Jharkhand University of Technology Ranchi, 834010

SCHEME OF INSTRUCTION AND SYLLABUS

For B.Tech. Program in Mechanical Engineering

(Effective from)

DEPARTMENT OF MECHANICAL ENGINEERING

B.Tech in Mechanical Engineering Semester- Vth

ADVANCED MECHANICS OF SOLIDS

L:T:P-

Course Code:

Rationale:

Course Outcomes:

After successful completion of the course, Students will be able to:

CO:1	Understand fundamentals of stress at a point; Invariants and Traction vectors
CO:2	Apply principles of elasticity theory to estimate stresses and strains in isotropic materials using tensorial approach
CO:3	Formulate and solve boundary value problems in solid continua using stress and displacement based solution Strategies
CO:4	Formulate and solve planar problems using Airy stress function in rectangular and polar co-ordinates
CO:5	Understand theories of failure, yielding and strain hardening rules of plastic flow

Course Contents

UNIT 1

Analysis of Stress and Strain: State of stress at a point; stress tensor; Geometrical representation of stress at a point; Traction vector and its components on a plane; Normal and shear stress components on a plane; Stress transformations; Principal stresses and principal planes.

UNIT 2

Octahedral stress; Invariants of a stress tensor; Decomposition of a stress tensor to hydrostatic and deviatoric components; Equations of equilibrium.

UNIT 3

State of strain at a point; Principal strains; Strain-displacement relations for finite and infinitesimal strains; Strain compatibility conditions; Constitutive Equations: General theory; generalized Hooke's law for isotropic and anisotropic material; Common equations of elasticity theory like Mitchel Beltrami and Navier equations.

UNIT 4

Principle of Virtual work; Strain energy and Castigliano's theorem**,** Solution of Some Special Boundary Value Problems: Simplifications; two-dimensional problems in rectangular and polar coordinates.

UNIT 5

Airy's stress function; Principle of superposition, torsion of bars; Membrane analogy; Plane problems in Cartesian and polar coordinates, Stress functions, axisymmetric problems. Criterion of yielding, Tresca and Von Mises criterion of yielding, Yield surface; Representation of failure theories in stress space

Textbooks:

1. Timoshenko S. P. and Goodier J. N. - 'Theory of Elasticity'- McGraw Hill International Editions, 1970 - 3rd Edition
2. L. S. Srinath - 'Advance Mechanics of Solids' - McGraw Hill Education - 2009 - 3rd Edition

Reference Books:

1. M. H. Sadd, Elasticity: theory, applications, and numeric, 3rd edition, Academic Press, 2014.
2. R. G. Budynas, Advanced Strength and Applied Stress Analysis, 2nd Edition, McGraw Hill, 1999

APPLIED THERMODYNAMICS

L:T:P-

Course Code:
Rationale:
Course Outcomes:

COUSE CONTENT

UNIT I

Steam Power Plant – Reheat, regenerative steam power cycles, low temperature power cycles, ideal working fluid and binary/multi-fluid cycles; Types of boilers and their attachments, Steam Turbine types and analysis using velocity triangles.

UNIT II

Properties of moist air: psychrometry and psychrometric charts, condensers and cooling towers;

UNIT III

IC Engines – SI, CI, two- and four-stroke engines, MEP, efficiency and specific fuel consumption, conventional and alternative fuels, pressure-crank angle diagram, carburetor and fuel injection systems;

UNIT IV

Gas Turbine Engines – Types of gas turbine engines, reheat, intercooling and regenerative cycles, combined cycles, introduction to jet propulsion;

UNIT V

Compressors and Turbines – Reciprocating air compressors: work transfer, volumetric efficiency, isothermal efficiency, multistage compression with intercooling, centrifugal compressor, axial flow compressors, axial flow turbines.

Texts:

1) G. F. C Rogers and Y. R. Mayhew, Engineering Thermodynamics Work and Heat Transfer, Pearson, 2003.
2) T. D. Eastop and A. McConkey, Applied Thermodynamics for Engineering Technologists, Pearson, 2003.

References:

1) M. M. El-Wakil, Power Plant Technology, McGraw Hill International, 1992.

2) P. K. Nag, Powerplant Engineering, Tata McGraw Hill, 2002.
3) W. W. Pulkrabek, Engineering Fundamentals of the Internal Combustion Engine, PHI, 2002.
4) H. I. H Saravanamuttoo, G. F. C. Rogers and H. Cohen, Gas Turbine Theory, Pearson, 2003

Professional Elective-I

Convective Heat Transfer

L:T:P-

Course Code:

Rationale:

- To familiarize governing equations of fluid flow and heat transfer.
- To exploit order of magnitude analysis to simplify complex mathematical equations using physical understanding of problems.
- To deeply analyze forced convection heat transfer in external and internal flows
- To study the boundary layer development with free convection phenomenon
- To understand the basics of heat transfer occurring with change of phase.

Course Outcomes:

CO1	To comprehend the governing equations involved in fluid flow and heat transfer problems.
CO2	To simplify complex mathematical equations using order of magnitude analysis.
CO3	To analyze forced and free convective heat transfer problems.
CO4	To understand the effect of different parameters on the heat transfer characteristics.
CO5	To conceptualize the similarity solution method for heat transfer analysis and study phase change effects

Course Content

UNIT I

Introduction: Convection definition and review of fluid mechanics. Derivation of governing equations of mass conservation, momentum balance and energy conservation. Order of magnitude analysis, Reynolds analogy.

UNIT II

Forced Convective Heat Transfer in External Flows: Derivation of hydrodynamic and thermal boundary layer equations, Similarity solution techniques, Momentum and energy integral methods and their applications in flow over flat plates with low and high Prandtl number approximations. Introduction to turbulence, Reynolds averaging, Eddy viscosity and eddy thermal diffusivity, Laws of the wall.

UNIT III

Forced Convective Heat Transfer in Internal Flows: Concept of developing and fully developed flows. Thermally developing flows: Graetz problem. Concept of thermally fully developed flow and its consequences under constant wall flux and constant wall temperature conditions. Steady forced convection in Hagen Poiseuille flow, Plane Poiseuille flow, and Couette flow and analytical evaluation of Nusselt numbers in limiting cases.

UNIT IV

Free Convective Heat Transfer: Free convection boundary layer equations: order of magnitude analysis, similarity, and series solutions. Concept of thermal stability and Rayleigh-Benard convection.

UNIT V

Convection with Phase Change: Concept of boiling heat transfer and regimes in pool boiling Condensation: Nusselt film condensation theory, dropwise condensation and condensation inside tubes, effects of non-condensable Deviations from continuum: wall slip and thermal creep.

References

1. A Bejan, Convection heat transfer. John wiley & sons, 2013.
2. L G Leal, Advanced transport phenomena: fluid mechanics and convective transport processes. Vol. 7. Cambridge University Press, 2007.
3. S K Som, Introduction to heat transfer. PHI Learning Pvt. Ltd., 2008.
4. F M White, Viscous fluid flow. Vol. 3. New York: McGraw-Hill, 2006.
5. T L Bergman, S L Adrienne, F P Incropera and D P DeWitt, Introduction to heat transfer. John Wiley & Sons, 2011.

Tool Design

L:T:P-

Course Code:
Rationale:
Course Outcomes:

CO1	Design Locating and Clamping systems for the given component based on geometrical and dimensional features.
CO2	Design progressive, compound or combination dies for producing a given component.
CO3	Design single point and multipoint cutting tools for conventional and CNC Machining.
CO4	Design jigs and fixtures for conventional and NC machining.
CO5	Design Locating and Clamping systems for the given component based on geometrical and dimensional features.

Course Content

UNIT I

Introduction: Tool design – An overview, Introduction to Jigs and fixtures.

Work holding devices: Basic principle of six-point location, Locating methods and devices, Principle of clamping and Types of clamps.

UNIT II

Design of jigs: Type of Drill bushes, Classification of drill jigs, Design of drill jigs.

Design of fixtures: Design of milling fixtures, Design of turning fixtures.

UNIT III

Introduction of press tool design: Introduction to Die cutting operations, Introduction to press and classifications, Die set assembly with components, Introduction to Centre of pressure, Examples of center of pressure, Design of piercing die, Design of blanking die, Progressive, Compound and Combination dies.

UNIT IV

Design of cutting tools: Introduction to cutting tools, Design of single point tool, Design of drill bit, Design of milling cutter.

UNIT V

Brief introduction of NC machines work holding devices: Tool design for NC machines- An introduction, Fixture design for NC Machine, cutting tools for NC Machine, Tool holding methods for NC Machine, ATC and APC for NC Machine, Tool presetting for NC Machine.

Text Books:

1. F. W. Wilson, Fundamentals of Tool Design, ASME, PHI, 2010
2. Donaldson C, G. H. Lecain and V. C. Goold, Tool Design, TMH, 2010

Reference Books:

1. Prakash Joshi, Jigs and Fixtures Design Manual, McGraw-Hill, 2002, 2nd Edition
2. K. Venkataraman, Design of Jigs, Fixtures and Press Tools, Wiley Athena Academic, 2015, 1st Edition

Industrial Robotics

L:T:P-

Course Code:

Rationale:

- To familiarize robot structures and their workspace and distinguish between different sensors and drives.
- To develop skills in performing spatial transformations and kinematic analysis of robot manipulator.
- To develop knowledge in the Industrial applications of robots using image processing concepts.

Course Outcomes:

CO1	Identify the components of a robot and distinguish the types of robot configurations
CO2	Compare, evaluate and choose sensors/drives for robots
CO3	Construct a kinematic model of a given manipulator and evaluate whether the inverse kinematic model is solvable
CO4	Choose and apply appropriate image processing techniques for object recognition in robotic systems
CO5	Familiarize with robot cell design and robot programming
CO6	Design and develop a robotic system for a given industrial application

Course Content

Unit I

Evolution of robotics. Robot anatomy- Co-ordinate Systems, Work envelope, types and classification – Specifications – Pitch, Yaw, Roll, Joint Notations, Speed of Motion: Accuracy, Resolution, Repeataility. Pay Load – Basic robot motions - Point to point control, Continuous path control. Robot Parts and Their Functions – Need for Robots Different Applications.

Unit II

Robot drive systems: Pneumatic Drives – Hydraulic Drives – Mechanical Drives – Electrical Drives – D.C. Servo Motors, Stepper Motor, A.C. Servo Motors – Salient Features, Applications. Harmonic drives. End Effectors – Grippers – Mechanical Grippers, Pneumatic and Hydraulic Grippers, Magnetic Grippers, Vacuum Grippers; Two Fingered and Three Fingered Grippers; Internal Grippers and External Grippers; Selection and Design Considerations.

