COURSE STRUCTURE
&
SYLLABUS

For

B. Tech in Mechanical Engineering

(VII & VIII – SEMESTER)

For Academic Session 2023-24

Indian Institute of Petroleum and Energy

Visakhapatnam, Andhra Pradesh - 530 0

Semester-VII				
S.No.	**Subject Code**	**Subject Name**	**L-T-P**	**Credits**
1	IE4002	Elective II	3-0-0	3
2	IC4101	Engineering Economics & Costing	2-0-0	4
3	IC4102	Industrial Psychology & Professional Ethics	2-0-0	
4	ME4101	Project Engineering and Management	2-0-0	4
5	ME4202	Industrial Safety	2-0-0	
6	IC4103	Industrial Training	0-0-0	2
7	IC4104	Project II	0-0-3	2
Total			11-0-6	15
Semester-VIII				
S.No.	**Subject Code**	**Subject Name**	**L-T-P**	**Credits**
1	IE4003	Elective-III	3-0-0	3
2	IE4004	Elective-IV	3-0-0	3
3	IE4005	Elective-V	3-0-0	3
4	IC4201	Project III	0-0-9	6
5	IC4202	Comprehensive Viva-Voce	0-0-0	2
Total			9-0-9	17
Total Credit				126

List of electives

ELECTIVES	
Elective - II	1. Advanced Solid Mechanics 2. Unconventional Manufacturing Processes 3. Energy conservation and waste heat recovery 4. Principles of Energy conversion
Elective - III	1. Industrial Tribology 2. Microfluidics 3. Composite Materials 4. Non- conventional energy source (Nuclear Wind and Geothermal)
Elective - IV	1. Finite Element Method 2. Hybrid and Electric Vehicles 3. Smart Manufacturing (INDUSTRY 4.0) 4. Energy Storage System
Elective - V	1. Advanced Material Design 2. Radiation Heat transfer 3. Welding Technology 4. Solar Thermal Energy Utilization
***Note**: Electives will be offered based on the availability of resource person**	

Elective-II

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-II		Advanced Solid Mechanics	3	0	0	3
Course Objective						
• To analyze the transformation of stresses and strains in 3D. • To study engineering properties of materials, force-deformation, and stress-strain relationship. • To understand the plastic behaviour of deformable bodies.						

Unit No.	Topics to be Covered
1	Introduction: Review of basic concepts and equations in mechanics, Classification of materials, Outline of general techniques to solve boundary value problems
2	Mathematical Preliminaries: Indicial notation, Introduction to tensors, Representation of tensors, Gradient and related operators, Divergence theorem
3	Kinematics: Motion field, Displacement field, Deformation gradient, Transformation of curves, surfaces and volumes, strain measures, linearized strain measures, Principal strains and principal directions, Transformation of strain components with changes in coordinate basis, Compatibility conditions for linearized strain
4	Traction and stresses: Concept of traction, Cauchy's stress theorem, Postulate of Cauchy stress tensor, Traction on arbitrary planes, Extreme normal and shear traction, Octahedral shear stress, Other stress measure - Engineering stress
5	Equilibrium equations: Derive equilibrium equations in Cartesian and cylindrical polar coordinates
6	Constitutive relations: Restrictions on constitutive relations, General relationship between Cauchy stress and Cauchy Green strain for isotropic materials, General Hooke's law and its reduction for isotropic and orthotropic materials

7	Boundary value problems: Formulation : Displacement method, Stress method, Airy's stress functions for plane stress and strain problems, Uniaxial Tension, Thick-walled annular cylinder subjected to uniform boundary pressure, Infinite medium with a stress free hole under far field tension loading
8	Bending of prismatic straight beams: Pure bending, bending due to uniform transverse loading and bending due to transverse sinusoidal loading of a beam, Asymmetrical bending of straight beams, Shear center, Shear stresses in thin walled open sections
9	End torsion of prismatic beams: Formulation of the BVP for torsion of beams with solid cross section - warping function and Prandtl stress function approach, Torsion of circular, elliptic, rectangular and triangular cross sections, Membrane analogy, Torsion of thin walled tubes, thin rectangular sections,rolled sections and multiply connected sections
10	Bending of curved beams: Winkler-Bach Formula, Elasticity solution for : pure bending of curved beams, curved cantilever under end loading
11	Beam on elastic foundation: Derivation of the basic governing equation, Solution to beam on an elastic foundation subjected to a point load at the center, moment at the center, uniformly distributed load over some length 'a' symmetrically about the center

