machining.	
	MICRO FORMING PROCESSES	**(09 Hours)**
	Micro scale plastic deformation, size effect, micro deep drawing, micro extrusion, micro punching, micro blanking, micro fabrication using bulk metallic glasses, flow induced defects.	
	MEMS AND NEMS TECHNIQUES	**(07 Hours)**
	Classification, principle and working, photo lithography, chemical etching, LIGA, materials Non-traditional optimization techniques: Genetic algorithms, Simulated annealing (Example of Cylindrical storage heater)	

	INTRODUCTION TO NANO MANUFACTURING	**(08 Hours)**
	Transition from nano technology to nano manufacturing; diamond turn machining; nano joining, nano soldering, nano welding, mechanical bonding, fastening; chemical vapor deposition, scanning tunnelling microscopy, nano lithography	
	ABRASIVE BASED NANO FINISHING PROCESSES	**(04 Hours)**
	Abrasive flow finishing, chemo-mechanical polishing, magnetic abrasive finishing, magnetorheological finishing, magnetorheological abrasive flow finishing, magnetic float polishing, hybrid nanofinishing: chemo-mechanical magnetorheological finishing, electrochemical magnetic abrasive finishing	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	Kei Cheng & Dehong Heo, Micro Cutting: Fundamentals and Applications, John Willey & Sons, 2013.
2	V K Jain, Micromanufacturing Processes, CRC Press, 2013.
3	Mark J. Jackson,Micromachining with Nanostructured Cutting Tools, Springer, 2013.
4	N. Maluf and K. Williams, Introduction to MEMS Engineering, 2nd edition, Artechhouse, 2004.
5	V K Jain, Nanofinishing Science and Technology, CRC Press, 2017.

B.Tech. III (DoME) Semester – 6 HYDRO AND WIND ENERGY (HONORS) MEHE3	Scheme	L	T	P	Credit
		3	1	0	04

1. **Course Outcomes (COs):** **At the end of the course, students will be able to**	
CO1	Introduce the fundamental principles of hydropower, including the conversion of potential energy in water into mechanical and electrical energy.
CO2	Explore the various auxiliary systems and supporting structures essential for the operation, safety, and efficiency of the Hydro power plant.
CO3	Evaluate the different types of hydraulic turbines and understand their operating mechanisms, performance, design differences, and applications.
CO4	Understand of the fundamental principles, technologies, and applications of wind energy as a renewable power source.
CO5	Comprehend the fundamental concepts of wind energy conversion, including the basic principles of harnessing wind energy and converting it into electrical energy.
CO6	Assess theoretical and practical performance of wind turbines including optimal tip speed ratio requirement

2.	**Syllabus**	
	INTRODUCTION TO HYDROPOWER	**(08 Hours)**
	Introduction, Water Cycle in Nature, Application of Hydro-Electric power plants, Status of Hydro power worldwide, Advantages and disadvantages, Introduction to small Hydro Power Plants, Selection of site for Hydropower plant, Classification, Operational terminology.	
	HYDROPOWER ELEMENTS	**(08 Hours)**
	Important Parts of Hydropower Station: Turbine, Electric Generator, Transformer and Power House, Structural parts: Dam and Spillway, Surge Chambers, Stilling Basins, Penstock and Spiral Casing, Tailrace, Pressure Pipes, Caverns, auxilliary parts.	
	HYDRAULIC TURBINES	**(08 Hours)**