Unit III

Coordinate frames. Mapping: Mapping between rotated frames - Mapping between translated framesMapping between rotated and translated frames-Description of objects in space-Transformation of vectors – Rotation translation combined with rotation-translation of vectors-composite transformation - Inverting a homogenous transform- Fundamental rotational matrices.

Unit IV

Direct Kinematic Model – Mechanical structure and notations-Description of links and jointsKinematic modeling of manipulator-Denavit-Hartenberg Notation-Kinematic Relationship between adjacent links-Manipulator Transformation Matrix. Inverse Kinematic Model – Manipulator Workspace-Solvability-Solution techniques-Closed form solution.

Unit V

Imaging components-image representation-picture coding-object recognition and categorizationvisual inspection. Robot cell-design and control layouts. Robot programming Languages –VAL Programming – Motion Commands, Sensor Commands, End effecter commands, and Simple programs. Industrial Applications – Material Handling, Process, Assembly, Inspection.Non-Industrial Applications.

Textbooks:

1. Fu, K.S., Gonzalez, R.C. and Lee C.S.G. – ‘Robotics: Control, Sensing, Vision, and Intelligence’ – McGraw Hill, New York, NY – 1987

Reference Books:

1. R K Mittal and I J Nagrath, ‘Robotics and Control’, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2003.
2. J Craig, ‘Introduction to Robotics: Mechanics and Control’, Addison-Wesley, Reading, MA, 1989 (second edition).

IC Engines and Emission

L:T:P-

Course Code:

Rationale:

- To familiarize mixture requirement for SI and CI for complete combustion using
- thermodynamic analysis.
- To familiarize normal and abnormal combustion from pressure data and interpret its effect on
- engine performance.
- To introduce the effect of boosting devices on engine performance, emission, heterogeneous
- combustion and spray behavior.
- To appraise the need for alternate fuels and methods to reduce emissions

Course Outcomes:

CO1	Analyze thermo-chemistry of combustion by applying thermodynamic laws in engine cycles
CO2	Understand and analyse the operation of internal combustion engines
CO3	Elucidate the effect of supercharging and turbo-charging on engine performance
CO4	Understand various fuel-metering systems like CRDI, PFI, GDI diesel fuel injection system and latest technology in fuel injection systems in SI and CI engines
CO5	Understand emission control techniques in engines, based on emission standards/norms and to recommend modification in engine for using alternate fuels

Course Content

UNIT 1

Spark Ignition engines: Mixture requirement-Fuel injection systems. Stochiometric combustion-combustion with excess air-equivalence ratio

UNIT 2

Stages of combustion: Normal and Abnormal combustion-Knock. Combustion chambers. Simple thermodynamic analysis of SI engine combustion.

UNIT 3

Compression ignition engines: Nature of combustion in IC engines-Direct and Indirect injection systems- Air motion- Combustion Chambers-Spray penetration and evaporation. Supercharging – Turbo charging. Thermodynamic analysis of CI engine combustion. Wankel Engine: Operation & applications.

UNIT 4

Hybrid engines. Thermo chemistry: Pollutant formation, Instrumentation to measure pollutants-Pollutant calculation-Effect of air- fuel ratio.

UNIT 5

Emission standards: EGR on engine emissions-Emission standards-Emission control devices. Thermal & catalytic exhaust clean-up-catalysts-automotive catalytic converters-Engine modifications to reduce emissions. Heat release analysis of IC engines. Alternate Fuels: Engine modifications for alternate fuels (liquid and gaseous fuels), homogenous charge compression ignition engines. Additives for enhancing performance and pollution control.

Textbook

1. Heywood, J. B., ‘Internal Combustion Engine Fundamentals’, McGraw-Hill, First Indian edition, 2017. BS VI emission norms (ARAI)

Reference

1. Ferguson, C.R, ‘Internal Combustion Engines’, John Wiley, 1989.
2. Degobert, P., ‘Automobiles and Air Pollution’, SAE, 2002

   B.P.Pundir, ‘IC Engines Combustion and Emissions’,Narosa Publishing House, 2010

Renewable Energy Sources

L:T:P-

Course Code:

Rationale:

- To learn the present energy scenario and the need for energy conservation
- To understand the monitoring / targeting aspects of Energy
- To study the different measures for energy conservation of various thermal energy systems
- To learn economic analysis and project planning on energy conservation
- To understand the energy conservation principle with electrical equipment

Course Outcomes:

CO1	To estimate solar radiation and formulate heat transfer equations and analyze of modern energy conversion technologies
CO2	To describe various renewable energy resources and techniques to utilize them effectively.
CO3	Compute wind energy potential and predict the performance of wind turbines
CO4	Describe and analyze photovoltaic systems
CO5	Distinguish the various form of energies such as magneto hydrodynamic, thermionic and fuel cell.

Course Content

UNIT I

Renewable Energy Resources

Environmental consequences of fossil fuel use, Importance of renewable sources of energy. Sustainable Design and development, Types of RE sources, Limitations of RE sources, Present Indian and international energy scenario of conventional and RE sources

UNIT II

Wind Energy

Power in the Wind-Types of Wind Power Plants(WPPs)-Components of WPPs-Working of WPPs Siting of WPPs-Grid integration issues of WPPS

UNIT III

Solar Pv And Thermal Systems

Solar Radiation, Radiation Measurement, Solar Thermal Power Plant, Central Receiver

Power Plants, Solar Ponds. Thermal Energy storage system with PCM- Solar Photovoltaic systems: Basic Principle of SPV conversion Types of PV Systems- Types of Solar Cells, Photovoltaic cell concepts: Cell, module, array, PV Module IV Characteristics, Efficiency & Quality of the Cell, series and parallel connections, maximum power point tracking Applications.

UNIT IV

Biomass Energy

Introduction-Bio mass resources Energy from Bio mass: conversion processes-Biomass Cogeneration-Environmental Benefits. Geothermal Energy: Basics, Direct Use, Geothermal Electricity. Mini/micro hydro power: Classification of hydropower schemes, Classification of water turbine, Turbine theory, Essential components of hydroelectric system.

UNIT V

Other Energy Sources

Tidal Energy Energy from the tides, Barrage and Non Barrage Tidal power systems. Wave Energy Energy from waves, wave power devices. Ocean Thermal Energy Conversion (OTEC)- Hydrogen Production and Storage-Fuel cell Principle of working- various types-construction and applications. Energy Storage System Hybrid Energy Systems.

Text Books:

1. Joshua Eamest, Tore Wizeliu, Wind Power Plants and Project Development, PHI Leaming Pvt.Ltd, New Delhi, 2011.
2. D.P.Kothari, K.C Singal, Rakesh Ranjan "Renewable Energy Sources and Emerging Technologies", PHI Learning Pvt. Ltd, New Delhi, 2013.
3. Scott Grinnell, "Renewable Energy & Sustainable Design", CENGAGE Learning, USA, 2016.

References

4. A.K.Mukerjee and Nivedita Thakur, Photovoltaic Systems: Analysis and Design", PHI Learning Private Limited, New Delhi, 2011
5. Richard A. Dunlap, Sustainable Energy Cengage Learning India Private Limited, Delhi, 2015.
6. Chetan Singh Solanki, Solar Photovoltaics Fundamentals, Technologies and Applications", PHI Learning Private Limited, New Delhi, 2011
7. Bradley A. Striebig, Adebayo A.Ogundipe and Maria Papadakis, Engineering Applications in Sustainable Design and Development, Cengage Learning India Private Limited, Delhi, 2016.

8. Godfrey Boyle, Renewable energy", Open University, Oxford University Press in association with the Open University, 2004.
9. Shobh Nath Singh, "Non-conventional Energy resources Pearson Education 2015.

Computational Fluid Dynamics

L:T:P-

Course Code:

Rationale:

- To study the basic governing equations and understand the basic properties of CFD.
- To understand discretization techniques and solving methods for improving accuracy.
- To inculcate the knowledge required to solve real-time physical problems using simulation software.

Course Outcomes:

CO1	Understand the classification of PDEs, and governing equations.
CO2	Understand the basic principles of computational methods.
CO3	Apply finite volume method to solve steady and unsteady diffusion, advection-diffusion problems.
CO4	Select Solution algorithms and various discretization schemes.
CO5	Solve engineering problems using CFD software.

Course Content

Unit I

Introduction to Computational Fluid Dynamics and Principles of Conservation: Continuity Equation, Navier Stokes Equation, Energy Equation and General Structure of Conservation Equations,

Classification of Partial Differential Equations and Physical Behavior, Approximate Solutions of Differential Equations: Error Minimization Principles.

Fundamentals of Discretization: Finite Element Method, Finite Difference and Finite Volume Method, Consistency, Stability, and Convergence. 1-D Steady State Diffusion Problems- Source term linearization, Implementation of boundary conditions.

Unit II

1-D unsteady state diffusion problems: implicit, fully explicit and Crank-Nicholson scheme. Finite volume discretization of convection-diffusion problem. Central difference scheme, Upwind scheme, Exponential scheme and Hybrid scheme, Power law scheme, Generalized convection-diffusion formulation, Finite volume discretization of two-dimensional convection-diffusion problem. The concept of false diffusion, QUICK scheme, TVD schemes and flux limiter functions.

Unit III

Finite Volume Discretization of 2-D unsteady State Diffusion type Problems, Solution of Systems of Linear Algebraic Equations: Elimination Methods, Iterative Methods

Unit IV

Discretization of Navier Stokes Equations, primitive variable approach, SIMPLE Algorithm, SIMPLER Algorithm, Unstructured Grid Formulation.

Unit V

Introduction to Turbulence Modeling, Important features of turbulent flow, General Properties of turbulent quantities, Reynolds average Navier stokes (RANS) equation, Closure problem in turbulence: Necessity of turbulence modeling and applications.

List of computational exercises

1. Computational solution of 1-D heat conduction equation using implicit, fully explicit and Crank-Nicholson scheme.
2. Computational solution of 1-D heat conduction equation using implicit, fully explicit and Crank-Nicholson scheme.
3. Computational solution of convection-diffusion problem using Central difference scheme, Upwind scheme, Exponential scheme and Hybrid scheme, Power law scheme.
4. Solve practical fluid dynamics and heat transfer problems using CFD tools such as Open FOAM, Ansys Fluent etc.