References:

1. L.S.Srinath,"Advanced Mechanics of Solids" Tata McGraw Hill, 2007.
2. A.R. Ragab, and S.E.Bayoumi,"Engineering Solid Mechanics: Fundamentals and Applications", CRC Press, 1999.
3. M.H.Sadd,"Elasticity: Theory,Applications and Numerics",Academic Press, 2006.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-II		Energy Conservation and Waste Heat Recovery	3	0	0	3

Course Objective

Estimates from analyses and audits from various industries suggest that 20 to 50% of industrial energy input is lost as waste heat. This waste heat can be in the form of hot exhaust gases, water streams (from condensers in power plants) or heat lost from hot equipment and surfaces. As the world strives for higher energy effciencies, it is imperative that along with better equipment we focus on recovering the energy stored in this "waste heat" and utilize it for useful purposes. The proposed course introduces us to various methods of Waste Heat Recovery that has been employed by the industry to harness the energy stored in waste heat and use it for generation of additional electric power.

Unit No.	Topics to be Covered
1	Introduction to Waste Heat, Importance of Waste Heat Recovery, Review of Thermodynamics – Introduction to First and Second Laws
2	Review of Thermodynamics – Entropy, Entropy Generation, First and Second Law efficiency
3	Power Plant Cycles - Energy Cascading, Rankine Cycle, modification of Rankine cycle, examples
4	Gas Turbine Cycle, Combined Cycle, Combined Gas Turbine-Steam Turbine Power Plant, Heat Recovery Steam Generators
5	Thermodynamic cycles for low temperature application, Cogenerations, Introduction to Heat Exchangers, Analysis – LMTD and ε-NTU method
6	Analysis of Heat Exchanger – continued, Problem solving, Special Heat Exchangers for Waste Heat Recovery, Synthesis of Heat Exchanger Network
7	Heat pipes & Vapor Chambers, Direct conversion technologies – Thermoelectric Generators.
8	Direct conversion technologies – Thermoelectric Generators (contd.), Thermoionic conversion, Thermo-PV, MHD
9	Heat Pump; Heat Recovery from Incinerators, Energy Storage – Introduction.
10	Energy Storage Techniques – Pumped hydro, Compressed Air, Flywheel, Superconducting Magnetic storage
11	Energy Storage Techniques – Thermal storage (Sensible & Latent), Battery, Chemical Energy Storage, Fuel cells.
12	Energy Economics

References:

Reddy, Chirla Chandra Sekhara and Rangaiah, Gade Pandu, Waste Heat Recovery: Principles and Industrial Applications, 2022.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-II		Unconventional Manufacturing Processes	3	0	0	3

Course Objective

To provide detailed understanding of advanced manufacturing processes. The prospect of future research will also discuss in the course which will encourage the PG students to carryout research in the advance area.

Learning Outcomes

Upon successful completion of this course, students will:

- Broad understanding of machining using different energy sources.
- Students will be able to think about the possibility of combining different process to develop more efficient machining process
- It will help the students to select the best process among various alternative.

Unit No.	Topics to be Covered	Learning Outcome
1	Introduction and classification, Theory of machining by Abrasive Jet, Abrasive water Jet, Abrasive flow; Ultrasonic machining.	Understanding of mechanical based unconventional processes (UMP). It will develop the ability of select the process for particular application.
2	Electrochemical Machining and grinding, polishing, sharpening, honing and turning. Chemical Machining. Electrochemical Discharge machining and Grinding; Electro-stream and Shaped Tube Electrolytic Machining.	Understanding of electrical and chemical based unconventional processes (UMP). The students will learn the principle of hybrid process and their applications.
3	Thermal energy methods of material processing (machining/welding/heat treatment) by Electrodischarge, Laser and Electron beam, Plasma arc and Ion beam.	Understanding of thermal based unconventional processes (UMP). The students will learn the importance of high pulse energy source.
4	Unconventional metal forming processes: principle, working and applications, High Energy Rate Forming and Electroforming, Physical Vapour and Chemical Vapour Deposition and Plasma Spraying.	The students will understand the use of controlled explosive and spark energy in deformation process. The students will also learn about thin coating techniques. Flow to 3D flow cases