	Hydraulic Turbines: Classification of Hydraulic Turbines, Impulse and Reaction Hydraulic Turbines, Theory of Hydro Turbines, Cost of Hydro power, Hydrology: Cyle, Measurement of run-off, Hydro graph and flow duration curve.	
	INTRODUCTION TO WIND ENERGY	**(08 Hours)**
	Introduction, History of wind energy, Current status and future prospects, Wind energy in India, Advantages and Disadvantages of Wind Energy, Environment aspects of Wind Energy, Sources of Wind, Wind availability and measurement.	
	WIND ENERGY CONVERSION SYSTEMS (WECS)	**(08 Hours)**
	Principle of Wind Energy Conversion, Wind Power, Basic Components of Wind Energy Conversion System, Advantages and Disadvantages of WECS, Considerations for Selection of Site for WECS.	
	WIND TURBINES	**(05 Hours)**
	Basic Terminologies and definitions, Power available in the wind, Horizontal and Vertical axis wind turbine, Wind turbine power and torque characteristics, Tip speed ratio, Optimal tip speed ratio, Wind speed prediction and forecasting, Betz limit, Govt. Policies.	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	Freris L.L., Wind Energy Conversion Systems, Prentice Hall 1990.
2	Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, 1994
3	Er. R. K. Rajput, Non-Conventional Energy Sources and Utilisation, S. Chand Publication, 2008
4	Dr. R. K. Singhal, Non-Conventional Energy Resources, S.K. Kataria and Sons, 2010
5	Wagner, Hermann-Josef, Mathur, Jyotirmay, Introduction to Hydro Energy Systems Basics, Technology and Operation, Springer, 2011

B.Tech. IV (DoME) Semester – 7 ADVANCED VIBRATION (HONORS) MEHD4	Scheme	L	T	P	Credit
		3	1	0	04

3. Course Outcomes (COs): **At the end of the course, students will be able to**	
CO1	Illustrate different vibration systems.
CO2	Analyse single and multi-degree freedom systems.
CO3	Solve the problems related to isolation and stability criteria.
CO4	Analyze the vibration and fault detection in rotating components.
CO5	Illustrate different vibration systems.
CO6	Analyse single and multi-degree freedom systems.

2.	**Syllabus**	
	INTRODUCTION	**(07 Hours)**
	Free and forced vibrations with and without damping, transient vibrations, Laplace transform formulation	
	ISOLATION AND STABILITY CRITERION	**(08Hours)**
	Vibration isolation and transmissibility, undamped vibration absorbers, self-exited vibrations, criterion of stability, effect of friction on stability	
	NONLINEAR VIBRATION	**(10 Hours)**
	Free vibration with nonlinear spring force or nonlinear damping, phase plane, energy curves, Lienard's graphical construction, methods of isoclines, random vibration, power spectral density, bandwidth in vibration, numerical methods for vibration analysis, vibration of continuous systems, Euler equation for beams, effect of rotary inertia and shear deformation	
	VIBRATION ANALYSIS OF ROTORS	**(10 Hours)**
	Transverse vibrations single, two and three rotor systems, critical speeds of shafts, torsional vibrations of rotors: one, two and three disc rotor system, frequency of torsional vibration systems, coupling of torsional and bending vibrations due to pre-twist and eccentricity, rotor faults, forward and backward rotor whirl model, variable elasticity effects in rotating systems, flow induced vibration in rotating systems, Newkirk effect, stresses in rotating disc and blade,	

	disc of uniform strength, thermal stresses	
	DIAGNOSTIC TECHNIQUES	**(10 Hours)**
	Introduction to diagnostic maintenance and instrumentation in machinery vibration, amplitude, frequency and phase characteristics, signature analysis-trend plot, time-domain plot, frequency-domain plot, FFT, spectrum plot, fault detection transducers, artificial intelligence techniques applied to vibration analysis	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	S. S. Rao. Mechanical Vibrations, 4thEdition, Pearson Education, 2007
2	L. Meirovitch. Fundamentals of Vibrations, McGraw Hill, 2001
3	E. Krämer. Dynamics of Rotors and Foundations, Springer-Verlag, New York, 1993
4	R. Subbiah and J. E. Littleton. Rotor and Structural Dynamics of Turbomachinery-A Practical Guide for Engineers and Scientists, Springer International Publishing, 2018
5	G. Genta. Dynamics of Rotating Systems, Springer, New York, 2005

B.Tech. IV (DoME) Semester – 7 DESIGN AND ANALYSIS OF ROTODYNAMIC MACHINES (HONORS) MEHT4	Scheme	L	T	P	Credit
		3	1	0	04

3. Course Outcomes (COs): **At the end of the course, students will be able to**	
CO1	Explain the working principles of Rotodynamic machines and apply it to various types of turbomachines
CO2	Design compressors and gas turbines.
CO3	Determine the off-design behavior of axial and Radial turbines and compressors
CO4	Design pumps and hydro turbines
CO5	Establish performance characteristics curves of thermal and hydro Rotodynamic machines
CO6	Assess & analyze the performance outcomes of thermal and hydro Rotodynamic machines.