Textbooks:

1. Versteeg, H.K., and Malalasekara, W, "An Introduction to Computational Fluid Dynamics", The Finite Volume Method, 2007.
2. Moukalled, F., Mangani, L., &Darwish, M. "The finite volume method in computational fluid dynamics. An Advanced Introduction with OpenFOAM and Matlab", 2016

Reference Books:

1. Patankar, S.V., "Numerical Heat Transfer and Fluid Flow", Hemisphere Publishing Corporation, 1980.
2. Anderson, J. D., & Wendt, J., "Computational fluid dynamics" (Vol. 206). New York: McGraw-Hill, 1995.

Alternative Refrigerants

L:T:P-

Course Code:

Rationale:

- understand the importance of refrigerant and its properties
- To understand the impact of refrigerants on the environment.
- To understand the safety measures applicable for refrigerants.
- To provide design procedures with alternative refrigerants.
- To identify the changes in retrofitting the systems with alternative refrigerants.

Course Outcomes

CO1	To comprehend the significance of refrigerants and their characteristics.
CO2	To recognize the environmental impact of refrigerants.
CO3	To understand the safety protocols associated with refrigerants.
CO4	To offer design guidelines for using alternative refrigerants.
CO5	To identify the modifications required when retrofitting systems with alternative refrigerants.

Course Content

UNIT I

Refrigerants and its classification – Need of alternate refrigerants, Desirable properties- thermodynamic-chemical and transport properties - designation of refrigerants - inorganic, halo carbon refrigerants - secondary refrigerants - Properties of mixtures of refrigerants, Ozone depletion potential and global warming potential.

UNIT II

Flammability of the alternate refrigerants, methods for identifying the safe zone of operation,

UNIT III

Measuring the financial and environmental impact of leakage of refrigerants on the environment, Refrigerant Hazards.

UNIT IV

Safety and risk assessment of alternative refrigerants, System design using alternative refrigerants, Leak detection of alternative refrigerants,

UNIT V

Maintenance and repair of alternative refrigerant systems, Retrofitting existing systems.

References

1. 1.Arora, R.C., Refrigeration and Air Conditioning, PHI Pvt Ltd, 2010
2. 2 Arora, C.P., Refrigeration and Air Conditioning, 2nd ed., Tata McGraw-Hill, 2000
3. Randall F. Barron, Cryogenic Systems, McGraw-Hill, 1985.
4. 3 Klaus D. Timmerhaus and Thomas M. Flynn, Cryogenic Process Engineering, Plenum Press New York, 1989.
5. 4 Randall F. Barron, Cryogenic heat transfer, CRC Press,1999.
6. 5 Stoecker N.F and Jones, Refrigeration and Air Conditioning, TMH NewDelhi,2nd edition 1982.

Mechanical Measurements

L:T:P-

Course Code:
Rationale:
Course Outcomes:

CO1	Understand the measurement terminologies and the concept of a generalized measurement system.
CO2	Estimate errors and uncertainty in measurements using statistical analysis.
CO3	Analyze the zeroth, first and second order measurement systems.
CO4	Select sensors for measurement of specific parameters with required accuracy.
CO5	Calibrate measuring instruments with given standards.
CO6	Design experiments by combining measuring devices to obtain desired outputs.

Course Content

UNIT I

Basics of Measurements: Introduction, Generalized measurement system, Signal flow diagram of measurement system, Inputs and their methods of correction, Dynamic response – zeroth, first and second order measuring systems.

Presentation of experimental data: Errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis.

UNIT II

Pressure measurement: Different pressure measurement instruments and their comparison, Transient response of pressure transducers **Thermometry:** Overview of thermometry, Thermo-electric temperature measurement, Resistance thermometry, Pyrometer, Other methods, issues in measurements.

Flow Measurement: Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, Other methods.

Thermal and transport property measurement: Measurement of thermal conductivity, diffusivity, viscosity, humidity and gas composition.

UNIT III

Nuclear, thermal radiation measurement: Measurement of reflectivity, transmissivity, emissivity, nuclear radiation, neutron detection, etc.

Other measurements: Basics in measurement of torque, force, strain

UNIT IV

Advanced topics: Issues in measuring thermos-physical properties of micro and Nano fluidics

UNIT V

Design of Experiments: Basic ideas of designing experiments, Experimental design protocols with some examples.

Text Books:

1. Thomas G Beckwith, Mechanical Measurements, Pearson publications, 2006, 6th Edition
2. Ernest O Doebelin, Measurement systems, Tata McGraw Hill publications, 2019, 7th Edition
3. J P Holman, Experimental Methods for Engineers, Tata McGraw Hill publications, 2011, 7th Edition

Reference Books:

1. John R. Taylor, An Introduction to Error Analysis,University Science Books, 1997, 2nd Edition
2. S P Venkateshan, Mechanical Measurements, Ane Books Pvt. Ltd., 2015, 2nd Edition.

Other Suggested Readings:

1. Mechanical Measurements and Metrology by Prof. S P Venkateshan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106138/).
2. Principles of Mechanical Measurement by Prof. Dipankar N Basu (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/112/103/112103261/).

Automobile Engineering

L:T:P-

Course Code:

Rationale:

Course Outcomes:

CO1	Understand the basic layout of an automobile.
CO2	Understand the operation of engine cooling, lubrication, ignition, electrical and air conditioning systems.
CO3	Analyze the vehicle transmission, suspension, steering and braking systems.
CO4	Understand automotive electronics.
CO5	Explore latest developments in automobiles.

Course Content

UNIT I

Introduction: Overview of the course, Examination and Evaluation patterns, History of Automobiles, Classification of Automobiles.

Power Plant: Classification, Engine Terminology, Types of Cycles, working principle of an IC engine, advanced classification of Engines- Multi cylinder engines, Engine balance, firing order.

UNIT II

Fuel System and Ignition System and Electrical system: spark Ignition engines- Fuel tank, fuel filter, fuel pump, air cleaner/filter, carburettor, direct injection of petrol engines. Compression Ignition engines, Fuel Injection System- air & solid injection system, Pressure charging of engines, super charging and turbo charging, Components of Ignition systems, battery ignition system, magneto ignition system, electronic ignition and ignition timing. Main electrical circuits, generating & stating circuit, lighting system, indicating devices, warning lights, speedometer.

UNIT III

Lubricating system and cooling systems: Functions & properties of lubricants, methods of lubrication-splash type, pressure type, dry sump, and wet sump & mist lubrication. Oil filters, oil pumps, oil coolers. Characteristics of an effective cooling system, types of cooling system, radiator, thermostat, air cooling & water cooling.

UNIT IV

Chassis: Systems in an automobile, body, chassis frame, parts of the automobile body, terminology, automobile frames, functions, constructions, sub frames, materials and defects in frames.

Transmission, axles, clutches, propeller shafts and differential: Types of gear boxes, automatic transmission, electronic transmission control, functions and types of front and rear axles, types and functions of the clutches, design considerations of Hotchkiss drive torque tube drive, function and parts of differential and traction control.

UNIT V

Steering System: functions of steering mechanism, steering gear box types, wheel geometry.
Braking and suspension system: functions and types of brakes, operation and principle of brakes, constructional and operational classification and parking brake. Types of springs shock observers, objectives and types of suspension system, rear axles suspension, electronic control and proactive suspension system.
Automotive air conditioning: ventilation, heating, air condition, refrigerant, compressor and evaporator.
Wheels and tyres: Wheel quality, assembly, types of wheels, wheel rims. Construction of tyres and tyre specifications.

Text Books:

1. K.M. Gupta.l, Automobile Engineering, Vol.I & II, Umesh Pub, 2010.
2. W.H. Crouse and D.L. Anglin, Automotive Mechanics, Tata McGraw Hill, New Delhi,2005.
3. J. Heitner, Automotive Mechanics, Affiliated South West Press, New Delhi, 2000.
4. Anderson, J. D., Fundamentals of Aerodynamics,McGraw-Hill Education, 2016, 6th edition

Reference Books:

1. G.B. Narang, Automobile Engineering, Khanna Publishers, New Delhi, 2001.
2. Kamaraju Ramakrishna, Automobile Engineering,PHI Learning pvt. Ltd., New delhi-2012.
3. D. Crolla, D. E. Foster, T. Kobayashi and N. Vaughan (Editors-in-Chief), Encyclopedia of Automotive Engineering, Parts 1-6, Wiley, 2015.
4. R. Stone and J. K. Ball, Automotive Engineering Fundamentals,SAE International, 2004.

Geometric Modelling for CAD

L:T:P-

Course Code:
Rationale:
Course Outcomes:

CO1	Apply geometric transformations and projection methods in CAD.
CO2	Develop geometric models to represent curves.
CO3	Design surface and solid models for engineering design.
CO4	Apply mesh generation method for engineering analysis.

Course Content

UNIT I

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, Requirements of Modelling, Geometric modelling, Software tools for CAD, Input and Output Devices for CAD System.

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

UNIT II

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections. Implementation of the projection formulations using computer codes.

Curves in Geometric Modeling for Design: Differential geometry of curves**,** Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Castegliau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS. Conversion of one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

UNIT III

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, parametric representation, Curvatures, Developable surfaces. Surface's entities (planar, surface of revolution, lofted etc). Free-form surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

UNIT IV

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD software. Data Exchange Formats and CAD Applications**.**

UNIT V

Introduction to Engineering Analysis: Finite Element Analysis, Criteria of Mesh Quality, Mesh Generation Methods (Mapped Mesh Generation, Triangulation etc.).

Text Books:

1. Michael E. Mortenson, Geometric Modeling, Tata McGraw Hill, 2013.
2. A. Saxena and B. Sahay, Computer-Aided Engineering Design, Anamaya Publishers, New Delhi, 2005.
3. Rogers, David F., An introduction to NURBS: with historical perspective, Morgan Kaufmann Publishers, USA, 2001.
4. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.

Reference Books:

1. Kunwoo Lee, Principles of CAD/CAM/CAE, Pearson, 1999.

Program Elective-II

Vehicle Dynamics

L:T:P-

Course Code:

Rationale:

- To study the vibration of SDOF and MDOF vibrational systems.
- To understand various numerical techniques used to evaluate the natural frequencies and mode shapes of MDOF systems.
- To impart the knowledge of vehicle load distribution while acceleration, deceleration, and braking.
- To study the mechanical properties of tires and their rolling resistance.
- To understand the lateral and vertical dynamics of vehicle.