Text books:

1. Fundamentals of Machining Processes (Conventional and Nonconventional Processes), Hassan AbdelGawad El-Hofy, CRC press, 3rd Edition, 2018

Reference books:

1. Non-traditional manufacturing processes, Gary F. Benedict, CRC press, 2015
2. Fundamentals of modern manufacturing processes, M. P. Groover.
3. Unconventional Machining, P K Mishra
4. Unconventional Machining, V K Jain
5. Unconventional Machining, Pandey and Shah

Elective-III

ourse Type	Course Code	Name of Course	L	T	P	Credit
Elective III		Industrial Tribology	3	0	0	3

Unit No.	Topics to be Covered
1.	The fundamentals of lubricants business: Lubricant value chain. Types of Lubricants- Automotive, Industrial, Marine, Railroad, Air.Applications of lubricants – Automotive (Trucks, Cars, 2-Wheelers, Tractors, Gear Oils, Natural Gas.Engine Oils etc.) and Industrial (Cutting Oils, Rust Preventives, Rolling Oils, Compressor Oils,Hydraulic, Drilling Oils etc.)Properties of Lubricants. Bio-Lubricants.
2.	Fundamentals of Base Oils.Type of Crude Oils.Refinery process – Brief introduction. Base Oil Groups.Properties of Base Oils.
3.	Fundamentals of AdditivesProperties & key characteristics.Composition of additives for various applications. Additive Chemistry.Types of additives. Performance contribution of additive to Lubricants.
4.	Lubricants – AutomotiveUnderstanding of Key specifications like API, JASO, ACEA.Global Specifications and Viscometrics.India- Current scenarios of Lubricants in India & Future trends.
5.	Lubricants-Industrial, Marine, Railroad, Air sectorIndian Lubricant Market-Current size & key players.Growth Potential.
6.	New trends impacting lubricants, base Oils and additive industryBS IV to BS VI Transition by 2020.Transition towards high-quality lighter lubricants.New slate of Base Oils over next 10 years.
7.	Finance and Cost optimization of Lubricants Tools and techniques: value engineering and collaborative optimization. Global best practices to drive down the total costs of ownership.

Textbooks

1. Engineering Tribology, Gwidon W. Stachowiak and Andrew W. Batchelor, 4th Edition,2014
2. Tribology: Friction and Wear of Engineering Materials, Ian Hutchings and Philip Shipway, 2nd Edition, 2017

References

1. Introduction to Tribology , Bharat Bhushan, Wiley, 2nd Edition, 2002
2. Engineering Tribology by. Prasanth Sahoo, Prentice Hall India Learning Private Limited, 2005 Fundamentals of Tribology, Ramsay Gohar and Homer Rahnejat, Imperial College Press, 2nd Edition, 2012

CourseType	Course Code	Name of Course	L	T	P	Credit
Elective- III		**Microfluidics**	3	0	0	3
Course Objective						
The fundamentals of fluid flows at micro-scale including intermolecular forces, low Re flows, slip theory, capillary flows and electro kinetics are discussed. The principles of microfabrication with silicon and polymer substrates are illustrated. Theory and design of various microfluidic components including micro pumps, micro mixers, micro valves etc. is discussed. Few applications of microfluidic systems are also covered.						

Unit No.	Topics to be Covered
1.	**Introduction** Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws.
2.	**Micro-scale fluid mechanics** Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.
3.	**Capillary flows** Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect.
4.	**Electrokinetics** Electrohydrodynamics fundamentals. Electro-osmosis, Debye layer, Thin EDL limit, Ideal electroosmotic flow, Ideal EOF with back pressure, Cascade electroosmotic micropump, EOF of power-law fluids. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size. Dielectrophoresis, Induced polarization and DEP ,Point dipole in a dielectric fluid,