2.	**Syllabus**	
	DESIGN OF CENTRIFUGAL COMPRESSORS	**(06 Hours)**
	Components of centrifugal compressor, velocity diagrams, slip factor, energy transfer, power input factor, Mollier chart, stage pressure rise and loading coefficient, degree or reaction, pre-whirl and inlet guide vanes, kinematic parameters, Centrifugal compressor — Inlet section, Impeller passages, operational range, velocity variation, Losses.	
	DESIGN OF AXIAL FLOW COMPRESSORS	**(15 Hours)**
	Description of axial flow compressor, Mollier chart, velocity diagrams, Stage characteristics, Blading efficiency, Design parameters, Blade loading, reaction ratio, Lift coefficient and solidity, Three dimensional flow considerations, Radial equilibrium design approach, Actuator disc theory approach, Design procedure and calculations, free vortex blade, forced vortex or solid rotation blades, constant reaction blade, multistage compression, secondary flow (passage vortex, trailing vortex, corner vortex, horseshoe vortex, leakage vortex, scraping vortex) and loss assessment, rotating stall, surge, chocking, operating range.	
	DESIGN OF TURBINE FLOW PASSAGES	**(06 Hours)**
	Introduction, Isentropic Velocity ratio, Energy distribution in turbines, different efficiencies (nozzle efficiency, carryover efficiency, blade passage efficiency, vane efficiency, stage	

	efficiency), reheat factor, losses in turbine, h – s diagrams of turbines.	
	DESIGN OF IMPULSE TURBINE FLOW PASSAGES	**(08 Hours)**
	Velocity triangles, work and energy relationship, stage efficiency, Blade pitch and width, Blade height, Blade entrance and exit angles, Geometry of impulse blade profiles, Losses in impulse blade passages, Design procedure for single stage and multistage impulse turbines, diagram efficiency of a two-stage turbine, Pressure compounding (Rateau Turbine), Velocity compounding (Curtis Turbine), Pressure and Velocity compounding. Work done and efficiency of a Pelton wheel turbine, heads and efficiencies of Pelton wheel turbine.	
	DESIGN OF REACTION TURBINE FLOW PASSAGES	**(06 Hours)**
	Reaction blade profiles, Blade angles, Blade width and height, Losses in reaction blade passages, Degree of reaction, design procedure for impulse reaction turbines, Calculations for axial thrust, Turbines for optimum capacity.	
	HYDRAULIC DESIGN OF CENTRIFUGAL PUMPS	**(04 Hours)**
	Fundamental Equation of centrifugal pump, work done and manometric efficiency, pressure rise in pump impeller, overall, mechanical, volumetric and manometric efficiency, ideal, virtual and Manometric heads, Net Positive Suction Head, one dimensional theory, Selection of speed - determination of impeller inlet and outlet dimensions	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	Lee J.E., "Steam & Gas Turbine", McGraw Hill, NY, USA, 1962.
2	Harlock J.H., "Axial Flow Compressors", Butter Worth London, London 1958.
3	Harlock J.H., "Axial Flow Turbines", Butter Worth London, London 1973.
4	Yahya S.M., "Turbo Machine", Tata McGraw Hill, NY, USA, 1992
5	Sawhney G. S., "Thermal and Hydraulic Machines", Prentice Hall India Learning Pvt. Ltd., India, 2011

B.Tech. IV (DoME) Semester – 7 METAL ADDITIVE MANUFACTURING (HONORS) MEHM4	Scheme	L	T	P	Credit
		3	1	0	04

3. Course Outcomes (COs): At the end of the course, students will be able to	
CO1	Classify the metal AM processes, and explain tool path generation & slicing methods.
CO2	Explain principles of metal additive manufacturing methods.
CO3	Describe the metallurgical and manufacturing quality assessment for metal AM.
CO4	Describe various heat sources and their interaction with different feedstocks.
CO5	Compare the different metal AM processes and describe machine architectures.
CO6	Describe the pre & post processing for metal additive manufacturing.