Course Outcomes:

CO1	To illustrate the fundamentals of vibration and formulate the differential equations of the given vibration models.
CO2	To evaluate the natural frequencies and mode shapes of MDOF systems by appropriate numerical techniques.
CO3	Analyze road vehicles for their longitudinal dynamic response during acceleration and braking.
CO4	To design tires which provide proper rolling resistance and contact pressure distribution.
CO5	To evaluate road vehicles for their lateral and vertical dynamic response while cornering and moving on a rough patch of the road.

Course Content

UNIT 1

Fundamentals of Vibration: Review of free, forced, and damped vibrations of Single Degree of Freedom Systems (SDOF). Multi Degree of Freedom Systems: Close-coupled system, Eigen valve problems, Far-coupled systems, Orthogonality of mode shapes, Modal analysis, Forced vibration by matrix inversion.

UNIT II

Numerical Methods: Approximate methods for fundamental frequency – Dunkerley's lower bound method, Rayleigh's upper bound method, Holzer method for close-coupled systems.

UNIT III

Longitudinal Dynamics: Vehicle load distribution – Acceleration and Braking, Brake force distribution, Braking efficiency and braking distance, Passenger car and Tractor-semi trailer models.

UNIT IV

Tire Mechanics: Mechanical properties of rubber – Slip, grip and rolling resistance, Tire construction and force development, contact patch and contact pressure distribution, Tire Brush Model, Lateral force generation – ply steer, conicity, and camber, Magic Formula Tire Models, Combined Slip.

UNIT V

Lateral dynamics: Bicycle Model, Stability and steering conditions, Understeer gradient, Handling response of a vehicle, Parameters affecting vehicle handling characteristics, Rollover prevention. **Vertical Dynamics:** Full car model, Half car model, Quarter car model.

References

1.Thomson, W.T., 2010. Theory of Vibration and its Applications, 5th Edition, Pearson Eduation, New Delhi.

2.Rao, J.S., 1999. Introductory Course on Theory and Practice of Mechanical Vibrations. New Age International.

3.Gillespie, T., 1992. Fundamentals of Vehicle Dynamics. SAE international.

4.Pacejka, H., 2006. Tire and Vehicle Dynamics. Elsevier.

5.Wong, J.Y., 2008. Theory of Ground Vehicles. John Wiley & Sons.

6.Karnopp, D., 2004. Vehicle Stability. CRC Press.

Mechanics of Composite Materials

L:T:P-

Course Code:

Rationale:

Course Outcomes:

CO1	Understand the industrial need for composite materials.
CO2	Identify suitable processes to develop fiber reinforced composite materials.
CO3	Apply the micro and macro mechanics for fiber reinforced composite materials.
CO4	Develop governing equation for Bending, Buckling, and Vibration of Laminated plates.
CO5	Design the composite structures with the help of computers.

Course Content

UNIT I

Introduction to composite materials: Introduction, What is a composite material, Current and potential advantages of fibre reinforced composites, Applications of composite materials, Military, civil, space, automotive and commercial applications

UNIT II

Macro and micro mechanical behaviour of a lamina: Stress strain relations for anisotropic materials, Restrictions on engineering constants, Strengths of an orthotropic lamina, biaxial strength criteria for orthotropic lamina

UNIT III

Micro mechanical behaviour of lamina and laminates: Mechanical of material approach to stiffness, Elasticity approach to stiffness, Classification lamination theory, Special cases, strength of laminates

UNIT IV

Bending, Buckling and Vibration of laminated plates: Governing equations for bending buckling and vibration of laminated plates, Deflection of simply supported laminated plates, Vibration of simply supported laminated plates

UNIT V

Design of composite structures: Introduction, design philosophy, Anisotropic analysis, Bending extension coupling, Micromechanics, Nonlinear behaviour, Inter-laminar stresses, transverse shearing, Laminate optimization

Text Books:

1. Ronald F. Gibson, Principles of composite material mechanics, CRC Press, 2011.
2. Robert M Jones, Mechanics of Composite Materials, Taylor & Francis, 2000.

Reference Books:

1. Lawrence E. Nielsen, Nielson, Paul Nielsen, Mechanical Properties of Polymers and Composites, Second Edition, CRC press, 2000

Quality Control And Reliability Engineering

Course Code: **L:T:P:**

Rationale:

- To introduce the principles and techniques of statistical quality control and their applications
- To familiarize with basic concepts and techniques of reliability engineering

Course Outcomes:

CO1	Apply the knowledge of statistics and probability to attain the quality improvement in industries
CO2	Analyze the product quality using statistical tools
CO3	Determine the reliability and maintainability of systems

Course content

UNIT I

Basic concepts in Quality Engineering and Management: definitions, approaches and relevance to organizational excellence. Product quality control: Acceptance sampling methods- single, multiple and sequential sampling plans; Recent developments in inspection methods.

UNIT II

Statistical Process Control: Process evaluation and control by control charts: Various control charts including CUSUM charts and multivariate charts. Process capability studies: Various indices and approaches; use of Nomographs; Discussions on capabilities of Process, Machine and Gauge; Unit yields and rolled throughput yield.

UNIT III

Total Quality Management perspective, methodologies and procedures; Roadmap to TQM, ISO 9000, KAIZEN, Quality Circles, Models for organizational excellence.

UNIT IV

Quality Function Deployment, Quality cost systems and Quality Policy Deployment Process evaluation and control by designs of experiment: Various basic designs; Special methods such as EVOP and ROBUST design (Taguchi Methods).

UNIT V

Six Sigma Management: Concepts, Steps and Tools ; Benchmarking and Balanced Score Cards Reliability engineering; statistical analysis of life time data and determination of reliability, availability and maintainability; TPM; FMECA, Fault Tree Analysis Quality and reliability perspectives of JIT. Application of Software tools and Case Studies.

References

1) A.J.Duncan, Quality Control and Industrial Statistics, Richard Darwin Inc., USA.1965
2) A.V.Feigenbaum, Total Quality Control, McGraw Hill International Editions, USA.1987
3) D.C.Montgomery, Design and Analysis of Experiments, John Wiley and Sons, USA.1984
4) J.M.Juran, Juran on Quality Control by Design, The Free Press.1992.
5) W.E.Deming, Out of Crisis: Quality, Productivity and Competitive Position, Productivity and Quality Publishing Private Limited, Madras.1992
6) A.Mitra, Fundamentals of Quality Control and Improvement, Pearson Education, 2nd ed. 2005.
7) J.R.Evans and W.M.Lindsay, The Management and Control of Quality, Thomson.2005.
8) H.M.Wadsworth, K.S.Stephens and A.B.Godfrey, Modern Methods for Quality Control and Improvement, John Wiley & Sons.2004.

Computer Aided Design and Drafting

L:T:P-

Course Code:

Rationale:

- Introduce the student to the basic tools of computer-aided design (CAD) and computer-aided manufacturing (CAM).
- Expose the student to contemporary computer design tools for aerospace and mechanical engineers.
- Prepare the student to be an effective user of a CAD/CAM system.
- Apply mathematical techniques for representing and manipulating geometric entities
- Develop and modify solid models using feature-based approaches

Course Outcomes:

CO1	Introduce the student to the basic tools of computer-aided design (CAD) and computer-aided manufacturing (CAM).
CO2	Expose the student to contemporary computer design tools for aerospace and mechanical engineers.
CO3	Prepare the student to be an effective user of a CAD/CAM system.
CO4	Apply mathematical techniques for representing and manipulating geometric entities

Course Content

UNIT I

CAD hardware - Product cycle - CAD tools, CAD systems; system evaluation, CAD specific I/O devices.

UNIT II

CAD software - Graphic standards – Modes of graphics operation, Software Modules.

UNIT III

Geometric modeling – Types and mathematical representation and manipulation of curves and surfaces.

UNIT IV

Solid modeling- fundamentals, feature based modeling manipulations of solid models.

UNIT V

Transformation of Geometric models and visual realism - Animation.

References

1. Zeid, I., CAD/CAM Theory and Practice, Tata McGraw-Hill, 2nd Edition, 2009.
2. Rogers, D.E and Adams, J.A., Mathematical Elements for Computer Graphics, 2nd ed. McGraw-Hill, 2002.
3. Anupam Saxena and Birendra Sahay, Computer Aided Engineering Design, by ISBN-13: 978-1402025556, Springer, 2005.
4. Farid M. L. Amirouche, Principles of Computer-aided Design and Manufacturing, Pearson Prentice Hall, 2004.
5. Ruben Hawkins , Computer Graphics: Principles and Practice, Larsen and Keller Education, 2017

Cryogenic Engineering

L:T:P-

Course Code:

Rationale: On successful completion of this course the student will be able to understand Concepts of cryogenic, cryogenic refrigeration and handling of the cryogens.

Course Outcomes:

After successful completion of the course, Students will be able to:

CO1	To give introductory knowledge of cryogenic Engineering
CO2	To impart knowledge in liquefaction, separation of cryogenics gases and working of cryocoolers.
CO3	To embark on a research career in Cryogenic Engineering

Course of Contents:

UNIT I INTRODUCTION

Insight on Cryogenics, Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Applications of Cryogenics in Space Programs, Superconductivity, Cryo Metallurgy, Medical applications.

UNIT II LIQUEFACTION CYCLES

Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve – Joule Thomson Effect. Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claudes Cycle Dual Cycle, Ortho-Para hydrogen conversion, Eollins cycle, Simpson cycle, Critical Components in Liquefaction Systems.

UNIT III SEPARATION OF CRYOGENEIC GASES

Binary Mixtures, T-C and H-C Diagrams, Principle of Rectification, Rectification Column Analysis – McCabe Thiele Method. Adsorption Systems for purification.

UNIT IV CRYOGENIC REFRIGERATORS

J. T. Cryocoolers, Stirling Cycle Refrigerators, G.M Cryocoolers, Pulse Tube Refrigerators Regenerators used in Cryogenic Refrigerators, Dilution refrigerators, Magnetic Refrigerators.

UNIT V HANDLING OF CRYOGENS

Cryogenic Dewar, Cryogenic Transfer Lines. Insulations used in Cryogenic Systems, Instrumentation to measure Flow, Level and Temperature.