	DEP force on a dielectric sphere, DEP particle trapping, AC DEP force on a dielectric sphere. Electro-capillary effects, Continuous electro-wetting, Direct electro-wetting, Electro-wetting on dielectric.
5.	**Microfabrication techniques** Materials, Clean room, Silicon crystallography, Miller indices. Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding. Polymer microfabrication, PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnections.
6.	**Microfluidics components** Micropumps, Check-valve pumps, Valve-less pumps, Peristaltic pumps, Rotary pumps, Centrifugal pumps, Ultrasonic pump, EHD pump, MHD pumps. Microvalves, Pneumatic valves, Thermopneumatic valves, Thermomechanical valves, Piezoelectric valves, Electrostatic valves, Electromagnetic valves, Capillary force valves. Microflow sensors, Differential pressure flow sensors, Drag force flow sensors, Lift force flow sensors, Coriolis flow sensors, Thermal flow sensors. Micromixers, Physics of mixing, Pe-Re diagram of micromixers, Parallel lamination, Sequential lamination, Taylor-Aris dispersion. Droplet generators, Kinetics of a droplet, Dynamics of a droplet, In-channel dispensers, T-junction and Cross-junction, Droplet formation, breakup and transport. Microparticle separator, principles of separation and sorting of microparticles, design and applications. Microreactors, Design considerations, Liquid-phase reactors, PCR, Design consideration for PCR reactors.
7.	Few applications of microfluidics Drug delivery, Diagnostics, Bio-sensing.

References:

1. Nguyen, N. T., Werely,S. T., Fundamentals and applications of Microfluidics, Artech house Inc., 2002. Bruus, H., Theoretical Microfluidics, Oxford University Press Inc., 2008.
2. Madou, M. J., Fundamentals of Microfabrication, CRC press, 2002.
3. Tabeling,P., Introduction to microfluidics, Oxford University Press Inc., 2005.
4. Kirby,B.J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
5. Colin,S., Microfluidics, John Wiley & Sons, 2009.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective-III		Composite Materials	3	0	0	3

Course Objective

- To learn the properties of fiber-reinforced polymer composites
- To learn the mechanical performance of laminated composites, including failure behavior.
- To model, simulate and optimize the performance of composite structures.

Learning Outcomes

Upon successful completion of this course, students will able to:

- Identify, describe and evaluate the properties of fibre reinforcements, polymer matrix materials and commercial composites.
- Develop competency in one or more common composite manufacturing techniques, and be able to select the appropriate technique for manufacture of fibre-reinforced composite products.
- Analyse the elastic properties and simulate the mechanical performance of composite laminates; and understand and predict the failure behaviour of fibre-reinforced composites
- Apply knowledge of composite mechanical performance and manufacturing methods to a composites design project

Unit No.	Topics to be Covered	Learning Outcome
1	Introduction to composites: Brief History, Constituent Materials, Laminate , FRP, micro-mechanics & macromechanics, Applications	Understand the Composite, its advantage, classification and the terminology used for studying mechanics of composites
2	Fabrication: Liquid resin impregnation routes, PrePregs methods, Consolidation of resin moulding compounds, Injection moulding and hot pressing of thermoplastics. Fabrication of metal matrix composite.	Understanding the manufacturing process of composite
3	Micromechanical Analysis: Assumptions, strengthstiffness, Shear , Poisson Ration	Develop concepts of volume and weight fraction of fiber and matrix, density and void fraction in composites
4	Elastic Properties of Unidirectional Lamina: , stress – strain relations for general anisotropic, specially orthotropic and transversely isotropic materials, Transformation Matrix	Find the engineering constants; Develop stress-strain relationships, elastic moduli, strengths of a unidirectional/bidirectional lamina
5	Analysis of Laminated Composites: Classical Laminate Theory, Displacement Field, Strain Displacements Relations, Constitutive Relations, Classification of Laminates and their properties.	Find the elastic stiffnesses of laminate based on the elastic moduli of individual laminas and the stacking sequence
6	Analysis of Laminated Plate & FEM: Classical Plate theory, Bending of composite plate, Shear deformation theories: FSDT, HSDT, Layerwise	Ability to analyze problems on bending, buckling, and vibration of laminated plates and beams
7	Hygrothermal Effects of Laminates , Failure Theories and Strength of Unidirectional Lamina Design of Composite structure & Example	Develop the relationships of mechanical and hygrothermal loads applied to a laminate to strains and stresses in each lamina