2.	Syllabus	
	INTRODUCTION TO ADDITIVE MANUFACTURING (AM)	**(04 Hours)**
	Need for additive manufacturing (AM), Manufacturing systems, Introduction to additive manufacturing (AM), Classification of additive manufacturing. Current and future estimation for metal AM market size, Applications of metal AM, Challenges and opportunities. Classification of metal additive manufacturing processes.	
	CAD DATA AND PRE-PROCESSING FOR AM	**(4 Hours)**
	CAD for additive manufacturing, CAD model development; Additive manufacturing file formats, Defects and Issues in Data Formats; Pre-processing - Part orientation and support structure generation, Design of support structure, Model slicing, Contour generation, Tool path generation, Build file preparation, Machine set-up.	
	METAL AM PROCESSES AND PHYSICS, LASER/ELECTRON BEAM AND BINDER JETTING	**(09 Hours)**
	Basic Processes: Direct Energy Deposition (DED) and Power Bed Fusion (PBF). AM Machine system and setup. Laser Beam: LASER theory, LASER generation unit, continuous and pulsed LASER, Type of LASER. Electron Beam: basics of electron beam, electron beam mechanism, electron beam for powder bed fusion. Process Parameters: AM process parameters, beam scanning strategies, parameters for PBF and DED, powder properties for PBF and DED techniques for powder production, wire properties for DED, ambient parameters for PBF, and	

	DED, geometry specific parameters for PBF, support structure for PBF.	
	METAL AM PROCESSES AND PHYSICS: BINDER AND MATERIAL JETTING	**(03 Hours)**
	Basic Process: Binder Jetting (BJ). AM Machine system and setup. Process Parameters: AM process parameters, powder properties for BJ, Techniques for powder production, ambient parameters for BJ, and geometry specific parameters for BJ, support structure for BJ.	
	FEEDSTOCKS, EMERGING METAL AM PROCESSES: FILAMENT, POWDER AND SHEET SYSTEMS	**(06 Hours)**
	Wire Fed Systems: Wire feed systems, positioning devices, printing heads. Powder Fed Systems: powder feeders and types, powder delivery nozzles, powder bed delivery and spreading system. **Emerging Metal AM Processes:** Material Extrusion, Material Jetting, Sheet Lamination. AM Machine system and setup. AM process parameters.	
	MECHANICAL AND METALLURGICAL PROPERTIES OF AM PARTS	**(09 Hours)**
	Metal AM Printed Parts: mechanical properties- tensile and static strength, fatigue behaviour, hardness, common defects in metal AM printed parts. Solidification: manufacturing of metallic materials, traditional and AM, solidification of metals, equilibrium and non-equilibrium phases for solidification: theory and mechanism for AM, description of metal AM parts. Phase diagrams: Iron-carbon, Al-alloy, Ti-alloy, and Ni-alloy. Intermetallic compounds, residual stress, dissimilar AM, corrosion.	
	POST PROCESSING AND TESTING	**(03 Hours)**
	Need of post processing, product quality evaluation, support structure removal, need of surface finishing, geometry and aesthetics, post processing techniques for metal AM parts. Non-destructive testing metal AM parts.	
	DESIGN FOR ADDITIVE MANUFACTURING	**(04 Hours)**
	Core concepts and objectives, Principles of design for manufacturing and assembly, Constraint approach to design for additive manufacturing: Guidelines and rules for part building, Topology optimization and generative design, exploring design freedom, design tools	
	RECENT TRENDS IN METAL ADDITIVE MANUFACTURING	**(03 Hours)**
	Composite 3D printing, 3D printing of bioimplants, 3D printing in space, 4D printing.	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	Ian Gibson, David Rosen, and Brent Stucker, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Springer, 2015. ISBN 978-1-4939-2112-6
2	J.O. Milewski, Additive manufacturing of metals, Springer International Publishing, 2017.
3	R. Leach, and S. Carmignato, eds., Precision Metal Additive Manufacturing, CRC Press, 2020.
4	K.R. Balasubramanian, and V. Senthilkumar, eds., Additive Manufacturing Applications for Metals and Composites, IGI Global, 2020.
5	R.M. Mahamood, Laser Metal Deposition Process of Metals, Alloys, and Composite Materials, Engineering Materials and Processes, Springer International Publishing AG, 2018.
6	Hod Lipson and Melba Kurman, The New World of 3D Printing, Wiley, 2013. ISBN 978-1-118-35063-8