REFERENCES

1. Klaus D. Timmerhaus and Thomas M. Flynn, Cryogenic Process Engineering ,Plenum Press ,New York, 1989.
2. Randall F. Barron, Cryogenic Systems, McGraw-Hill, 1985.
3. Scott R.B., Cryogenic Engineering, Van Nostrand and Co., 1962.
4. Herald Weinstock, Cryogenic Technology, Boston Technical Publishers, inc., 1969.
5. Robert W. Vance, Cryogenic Technology, John wiley & Sons, Inc., New York, London.
6. G.Venkatarathnam, Cryogenic Mixed Refrigerant Processes, Springer Publication, 2010.
7. J.G. Weisend, Hand Book of Cryogenic Engineering —II, Taylor and Francis, 1998.

Fundamentals of Mechanobiology

Course Code: **L:T:P:**

Rationale:

- To provide students with a comprehensive understanding of the basic biomechanical principles and their application in biological systems.
- To equip students with knowledge and skills in mechanics and dynamics as they relate to biological materials and systems at various scales.
- To explore the interplay between mechanical forces and biological responses, focusing on tissue mechanics and cellular behavior.
- To advance students understanding of biomechanics at the molecular and continuum levels, integrating advanced material properties and experimental techniques.

Course Outcomes:

CO1	Students will be able to analyze and solve static and dynamic problems in biomechanics
CO2	Students will demonstrate proficiency in evaluating linear and angular motion
CO3	Students will be adept at describing how mechanical forces influence biological processes at the cellular and tissue
CO4	To advance students understanding of biomechanics at the molecular and continuum levels, integrating advanced material properties and experimental techniques

Course Contents

UNIT 1

Introduction to Biomechanics: Force vectors, Coplanar, collinear and concurrent forces, Moment and torque, Statics: Analysis of systems in equilibrium, and Applications of statistics to Biomechanics.

UNIT 2

Mechanics and Dynamics: Introduction to dynamics, Linear kinematics and kinetics, Angular kinematics and kinetics, Work-energy methods, Stress and strain, Computational biomechanics, Multiaxial Deformations and stress analysis, Stress transformation, Principle stresses, Failure theories, Torsion and Bending.

UNIT 3

Mechanobiology and Tissue Mechanics: Skeletal tissues (bone, articular cartilage, tendons and ligaments) remodeling, Gait analysis, Cellular cytoskeleton, Intracellular signalling, Cell migration, Durotaxis, Mechanotaxis, Chemotaxis and Mechanics of biomembranes.

UNIT 4

Molecular Mechanics and Dynamics, Continuum mechanics, Microstructural models, Constitutive laws, Electromechanical and physicochemical properties of tissues, Viscoelasticity, Models of Viscoelasticity, Fracture and Fatigue, and Experimental measurements of mechanical behaviour Cells and tissues.

Textbooks:

1. Nihat Ozkaya and Margareta Nordin, Fundamentals of biomechanics: Equilibrium, Motion and deformation, 2nd Edi. Springer
2. Y.C Fung, Biomechanics – Mechanical Properties of Living Tissues, Springer , 1993

References:

1. Roger Bartlett, Introduction to Sports Biomechanics: Analysing Human Movement Patterns, Taylor and Francis , 2007
2. Christopher R. Jacobs, Hayden Huang, Ronald Y. Kwon, Introduction to Cell Mechanics and Mechanobiology, Garland Science

Power Plant Engineering

Course Code:
L:T:P-
Rationale:
Course Outcomes:

CO1	Understand functions of the components of power plant
CO2	Understand the working of nuclear, thermal and gas based power plants.
CO3	Evaluate the design layout and working of hydroelectric power plants
CO4	Evaluate economic and environmental implications on power plants.

Course Content

UNIT I

Introduction: Energy resources and their availability, types of power plants, review of basic thermodynamic cycles used in power plants.

Steam Power Plants: Flow sheet and working of modern-thermal power plants, site selection, plant efficiency.

Steam generators and their accessories: High pressure Boilers and its accessories, Draught system.

UNIT II

Fuel and combustion: coal storage, preparation, coal handling systems, mass and energy balance of steam generator, feeding and burning of pulverized fuel, Fluidized bed combustion system, ash handling systems, dust collection-mechanical dust collector and electrostatic precipitator.

Condensers: Direct Contact Condenser, Surface Condensers, Cooling towers and cooling ponds.

UNIT III

Combined Cycles: Gas turbine power plants, integrated gasification combined cycle, PFBC based combined cycle, re-powering of thermal power plant.

Nuclear Power Plants: Principles of nuclear energy, basic nuclear reactions, nuclear cross-section, and different components of nuclear power station, PWR, BWR, fast breeder, nuclear waste disposal.

UNIT IV

Non-conventional energy generation: Geothermal power plant, Tidal and wave power plant, solar power plant, wind power generation, direct to electricity method - Magneto-hydrodynamic (MHO) power generation.

UNIT V

Hydro Electric Power Plants: Rainfall and run-off measurements and plotting of various curves for estimating stream flow and size of reservoir, power plant design, comparison with other types of power plants.

Power Plant Economics: load curve, different terms and definitions, base load and peak load plants, energy storage, cost of electrical energy, tariffs methods of electrical energy performance & operating characteristics of power plants- incremental rate theory, input- output curves, efficiency, heat rate, economic load sharing, Problems.

Text Books:

1.Power Plant Engineering, P. K. Nag, McGraw Hill Education, 4th Edition, 2017

2.Power plant engineering, Arrora, Domkundwar, DhanpatRai & Sons, New Delhi, 2008

3.Power plant engineering, P. C. Sharma, S.K. Kataria & Sons, New Delhi, 2010

Reference Books:

1.Power plant Technology, M.M.Ei-Wakil, McGraw Hill Com., Other Suggested Readings:

2.https://www.alternative-energy-tutorials.com/

Mechatronics

L:T:P-

Course Code:
Rationale:
Course Outcomes:

CO1	Model and analyze mechatronic systems for an engineering application
CO2	Identify sensors, transducers and actuators for monitoring and controlling the behavior of processes and products.
CO3	Develop PLC programs for an engineering application.
CO4	Evaluate the performance of mechatronic systems.

Course Content

UNIT I

Introduction: Overview of the course, Examination and Evaluation patterns, History of Mechatronics, Scope and Significance of Mechatronics systems, elements of mechatronic systems, needs and benefits of mechatronics in manufacturing.

UNIT II

Sensors & Actuators: Proximity Sensor, force sensors, sensors used in mechatronics systems.
Electrical Actuators: Solenoids, relays, DC motor, Servo motor, BLDC Motor, AC Motor, stepper motors. Hydraulic & Pneumatic devices – Power supplies, different control valves, cylinder sequencing. Design of Hydraulic & Pneumatic circuits. Piezoelectric actuators, Shape memory alloys actuators.

UNIT III

Basic System Models & Analysis: Modelling of one and two degrees of freedom Mechanical, Electrical, Fluid and thermal systems, Block diagram representations for these systems.

Dynamic Responses of System: Transfer function, Modelling Dynamic systems, first order systems, second order systems, Time Domain Analysis, Stability analysis using Routh-Hurwitz criteria .

UNIT IV

Digital Electronics: Number systems, BCD codes and arithmetic, Gray codes, self-complimenting codes, Error detection and correction principles. Boolean functions using Karnaugh map, Design of combinational circuits, Design of arithmetic circuits. Design of Code converters, Encoders and decoders.

Signal Conditioning: Operational amplifiers, inverting amplifier, differential amplifier, Protection, comparator, filters, Multiplexer, Pulse width Modulation Counters, decoders. Data acquisition – Quantizing theory, Analog to digital conversion, digital to analog conversion.

Controllers: Classification of control systems, Feedback, closed loop and open loop systems, Continuous and discrete processes, control modes, Two step Proportional, Derivative, Integral, PID controllers.

UNIT V

PLC Programming: PLC Principles of operation PLC sizes PLC hardware components I/O section Analog I/O section Analog I/O modules, digital I/O modules CPU Processor memory module Programming. Ladder Programming, ladder diagrams, timers, internal relays and counters, data handling, analogue input and output. Application on real time industrial automation systems.

Case studies of Mechatronics systems: Pick and place robot, Bar code, Engine Management system, Washing machine etc.

Industry 4.0 Concepts & Principles: Introduction, AI, Cyber physical System, Cloud computing, machine learning

Text Books:

1. W. Bolton, Mechatronics, Addison Wesley Longman Ltd, 2010, 5thEdition
2. Devdas Shetty & Richard Kolk, Mechatronics System Design, PWS Publishing, 2009, 3rd Edition

Reference Books:

1. Alciatore David G and Histand Michael B, Introduction to Mechatronics and Measurement systems, Tata McGraw Hill, 2012, 4th Edition.
2. Clarence W. de Silva, Mechatronics : A foundation course, CRC Press, 2010.

Semester- VIth

Machine Design

L:T:P-

Course Code:
Rationale:
Course Outcomes:

CO1	Identify the preferred sizes and codes and selection of proper material for designing machine elements.
CO2	Design the machine element under static and dynamic loading conditions.
CO3	Design the temporary and permanent joints required to assemble the machine elements.
CO4	Design the required spring for the given application.

Course Content

UNIT I

Introduction: Engineering Design and classification, Basic design procedure, requirement of machine element, traditional design methods, standards and codes, selection of preferred sizes, Engineering material and its classification, Mechanical properties of engineering materials, Selection of materials, Manufacturing considerations and their selection.

UNIT II

Static Loading: Basics- Stresses in members subjected to different types of loads, Modes of failure, Principal stresses, Theories of failure- Rankine theory, Guests theory and Von Mises theory, Selection of failure theories to design simple machine parts.

UNIT III

Dynamic Loading: Stress concentration and its Importance in design, Methods to reduce stress concentration, Stress concentration factor-Theoretical and actual stress concentration factors, Notch sensitivity, Design of stress concentrated members subjected to various loads-Problems, Types of variable/Cyclic loads, Mean & amplitude Stresses, Fatigue Failure, Endurance Limit & Strength, S-N Diagram, Goodman and Soderberg criterion, Modifying factors: Size effect, surface effect, Reliability, Stress concentration effects etc., Problems on design of members for finite & infinite life in members subjected to individual & combined loading, Cumulative damage in fatigue.

Design of Bolted Joints: Forms of screw threads, Nomenclature of screw thread, Thread series and its designation, Power screws, Stress in screwed threads, Design of bolts based on uniform strength, Empirical relation for initial tightening, Eccentrically bolted joints in shear, Turnbuckle, Design of power screw-Problems.