Text books:

1. Mechanics of Composite Material & Structures, M Mukhopadhyay, Universities press 2013.

Reference books:

1. An Introduction to Composite Materials, By D. Hull and Clyne, Cambridge University Press 2010
2. Engineering mechanics of composite materials, I. M. Daniel & O. Ishai, 2nd edn., oxford university press, 2006.
3. Principles of composite material mechanics, R. F. Gibson, 2nd edn. CRC Press, 2007.
4. Mechanics of Composite Material, Autar K. Kaw, CRC Press
5. Mechanics of composite materials, Rr. M. Jones, 2nd edn. Taylor & francis, 1999.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective III		**Nuclear Wind and Geothermal Energy**	3	0	0	3

Course Objective
1. The course aims to give students a basic understanding of nuclear energy concepts such as nuclear fission, fusion, nuclear reactors, nuclear fuel, and their management. 2. To facilitate the students to achieve a clear conceptual understanding of technical and commercial aspects of wind energy generation. 3. To be familiar with fundamental concepts of geothermal energy generation.
Learning Outcomes
1. At the end of the course, students will learn and understand fundamental concepts of nuclear energy generation which include nuclear fission, fusion, nuclear reactors, nuclear fuel, and their management. 2. On completion of this course, the students will be able to exhibit conceptual knowledge of the technology, economics, and viability of wind energy generation. 3. Students will get to know about basic concepts of geothermal energy.

Unit No.	Topics to be Covered	LearningOutcome
1	Nuclear Energy: Basic nuclear models, radioactivity, nuclear reactions – energy systems based on fission & fusion reactions	The course aims to give students a basic understanding of nuclear energy concepts such as nuclear fission, fusion, nuclear reactors, nuclear fuel, and their management.
	Reactor heat generations and removal; Nuclear Fuel cycle from Uranium / Thorium supply, enrichment	
	Fuel management and waste disposal	
	Interaction of ionizing radiation with matter, radiation detection, shielding, and effects on human health.	
2	Wind Energy: Introduction to wind resources: wind speed and terrain properties, power density; Measurement of wind speed and turbulence	On completion of this course, the students will be able to exhibit conceptual knowledge of the technology, economics, and viability of wind energy generation.
	Wind turbine / rotor design: Thrust, torque, speed, and power; Turbine material design and structural analysis	
	Integration of variable power production into electrical systems: Control of rotor speed, maximum power in low wind speeds, constant power in high wind speeds	
	Offshore wind farm: Dynamic wind and wave loadings, grid integration, operational and maintenance strategies	
	Cost of energyfrom wind turbine during lifetime.	
3	Nature, occurrence, types and classification of geothermal fields;	Students will get to know about basic concepts of geothermal energy.
	Resource Exploration and Characterization	
	Geothermal Energy Recovery	
	Analysis of energy system proposals with reference to engineering, economic, socio-political, and environmental objectives.	

References

1. Grant, M.A. and Bixley, P.F. Geothermal Reservoir Engineering. Second Edition. Elsevier. 2011.
2. Glassley, W.E. Geothermal Energy. Second Edition. CRC Press. 2015.

Elective-IV

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective- IV		Finite Element Method	3	0	0	3

Course Objective
To learn and apply finite element solutions to structural dynamic problem To develop the knowledge and skills needed to effectively evaluate finite element analyses for stability analysis.
Learning Outcomes
Upon successful completion of this course, students will able: • To obtain an understanding of the dynamics FE theories. • To develop the dynamics stiffness matrix; • To understand the modal reduction techniques and its use • To understand the Nonlinear Dynamics FE analysis.