B.Tech. IV (DoME) Semester – 7 ENERGY CONSERVATION, MANAGEMENT AND AUDIT (HONORS) MEHE4	Scheme	L	T	P	Credit
		3	1	0	04

3. Course Outcomes (COs): At the end of the course, students will be able to	
CO1	Apply various energy conservation techniques to estimate energy saving potential in various thermal and electrical utilities.
CO2	Compare various appliances/utilities based on their stars and labelling, benchmarking values, PAT Scheme in industries.
CO3	Calculate the usage of energy for a given industrial thermal/electrical utility and suggest suitable way to minimize energy bill.
CO4	Analyse the saving potential of Cogeneration option for process industry.
CO5	Determine Energy conservation potential in various industrial utilities like fans, blowers, compressors, pumps etc.
CO6	Compute various performance parameters of HVAC systems and suggest suitable ways for improving energy efficiency.

2.	Syllabus	
	GLOBAL AND NATIONAL ENERGY SCENARIO	**(08 Hours)**
	Energy consumption in various sectors, Energy resources like Coal, Oil, and Natural Gas –their demand and supply management, Indian energy scenario, Indian Coal & LPG scenario, Primary and Secondary Sources of Energy, Commercial and Non-Commercial Sources, India's installed energy capacity, per capita energy consumption. General aspects of Energy conservation and management, Roles of energy auditors, Roles of an energy manager, Energy policy of industry, Energy Conservation Act and its amendments, PAT Scheme.	
	ENERGY EFFICIENCY IN BOILER, STEAM, AND FURNACE SYSTEM UTILITIES	**(10 Hours)**
	Energy conservation opportunities in boiler systems, retrofitting of FBC in conventional boilers, Steam line distribution standard practices including sizing and layouts, selection, operation, maintenance of steam traps, and energy-saving opportunities in steam systems. Energy Efficiency in Furnaces: Sankey diagram, Fuel economy measures in furnaces Insulation and Refractories: Types of insulations, Economic thickness of insulation, Typical refractories for industrial applications. Benchmarking in Glass and Steel Industries.	
	ENERGY EFFICIENCY IN FURNACES AND REFRACTORIES:	**(07 Hours)**

	Sankey diagram, Fuel economy measures in furnaces Insulation and Refractories: Types of insulations, Economic thickness of insulation, Typical refractories for industrial applications. Benchmarking in Glass and Steel Industries.	
	COGENERATION	**(07 Hours)**
	Principle of cogeneration, Technical options for cogeneration, Factors influencing cogeneration choice, Important technical parameters for cogeneration, case study on savings with and without cogeneration.	
	ENERGY CONSERVATION IN FANS, BLOWERS COMPRESSORS, AND PUMP SYSTEMS	**(08 Hours)**
	Energy-saving opportunities, performance evaluation and efficient system operation. Air Systems: Efficient operation of the compressed air system, Leakage tests. Pumps and Pumping Systems: Pump curves, factors affecting pump performance, Energy loss in throttling, Effects of impeller diameter change, Flow control strategy, Variable speed drives, and Energy conservation opportunities.	
	ENERGY CONSERVATION IN HVAC AND COOLING TOWERS	**(05 Hours)**
	HVAC: factors affecting the performance and energy savings opportunities in HVAC. Cooling towers: Cooling towers: types and performance assessment & limitations, water loss in cooling tower. Energy Saving in Cooling Towers.	
	(Total Contact Time: = 45 Hours)	

3.	**Books Recommended**
1	General Aspects of Energy Conservation, Management and Audit: Guide Book for Energy Managers and Energy Auditors; Bureau of Energy Efficiency, Ministry of Power
2	Energy Efficiency in Electrical Utilities: Guide Book for Energy Managers and Energy Auditors; Bureau of Energy Efficiency, Ministry of Power
3	Energy Efficiency in Thermal Utilities: Guide Book for Energy Managers and Energy Auditors; Bureau of Energy Efficiency, Ministry of Power
4	S. A. Roosa, Energy Management Handbook, Fairmont Press, 2018
5	Wayne C Turner, Energy Management Handbook. Prentice Hall 3rd Edition, 2000