UNIT IV

Design of Riveted and Welded Joints: Rivet heads, Terminology, Caulking and fullering, Analysis of riveted joint, Efficiency of a riveted joint, Design of boiler joints and structural joints, eccentrically loaded riveted joints, welding process, merits and demerits of welded joint over riveted joints, weld symbols, Strength of parallel and fillet weld, eccentrically loaded welded joints, Weld subject to bending moment and torsional moment, Problems.

UNIT V

Design of Springs: Types of Springs, Spring materials, terminology - Stresses in Helical coil springs of circular and non-circular cross sections, Compression-spring surge, Springs under eccentric loading and fluctuating loads, - Energy stored in springs, torsion, Belleville springs. Leaf Springs: Stresses in leaf springs, Nipping. Equalized stresses.

Text Books:

1. V B Bhandari, Design of Machine Elements, Tata McGraw Hill Education Private Limited, 2020, Fifth edition.
2. Robert L Norton, Machine design an integrated approach, Pearson Education, 2018, Fifth edition.

Reference Books:

1. Richard G. Budynas, J Keith Nisbett, Mechanical Engineering Design, Shigley's. McGraw Hill, 2011, Ninth edition.
2. Black and Adams, Machine Design, McGraw Hill and Co, New Delhi, 2002.

Refrigeration and Air-Conditioning

L:T:P-

Course Code:

Rationale:

Course Outcomes:

CO1	Demonstrate the working principles of various refrigeration systems using thermodynamic principles.
CO2	Evaluate the performance of basic refrigeration and air-conditioning machines.
CO3	Identify the Psychrometric processes for different applications and design the parameters of the air-conditioning system as per standards.
CO4	Analyze the performance of compressors using thermodynamic concepts, principles of design and their control during its operation.

Course Content

UNIT I

Introduction: Basic Definitions of Refrigeration and Air-Conditioning, History of Refrigeration, Natural and Artificial Refrigeration Methods, Techniques to produce low temperatures, refrigerants.

UNIT II

Thermodynamic analysis of Refrigeration cycles: Working principles and thermodynamic analysis of Refrigeration cycles such as air refrigeration, VCRS, VARS, Steamjet, Vortex tube refrigeration etc. Methods to improve performance of VCRS, concept of MultiStage VCRS and Cascade Refrigeration systems.

UNIT III

Psychrometry and air-conditioning: Psychrometry - Air-water vapor mixtures, Psychrometric Properties, Psychrometric or Air-Conditioning processes, Psychrometric Chart, Thermal Comfort.

UNIT IV

Analysis of psychrometric processes for the purpose of comfort air-conditioning. Mathematical Analysis of Air-Conditioning Systems. Overview of Cooling and Heating Load Estimation.

UNIT V

Compressors: Reciprocating compressors - Construction, P-V diagram, Clearance volume, Multi-stage compressors, Efficiency. Centrifugal and Axial Flow Compressors - Principle of Operation, T-s diagram, Performance Characteristics

Text Books:

1. Arora Ramesh Chandra, Refrigeration and Air Conditioning, PHI Learning Pvt. Ltd., India, 2012
2. Arora, C. P., Refrigeration and Air-Conditioning, Tata McGraw - Hill, New Delhi, 2000.

Reference Books:

1. Roy J. Dossat, Principles of Refrigeration, Wiley Limited, 1978
2. Stoecker, W. F., and Jones, J. W., Refrigeration and Air-Conditioning, McGraw - Hill, New Delhi, 1983.
3. Yahya, S.M., Compressors and Fans, Turbines, 4th Edition, McGraw Hill Education, 2017.

Data Books:

1. M. L. Mathur, and F. S. Mehta,Refrigerant and Psychrometric Properties - Tables andCharts [SI Units], Jain Brothers, 2020 (Revised Edition).

Refrigeration and Air Conditioning Laboratory

Course Code: **L:T:P**
Rationale:
Course Outcomes:
Course Contents:

1. Heat transfer experiments based on conduction and convection.
2. Heat transfer experiments based on radiation.
3. Experiments on heat exchangers.
4. Study and performance tests on vapor compression refrigeration.
5. Study and performance tests on vapor absorption refrigeration.
6. Study and performance tests on air conditioning test rig.

References:

1. Cengel Y.A., Afshin J.G., Heat and Mass Transfer: Fundamentals & Applications, 6th ed., McGraw-Hill, 2020.
2. Bergman T.L., Lavine A.S., Incropera F.P. and Dewitt, D.P., Fundamentals of Heat and Mass Transfer, 7th ed., John Wiley & Sons, 2012
3. Arora, C.P., Refrigeration and Air Conditioning, 2nded., Tata McGraw-Hill, 2000
4. Dossat R.D., Principle of Refrigeration, 4th ed., Prentice-Hall, 1997.
5. Holman J.P., Heat Transfer, 10th ed., Tata McGraw-Hill, 2010

Computational Laboratory

The major software packages available are:

Name of the Software	**Purpose of the Software**
CARIS Software	Mapping, spatial data analysis
STRAAP software	Structural analysis
AUTOCAD with AUTOCIVIL	Drafting
STAAD / Pro	Design
ARC GIS – University Lab kit 8.3 software	Mapping
REI HEADS Ver 2002	Highway Engineering design system
Geo Concept	Data interchange between maps
ENVI Ver 4.2	Image analysis
Build super fast	Estimation
Visual Modflow	Ground water flow modeling
Map info Professional Version 8	Mapping
GT STRUDL	Structural analysis and design
Bentley MX Road Max 2004	Road design
PLAXIS Professional V 8.2 + Dynamic Module + 3D Foundation V1.5	Analysis of Geotechnical problems
ANSYS	Stress analysis
STAAD Pro-2006	Structural analysis and design

Apart from above software , the department has developed many packages for specific engineering applications Principal among them are:

- RAPID:Rural Action Plan Integrated Database. A GIS based monitoring system developed in VB. TIMS:Travelers Information Management System OPERA : Online Processing of Electoral Results and Analysis MIGRAN:Model with Interactive Graphics for Route Analysis on Network . SPY:Simulation of Paddy Yield. DAM:Dam Safety Against Earthquake Load. WASP:Waste Data Acquisition and Analysis System for Online Processing
- AIMIL GEOTECHNICAL ANALYSIS SOFTWARE (AIMIL GAS) AIMIL Geotechnical Analysis Software (AIMIL GAS) is a suite of analysis software for common geotechnical

tests . It uses the data acquired by the AIMIL Data Acquisition System (AIMIL DAS) and generate a number of analysis graphs and data . Even though it can use the data acquired by AIMILDAS directly , it is not a constraint . It can use data in the proper format from any source . It accepts additional test data from the user and performs the analysis . The analysis data can be viewed on screen or printed on any PC compatible printer .

- AIMILDAS is an auto calibrating 16 channel , 16-bit Data Acquisition System which gathers data from energized transducers and saves the data. The AIMILDAS is designed to provide a bridge between existing test apparatus and the latest PC based technology using State of the art Graphical user interface on Windows. The Data Acquired by the energized transducer is converted into working units and presented in either a tabulated form or in a format which can be read directly by AIMILGAS. The acquired data can be post processed to produce various graphs of interest .

Automobile Engineering Lab

Course Code: **L:T:P**
Rationale:
Course Outcomes:
Course Contents:

Study on engine components. Fuel systems. Ignition systems - Transmission systems - Steering systems. Suspension and braking systems. Layout of electrical wiring - Light and heavy vehicles.

Program Elective-III

Product Design and Development

Course Code: **L:T:P:**

Rationale:

Course Outcomes:

CO-1	Develop conceptual product models using creativity and product design techniques
CO-2	Apply embodiment principles in the product development process.
CO-3	Develop products by considering the social, environmental and ethical concerns.
CO-4	Experience by developing CAD/ physical models using the concepts of product design theory.

Course Contents:

UNIT I: Introduction

Design thinking philosophy - Empathy, Define, Ideate, Prototype, Test. Product design context- types of designs, Asimov model, Design method vs scientific method, Considerations of a good design, Design activities/ Process, Product life and technological insertion cycles, organisational structures, business models, Design in teams-Team behavior and dynamics. Team formation and Course project assignment.

UNIT II: Problem identification

Need analysis, customer study and need identification tools, Product Quality and classification of Customer requirements, Kano Diagram. Establishing Engineering characteristics-Benchmarking, Quality Function Deployment- HOQ, Preparation of Initial PDS for the Course Project.

UNIT III: Gathering Information

Transformation from Data to knowledge, types and sources of information, intellectual property rights- classification, Patent searching, stages of patent filing. Importance of Codes and standards in Product Design

UNIT IV: Concept Generation/Improvement and Decision making

Creative thinking models, creative thinking aids and barriers, structured and unstructured creative design methods/theories- Brainstorming techniques, Random input technique and Synectics, concept map, Functional decomposition, Morphological analysis, TRIZ, Axiomatic Design, practice exercises. Decision making theories- criteria based selection, Pugh's concept, AHP.

UNIT V: Embodiment and Detailed Design

Product Architecture, Configuration and Parametric design Concepts, Detailed design, Engineering Requirements- failure mode and effects analyses, Legal and ethical issues in design. DFX, Course Project Reviews

Text Books:

1. George E Dieter, Engineering Design, Publisher, McGraw Hill, 4th edition.

Reference Books:

1. Kevin N. Otto, Kristin L. Wood, “Product Design”, Pearson Education, 2004.
2. W. Ernest Eder, S. Hosendl., “Design Engineering”, CRC Press, 2008.

Other Suggested Readings:

1. https://nptel.ac.in/courses/107/103/107103082/

INDUSTRIAL TRIBOLOGY

Course Code: **L:T:P:**

Rationale:

- To familiarize the various types of engineering surfaces in contact.
- To provide comprehensive knowledge of friction, wear, lubrication between various engineering surfaces and bearings.
- To provide comprehensive knowledge of various surface modifications and coatings techniques.
- A wealth of real world engineering problems and examples towards gaining the experience for how the knowledge of tribology is applied in engineering practice.
- The effective use of the knowledge of tribology to various engineering problems to enhance the performance of the mechanical elements.