Unit No.	Topics to be Covered	Learning Outcome
1	Approximate methods and FEM: Hamilton's principle, Rayleigh's quotient,Rayleigh Ritz method and method of weighted residuals	Understand to solve the FE problem by different types of Approximate Method
2	Finite element analysis of dynamics of planar trusses and frames: Analysis of axially vibrating rods and Euler-Bernoulli beams, Assembly of matrices ,FE modelling of planar structures	Understanding the basic concept of FEM problem and its formulation
3	Analysis of equations of motion: FRF-s and damping models-, Material damping models. Dynamic stiffness and transfer matrices. Analysis of grids and 3D frames: Twisting of circular bars and rectangular bars. Analysis of grids 3D frames	Understanding to develop the dynamics stiffness matrix for different critical structure
4	Time integration of equation of motion: Euler's forward and backward difference methods, Central difference method, Energy conservation. Nonlinear systems.	Understanding the time integration techniques for dynamic and nonlinear problem
5	Model reduction and sub-structuring schemes; Analysis of 2 and 3 dimensional continua - Plane stress models, 3d Solid element, Axisymmetric models. Plate bending elements., Plate bending elements	Understanding the Modal reduction technique
6	Structural stability analysis - Nonlinear dynamical systems, Energy methods in stability analysis, FEM for stability analysis. Dynamic analysis of stability and analysis of time varying systems, Dynamic analysis of stability and analysis of time varying systems., FE modelling of vehicle structure interactions	Understanding the Structural stability analysis & FEM for Structural stability analysis
7	FE model updating	Understanding the need of model updating & to create an appropriate practical FEM model

Text Books:

1. Introduction to finite element vibration analysis, Book by M. Petyt, Cambridge.

Reference Books:

1. Vibration Analysis by Finite Element Method, Jong-Shyong Wu 3. Weaver & Johnston, Structural Dynamics by Finite Elements, Prentice Hall.
2. K J Bathe, Finite Element Procedure, Prentice Hall.
3. Shames & Dym, Energy and FEM in Structural Mechanics, Wiley.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective- IV		Hybrid and Electric Vehicles	3	0	0	3

Course Objective

This course introduces the fundamental concepts, principles, analysis and design of hybrid and electric vehicles. The material for this course will be prepared in such a manner that it will be useful for post-graduate students, teachers, practitioners and final year undergraduate students. This course goes deeper into the various aspects of hybrid and electric drive train such as their configuration, types of electric machines that can be used, energy storage devices, etc. Each topic will be developed in logical progression with up-to-date information. A number of chosen problems will be solved to illustrate the concepts clearly. There shall be a suite of exercises based on MATLAB and Simulink.

Unit No.	Topics to be Covered
1	Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies.
2	Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.
3	Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.
4	Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.
5	Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.
6	Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices.
7	Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems
8	Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies.
9	Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV).

References:

1 A. E. Fuhs, Hybrid Vehicles and the Future of Personal Transportation , CRC Press, 2009

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective IV		Smart Manufacturing (Industry-4.0)	4	0	0	4

Course Objective

The objective of the course is to introduce concept of the transformation of industrial processes through the integration of modern technologies such as sensors, communication, and computational processing.

Learning Outcomes

Students will get to know about, technologies such as Cyber Physical Systems (CPS), Internet of Things (IoT), Cloud Computing, Machine Learning, and Data Analytics are considered to be the different drivers necessary for the transformation.

Industrial Internet of Things (IIoT) is an application of IoT in industries to modify the various existing industrial systems. IIoT links the automation system with enterprise, planning and product lifecycle

Unit No.	Topics to be Covered
1	Introduction: Sensing & actuation, Communication-Part I, Part II, Networking-Part I, Part II
2	Industry 4.0: Globalization, The Fourth Revolution, LEAN Production Systems
3	Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management
4	Cybersecurity in Industry 4.0, Basics of Industrial IoT: Industrial Processes-Part I, Part II, Industrial Sensing & Actuation

References:

1. Schwab, K. (2017). The fourth industrial revolution. Portfolio Penguin.
2. Lu, Y. 2017. Industry 4.0: A survey on technologies, applications and open research issues. Journal of industrial information integration, 6, pp.1-10.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective IV		Energy Storage Systems	4	0	0	4

Course Objective

This course covers the necessary technical knowledge of the fundamental principles and application areas of proven technologies for energy storage solutions. And to study details of various energy storage systems along with applications and enable to identify the optimal solutions to a particular energy storage application.

Learning Outcomes

After successful completion of the course, students will be able to: Students can identify available technologies for energy storage and their typical application areas with their advantages and development challenges and summarize the demand for further development, potential improvements, and possibilities for innovative solutions in the energy storage subject field.