Course Outcomes:

CO1	Analyze the failures due to friction in engineering surfaces
CO2	Analyze the failures due to wear in engineering surfaces
CO3	Apply the knowledge of lubrication and bearings in engineering applications
CO4	Apply the knowledge of surface engineering to engineering applications

Course Contents:

Unit 1: Friction and its types

Introduction to tribology, engineering surfaces, fundamentals of contact between the surfaces, surface roughness, stick slip phenomenon, friction of metals and non-metals, friction mechanisms – ploughing and adhesion, friction of ceramic materials, friction of polymers, friction measurement. [12 hours]

Unit 2: Wear and wear mechanisms

Introduction to wear, abrasive wear, abrasivity of particles, abrasive resistance of engineering materials, adhesive wear, adhesion mechanisms, effects of adhesion between mating surfaces, controlling adhesive wear, erosive wear, cavitation, corrosive wear, tribo-corrosion and tribochemical polishing, oxidative wear in various engineering environments, controlling oxidative wear, fretting, fatigue wear during sliding, fatigue wear during rolling, wear of metals, wear of polymers, wear of ceramics, wear of non-metals. Wear measurements. [12 hours]

Unit 3: Lubricants, lubrication mechanisms and bearings

Types of lubricants and their properties, Stribeck curve and regimes of lubrication, Greases, Solid lubricants, Reynolds equation, Hydrodynamic lubrication, Pad bearings, Journal bearings, Porous bearings, Elastohydrodynamic lubrication, Boundary and extreme pressure lubrication [12 hours]

Unit 4: Surface Engineering

Surface treatments, Wear resistant coatings and surface treatments, Physical vapor deposition, chemical vapor deposition, ion implantation, surface welding, thermal spraying, laser surface hardening and alloying, diamond like coatings, carbon based composite coatings, multi-layered coatings, nano-engineered coatings, Thick coatings. [9 hours]

Textbooks:

1. GwidonStachowiak, Andrew W Batchelor., "Engineering tribology", Elsevier Butterworth – Heinemann, USA, 2005.

Reference Books:

1. Hutchings.I.M and Shipway P, "Tribology, Friction and Wear of Engineering Material, Elsevier Butterworth –Heinemann , UK, 2017.
2. Bharat Bhushan, "Introduction to tribology", Wiley Publication, 2013.
3. Williams.J.A, "Engineering Tribology", Oxford University Press, 2005.
4. Stolarski.T.A, "Tribology in Machine Design", Industrial Press Inc., 1990.
5. Cameron.A, "Basic Lubrication Theory", Longman, U.K., 1981.
6. Neale.M.J., "Tribology Handbook", Newnes Butter worth, Heinemann, U.K., 1975.
7. Tomasz Liskiewicz and Daniele Dini, Fretting Wear and Fretting Fatigue, Elsevier UK, 2023.

ADVANCED CASTING TECHNOLOGY

Course Code: **L:T:P:**

Rationale:

- To understand the advanced casting processes and equipment
- To facilitate the usage of software packages in design and application for advanced casting methods
- To impart knowledge on the characterization and inspection methods for advanced casting.

Course Outcomes:

CO1	Design the basic tooling requirements for the advanced casting process.
CO2	Select a suitable process for manufacturing casting components.
CO3	Analyze the liquid metal flow and solidification characteristics using casting software.
CO4	Identify the defects in castings and suggest improvements

Course Contents:

Unit 1

Melt processing techniques for ferrous and non-ferrous alloys such as stainless steels, nickel, titanium alloys. Vacuum melting equipment and practice.

Unit 2

Elementary aspects of pattern and mould design using CAD software. Resin-bonded mould and core making processes and machines.

Unit 3

Special casting processes and their applications- low-pressure die casting, investment casting, squeeze casting, thixo-forming. Illustrations of automotive and aerospace applications.

Unit 4

Gating and riser design - principles of fluid flow, governing equations, heat transfer applied to casting solidification, governing equations, boundary conditions for different casting methods, the concept of directional solidification, gating, and risers, and application of simulation methods. Use of casting software in solving practical problems.

Unit 5

Casting defects and remedies. Inspection methods - visual, penetrant, magnetic, metallurgical, X-ray and Gamma ray radiography and Mechanization and Automation.

Textbooks:

1. Jain P. L. - ‘Principles of Foundry Technology’ - Tata McGraw Hill, New Delhi - 2011 - 3rd Edition

Reference Books:

1. Heine R. W., Loper C. R., and Rosenthal P. C. - ‘Principles of Metal Castings’ - Tata McGraw Hill, New Delhi - 1997 - 2nd Edition
2. Beeley- P. R.- ‘Foundry Technology’ - Butterworth Scientific, London – 2001

SOLAR AND WIND POWER TECHNOLOGIES

Course Code: **L:T:P:**

Rationale:

- To introduce the conversion technologies related to solar and wind power
- To familiarize the photovoltaic and thermal conversion of solar radiation
- To inculcate the feasibility of harvesting wind power

Course Outcomes:

CO1	Develop knowledge in solar radiation, its measurement and associated conversion technologies
CO2	Compare the different forms of solar thermal collectors
CO3	Understand the basics of wind energy conversion
CO4	Assess potential of wind energy as an alternate form of nonconventional energy

Course Contents:

Unit 1

Properties of Sun Light- Solar Radiation - Atmospheric effects - Solar Geometry - Measuring Instruments – Estimation of Solar Radiation. Solar cell physics & characteristics - Stand Alone PV System, Cost analysis and pay back calculations; Environmental and safety issues.

Unit 2

Solar Thermal Collectors – Flat plate collector construction and analysis – Thermal resistance network model –Heat transfer correlations – Concentrating type collectors – Construction and working – Tracking mechanisms.

Unit 3

Solar thermal energy utilisation – Heliostats with central receiver – Solar air heater – Solar chimney; Solar thermal power plants– Low, medium and high temperature systems – Performance analysis. Solar water heaters – Thermosyphon heaters – Active and passiveheating. Solar Ponds – Convective and non-convective ponds – Salt gradient solar pond – Experimental studies; Water desalination using solar still; Solar refrigeration.

Unit 4

Meteorology of wind: Global circulation, Forces influencing wind, Local Wind systems, Wind Turbines: Types, Rotor elements;

Unit 5

Horizontal and vertical axis wind turbines, Power in the wind, Power extracted from wind, Betz limit, Lift and drag coefficients, thrust and torque, power coefficient, thrust coefficient, axial interference factor. Pitch and stall regulation, power curve, and energy calculation.

Textbooks:

1. Wenham SR, “Applied Photovoltaic”, 2/e, Earthscan Publications Ltd, 2007
2. G.N. Tiwari, “Solar Energy-Fundamentals, Design, Modeling and Applications”, Narosa Publishers, 2002.
3. Joshua Earnest and Tore Wizelius, “Wind Power Plants and Project Development”, PHI Learning Pvt. Ltd., New Delhi, 2011.

Reference Books:

1. Garrett T. K., Newton K., and Steeds W. - ‘Motor Vehicles’ - Butterworth Heinemann - 2001
2. Fenton J. - ‘Handbook of Automotive Body and System Design’ - Professional Engineering Publishing, UK - 2005
3. Giri N. K. - ‘Automobile Mechanics’, Khanna Publishers, New Delhi - 2006 - 8th Edition
4. Bishop R. - ‘Intelligent Vehicle Technology and Trends’ - AR Tech House Inc. – 1999

AEROSPACE ENGINEERING

Course Code: **L:T:P:**

Rationale:

- Understand and describe the various types of aircrafts and its systems.
- To make students aware of the types of propulsion systems used and its merits and demerits

Course Outcomes:

CO1	Understand the earth's atmosphere and its properties
CO2	Select an appropriate propulsion method based on the requirement from the aircraft
CO3	Compare different engine systems used in aerospace applications
CO4	Understand the various instruments used in the aircraft and its working

Course Contents:

Unit 1

The atmosphere: Characteristics of Troposphere, Stratosphere, Mesosphere and Ionosphere - International Standard Atmosphere – Pressure, Temperature and Density variations in the ISA. Review of basic fluid dynamics – continuity, momentum and energy for incompressible and compressible flows – static, dynamic and stagnation pressures – phenomena in supersonic flows.

Unit 2

Application of dimensional analysis to 2D viscous flow over bodies (Basics only) – Reynolds number– Mach number similarity – Aerofoil characteristics – Pressure distribution – Centre of Pressure and Aerodynamic Center – Horse shoe vortex.

Unit 3

Straight and Level Flight – Stalling Speed – Minimum Drag and Minimum Power conditions – Performance Curves – Gliding – Gliding angle and speed of flattest glide – Climbing – Rate of Climb

– Service and Absolute Ceilings – Take off and Landing Performance – Length of Runway Required

– Circling Flight – Banked Flight – High Lift Devices – Range and Endurance of Air planes.

Unit 4

Propulsion: Momentum and Blade Element Theories (Basics only) – Propeller co-efficients and charts

– Aircraft engines – Reciprocating engines, Turbo jet, Turbo fan and Ram Jet engines – Bypass and After Burners.

Unit 5

Aircraft Instruments: Air speed indicators – Calculation of True Air Speed – Altimeters – Rate of Climb meter – Gyro Compass, Artificial horizon etc. Rocket Motors – Solid and Liquid Propellant Rockets – Calculation of Earth Orbiting and Escape Velocities Ignoring Air Resistance and assuming Circular Orbit.

Textbooks:

1. Mechanics of Flight - Kermode A. C.
2. Aerodynamics for Engineering Students - Houghton and Brock
3. Anderson J.D. Jr., (2007), Fundamentals of Aerodynamics, Tata McGraw-Hill, New Delhi.

Reference Books:

1. Bertin J.J., (2002), Aerodynamics for Engineers, 4th Ed. Prentice-Hall Inc.
2. Kuethe A. M. and Chow C.-Y., (1986), Foundations of Aerodynamics, John Wiley & Sons Inc.

Fracture Mechanics

Course Code: **L:T:P:**

Rationale:

Course Outcomes:

CO-1	Understand the concept of crack propagation leading to fracture failure.
CO-2	Analyze the fracture strength of mechanical components under different fracture modes.
CO-3	Apply fracture mechanics principles for determining Fracture Parameters using Experimental Methods.
CO-4	Design mechanical components against fracture
CO-5	Analyze the mechanical components against fracture through Non-Destructive Testing.

Course Contents:

UNIT I:

Introduction: Brittle and Ductile Fracture, Modes of Fracture Failure, Surface Energy, Griffith's Dilemma,

Realization and Analysis. Energy Release Rate, Energy Release Rate of DCB Specimen, Anelastic Deformation at Crack-tip, Crack Resistance, Stable and Unstable Crack Growth, Critical Energy Release Rate.