Unit No.	Topics to be Covered	Learning Outcome
1.	Scientific and engineering fundamentals of all significant energy storage methods, different types of energy storage systems (ESS), and their working principals;	Students can discuss energy storage systems and provide an understanding and appreciation of the scientific principles.
2.	Storage of energy as hydroelectric pumped storage, thermal, compressed air storage, flywheel storage, mechanical, electrostatic, and magnetic systems, phase transitions and reversible chemical reactions, organic fuels and hydrogen, and electrochemical systems;	Student will be able to relate with various upcoming energy storage technology.
3.	Energy storage technologies; basics of batteries; materials and methods; electrochemical ESS types.	They learned about the various parts of the battery and their functions.
4.	Safety issues; model codes and standards; traditional and emerging battery systems, EV and automotive technologies.	Understand how cells are used for everyday purposes: road, water, and air transport vehicles, portable and stationary use.

Text Book:

1. Fundamentals of Energy Storage by J. Jensen and B. Sorenson, Wiley-Interscience, New York.
2. Fundamentals and Application of Lithium-ion Battery Management in Electric Drive Vehicles by San Ping Jiang, Wiley.
3. Modern electric, hybrid electric, and fuel cell vehicles fundamentals, theory, and design by Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, CRC press.

Reference:

1. Energy Storage: Fundamentals, Materials, and Applications, by Robert Huggins, Springer Nature; 2nd ed.
2. Grid-Scale Energy Storage Systems and Applications, Fu-Bao Wu, Bo Yang, Ji-Lei Ye, Elsevier; 1st ed.

Elective-V

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective V		Advanced Material Design	3	0	0	3

Topics to be Covered
Materials characterization using optical and neutron spectroscopies; Multiscale atomistic modeling; Use of density functional theory to predict temperature dependent thermodynamic properties of new materials e.g., complex hydrides, and kinetic processes in diffusion; Introduction to molecular simulations; Semiconductor and oxide nanostructure for optoelectronic devices, high energy solar cells; Quantum dots; Thermoelectric materials.

Text Books:

1. Edward L. Wolf, Nanophysics and Nanotechnology. Wiley Verlag (2006).
2. Peter Würfel, Physics of Solar Cells: From Basic Principles to Advanced Concepts. Wiley (2009).
3. Charles Kittel, Introduction to Solid State Physics. Wiley (2012).
4. D. C. Rapaport, The Art of Molecular Dynamics Simulation. Cambridge University Press (1995).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective- V		Radiation Heat transfer	3	0	0	3

Course Objective

This course offers a comprehensive treatment of Radiative heat transfer. The course starts with standard optics on Radiative transfer and radiant exchange between surfaces and introduces modern state-of-the-art topics including Radiative properties of gases and particles, P-N approximation, the Monte Carlo method and the prediction of radiation transfer in absorbing, emitting, and scattering media.

Learning Outcomes

Upon successful completion of this course, students will:
1. be able to design the flat plate solar air / water heater.
2. be able to design focusing type solar collector.
3. be able to use this solar energy concept for designing solar storage systems.

UnitNo.	Topics to be Covered
1.	Fundamentals of Thermal Radiation, Introduction, Basic Laws of Thermal Radiation, Introduction to Radiative Properties, Radiative Properties of Opaque Surfaces
2.	View Factors, Evaluation Methods, Monte Carlo method
3.	Radiative Exchange between Black surfaces, Radiative Exchange between Gray, Diffuse, Surfaces, Radiative Exchange between Non-Ideal Surfaces
4.	Equation of Radiative Transfer for participating media
5	Solution Methods: Plane-Parallel Slab, Approximate Methods, Method of spherical harmonics and Discrete Ordinate Method.
6	Zone method and applications
7	Radiative Properties of Participating Media: Gas Properties, particle Properties
8	Spectral Models: Wide band model, Narrow-band models, k-distribution models

References:

1. Siegel, R. and Howell, J., Thermal Radiation Heat Transfer, Taylor and Francis 2002.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective- V		Welding Technology	3	0	0	3
Course Objective						
To familiarize students, the concepts of welding engineering, processes, affecting parameters related to welding. Also to introduce with fundamentals of arc welding processes, metal transfer and weldability of metals as well.						

Unit No.	Topics to be Covered
1.	Introduction: Welding as compared with other fabrication processes, Classification of Welding Processes
2.	Physics of Welding Arc: Welding arc, arc initiation and maintenance, voltage distribution along the arc, cathode and anode drops, Arc column, Thermionic and non thermionic cathode, Theories of cathode and anode mechanisms, arc characteristics, arc efficiency, heat generation at cathode and anode Effect of shielding gas on arc, isotherms of arcs, arc blow.
3.	Metal Transfer: Mechanism and types of metal transfer in various arc welding processes, factors controlling melting rate in various welding processes.
4.	Welding Power Sources: Basic characteristics of power sources for various arc welding processes, arc length regulation in mechanized welding processes, Transformer, rectifier and generators, Duty cycle and power factor, Static and dynamic characteristics of power sources
5	Welding Processes: Critical review of MMA; TIG. MIG and CO2 welding processes, plasma arc, submerged arc welding, electro- gas and electro-slag welding; resistance welding. Theory and mechanism of solid state welding; technique and scope of friction welding, diffusion welding; cold pressure welding and ultrasonic welding, scope and application of electron beam and laser welding processes.
6	Heat Flow in Welding: Calculation of peak temperature; width of Heat Affected Zone; cooling rate and solidification rates; weld thermal cycles; residual stresses and their measurement; weld distortion and its prevention.
7	Weldability of Metals: Effects of alloying elements on weld ability, welding of plain carbon steel, stainless steel, Cast Iron and aluminium.

References:

1 “Welding Handbook”, 7th Edition-Volume l to 5, American Welding Society. 1982
2 Houdlecroft P.T., “Welding Process Technology”, Cambridge University Press. 1977
3 Udin H, Fruk F and Wulff J, “Welding for Engineers”, John Wiley. 1978
4 Rossi E., “Welding Technology”, Mc-Graw Hill. 1969
5 Baldev, R., “Welding Technology for Engineers”, ASM International 2006
6 Bowditch, W.A., Bowditch M. A., Bowditch, K. E., “Welding Technology Fundamentals”, 4th Edition, Goodheart-Willcox Pub. 2009.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective- V		Solar Thermal Energy Utilization	3	0	0	3

Course Objective

Students can utilize the knowledge of this theoretical concept in solar based industries for manufacturing the collectors for capturing more and more energy from the Sun.

Learning Outcomes

Upon successful completion of this course, students will:

1. be able to design the flat plate solar air / water heater.
2. be able to design focusing type solar collector.
3. be able to use this solar energy concept for designing solar storage systems.

Unit No.	Topics to be Covered	LearningOutcome
1.	Need of sources of renewable energy, Introduction to different sources of renewable energy, Solar Energy and Applications	Students will learn about renewable sources of energy
2.	Basic concepts, Solar constant, Beam and diffused radiation	For understanding further topics, knowledge of solar constant is very important for the students
3.	Flat plate and concentrating collectors, Liquid Flat Plate Collector, Flat Plate Solar Air Heater, Concentrating Collectors	Knowledge of different types of solar collectors are very important for capturing solar energy
4.	Performance analysis of solar collector, Instantaneous collector efficiency	Collector efficiency is one of the important performance parameters for the solar collectors. Students will learn this terminology
5	Overall loss coefficient, Collector efficiency factor, Collector heat removal factor	Students will learn different losses during collection of energy through solar collectors
6	Concentration ratio, Tracking requirements, Thermal energy storages, Solar pond	Students will learn about concentrating solar collector. Also, they will learn about the storage the solar energy
7	Economic Analysis	Economics of solar energy utilization
8	Case studies: Performance test on CPC and Flat Plate collector	Students will do some case studies by conducting the experiments on CPC and Flat plate collector

Text Books: 1.
S. P. Sukhatme, Solar Energy - Principles of Thermal Collection and Storage, TMH, 3rd Edition, 2008.
References:
1. John A. Duffie and William A. Beckman, Solar Engineering for Thermal Process, Wiley and Sons, 1st Edition, 2013.
2. H. P. Garg, Solar Energy, 1st Revised Edition, 2000