UNIT II:

Stress Intensity Factor: Linear Elastic Fracture Mechanics (LEFM), Stress and Displacement Fields in Isotropic Elastic Materials, Westergaard's Approach.

UNIT III:

SIF of More Complex Cases: Applications of Westergaard Approach, Crack in a Plate of Finite Dimensions, Edge Cracks, Embedded Cracks, The Relation between GIand KI, Critical Stress Intensity Factor.

J-Integral: Definition of the J-Integral, Path Independence, Stress-Strain Relation, Experiments to Determine the Critical J-Integral,Comments on the Numerical Evaluation ofJ-Integral, A Simplified Relation for the J-Integral, Applications to Engineering Problems.

UNIT IV:

Test Methods: KIC-Test Technique, Test Methods to Determine JIC ,Test Methods to Determine GIC and GIIC ,Determination of Critical CTOD.

UNIT V:

Fracture Parameters: Direct Methods to Determine Fracture Parameters. Indirect Methods to Determine Fracture Parameters. Mixed Mode Crack Initiation and Growth.

Crack Detection through Non-Destructive Testing: Examination through Human Senses, Liquid Penetration Inspection, Ultrasonic Testing, Radiographic Imaging, Magnetic Particle Inspection.

Text Books:

1. Prashant Kumar, Elements of fracture mechanics, Tata McGraw-Hill Education, 2009

Reference Books:

1. Anderson, Ted L., Fracture mechanics: fundamentals and applications, CRC press, 2017
2. Broek, David, Elementary engineering fracture mechanics, Springer Science & Business Media, 2012
3. S.T. Rolfe and J.M. Barson, Fracture and Fatigue control in Structures, Prentice Hall Inc. New Jersy, 1977
4. M.F. Kanninen and C.H. Popelar, Advanced Fracture Mechanics, Oxford University Press, 1985
5. J.W. Hutchinson, Nonlinear Fracture Mechanics, Department of Solid Mechanics, The Technical University of Denmark Publications, 1979
6. Maiti, Surjya Kumar, Fracture mechanics: Fundamentals and applications. Cambridge University Press, 2015

Micro and Nano Manufacturing

Course Code: **L:T:P:**

Rationale:

Course Outcomes:

CO1	Understand different techniques for the synthesis and characterization of nano-materials
CO2	Design and analyze methods and tools for micro and nano-manufacturing.
CO3	Select micro and nano-manufacturing methods and identify key variables to improve the quality of MEMS.
CO4	Choose appropriate industrially viable process, equipment and tools for a specific product.

Course Contents:

UNIT I:

Introduction: Importance of Nano-technology, Emergence of Nanotechnology, Bottom-up and Top-down approaches, challenges in Nanotechnology, Scaling Laws in Mechanics, fluids, thermodynamics, Electromagnetism, tribology and Examples.

UNIT II:

Nano-materials Synthesis and Processing: Methods for creating Nanostructures; Processes for producing ultrafine powders- Mechanical grinding; Wet Chemical Synthesis of nano-materials- sol-gel process, Liquid solid reactions; Gas Phase synthesis of nano-materials.

UNIT III:

Structural Characterization: X-ray diffraction, Optical Microscope and their description, Scanning Electron Microscopy (SEM), TEM and EDAX analysis, Scanning Tunneling Microscopy (STM), Atomic force Microscopy (AFM).

Micro fabrication Techniques: Lithography – LIGA, Thin Film Deposition and Doping, Etching and Substrate Removal, Substrate Bonding, MEMS Fabrication Techniques, Bulk Micromachining, Surface Micromachining, High- Aspect-Ratio Micromachining

UNIT IV:

Nanofabrication Techniques: Laser based nana manufacturing, E-Beam and Nano-Imprint Fabrication, Epitaxy and Strain Engineering, Scanned Probe Techniques, Self-Assembly and Template Manufacturing.

UNIT V:

MEMS devices and applications: Pressure sensor, inertial sensor, Optical MEMS and RF-MEMS, Micro-actuators for dual-stage servo systems.

Text Books:

1. Tai-Ran Hsu, MEMS and Microsystems: Design and Manufacture, McGraw- Hill, 2008
2. Marc Madou, Fundamentals of Microfabrication: The Science of Miniaturization, CRC Press, 2002, Second Edition.
3. Mark James Jackson, Microfabrication and Nanomanufacturing, CRC Press, 2005.

Reference Books:

1. Gabor L. Hornyak, H.F Tibbals, Joydeep Dutta & John J Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2009.
2. Ray F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Springer, 2005.
3. Robert F Speyer, Thermal Analysis of Materials, Marcel Dekker Inc. New York, 1994.
4. B.D. Cullity, Elements of X-Ray Diffraction, Prentice Hall, 2002, 3rd edition.

Program Elective-IV

COMPUTER AIDED DESIGN AND MANUFACTURING

Course Code: **L:T:P:**

Rationale:

Course Outcomes:

Course Contents:

UNIT I

Basic concepts of CAD - CAD workstation - principles of computer graphics - graphics programming - mechanical drafting package.

UNIT II

Advanced modeling techniques - surface modeling - solid modeling, rendering methods. CAD/CAM data base development and data base management systems.

UNIT III

Principles of optimum design - CAD optimization techniques, Application of CAD - computer-aided process planning - post processing - NC code generation - principles of computer aided engineering and concurrent engineering.

UNIT IV

Computer aided manufacturing, programming and interface hardware – computer aided process monitoring - adaptive control, on-line search strategies.

UNIT V

Production systems at the operation level - computer generated time standards - machinability data systems - cutting conditions optimization - production planning - capacity planning - shop floor control - computer integrated manufacturing systems, system components, application.

References:

1) Radhakrishnan P & Kothandaraman C.P, “Computer Graphics and Design”, Dhanpat Rai & Sons, 1990.

2) Groover M P, “Automation, Production System and Computer Aided Manufacture”, Prentice Hall, 1984.

3) William M Newman & Robert Sproul,, “Principle of Interactice Computer Graphics”, Mc Graw Hill, 1984.

ADVANCED WELDING TECHNOLOGY

Course Code: **L:T:P:**

Rationale:

- Elucidate the concepts of continuity, mechanism, physics, and design elements in welding process
- Comprehend the characteristics of weldable materials and welding technologies
- Demonstrate the importance of modelling and simulation of welding process
- Develop intellectual skills for correlating the microstructural evolution with the defects and properties of weldments

Course Outcomes:

CO1	Describe welding processes, welding symbols, joint configurations, and heat source characteristics
CO2	Formulate governing equations and boundary conditions to simulate the thermal phenomenon in the course of a welding process
CO3	Evaluate the microstructural evolution on the properties of weldments
CO4	Identify appropriate techniques for detecting the welding defects

Course Contents:

Unit 1

Overview of welding processes and their classification, types of joints, edge preparation, weld symbols, weld nomenclature, bead geometry, power density, heat sources - Gaussian distribution of heat flux, welding techniques - linear and orbital. Arc characteristics.

Unit 2

Voltage-current characteristics. Types of welding manipulators and their applications. Advanced welding processes: submerged arc, TIG, MIG, electro-slag, ultrasonic, electron beam and laser beam welding. Case studies and applications - industrial, automotive and aerospace.

Unit 3

Thermal modeling and simulation of welding processes - governing heat transfer equations and boundary conditions for various types of welding processes. Estimation of cooling rates.

Prediction of mechanical properties, micro/macro-structures of weldments and heat-affected zone.

Unit 4

Prediction of weld defects such a crack, segregation, lack of fusion. Modeling and simulation of pulsed arc processes. Use of softwares for simulation. Solidification behaviour of fusion weld: structural zones, epitaxial growth, weld pool shape and columnar grain structures. Weldability of metals- steels, stainless steels, aluminium, copper, nickel and titanium alloys.

Unit 5

Microstructures of weldment.Segregation of alloying elements.Impact of micro/macro-structures and segregation on mechanical properties.Pre- and post-treatment. Effects of heat flow on residual stresses and distortion. Weldability tests. Welding defects - causes and remedies.Methods of testing weldments - mechanical, pressure and leak testing.Inspection methods - visual, penetrant, magnetic, ultrasonic, x-ray and gamma radiography.Use of imaging techniques for online monitoring

Textbooks:

1. Khanna O. P. - ‘A Text Book on Welding Technology’ – Dhanpat Rai and Sons, New Delhi - 2013
2. Parmar R. S. - ‘Welding Process and Technology’ - Khanna Publishers, Delhi – 1992

Reference Books:

1. Little R. L. - ‘Welding and Welding Technology’ - Tata McGraw Hill Publishing Company Limited, New Delhi – 1989
2. Grong O. - ‘Metallurgical Modelling of Welding’ - The Institute of Materials - 1997 - 2nd Edition
3. Kou S. - ‘Welding Metallurgy’ - John Wiley Publications, New York - 2003 - 2nd Edition.

TURBO MACHINERY

Course Code: **L:T:P:**

Rationale:

- To classify the turbo-machines based on energy interactions
- To study the performance characteristics of turbo-machines under different operating conditions
- To gain knowledge in the design parameters of turbo-machines

Course Outcomes:

CO1	Compare the features and working of various turbo machines
CO2	Apply the concepts of energy transformation in turbo machines
CO3	Analyse the performance of Hydraulic pumps and turbines
CO4	Thermal design and evaluation of critical parameters of Steam turbines
CO5	Evaluate the performance of axial and centrifugal compressors

Course Contents:

Unit 1

Definition and Classification of turbo machines, Specific Work, T-S and h-s Diagram, Incompressible and compressible flow, Losses, Total-to-Total efficiency, Total-to-Static efficiency, Effect of reheat and preheat factor, Degree of reaction, Energy transfer - Euler's equation, velocity triangles. Dimensional analysis, Dimensionless parameters and their physical significance, specific speed.

Unit 2

Elementary cascade theory, cascade nomenclature, compressor cascade, turbine cascade, cascade efficiency. Dimensional analysis of compressible flow machines, stalling and surging.

Unit 3

Hydraulic Pumps: Centrifugal Pumps – Some definitions, pump output and efficiencies, effect of vane angle, Cavitation, pump characteristics, multistage pumps.

Hydraulic Turbines: Classification of hydraulic turbines - Velocity triangle, Efficiencies of draft tubes, Hydraulic turbine characteristics, Francis and Kaplan turbines: Velocity triangle,

Efficiencies of Draft tubes, Turbine characteristics.

Unit 4

Steam and Gas Turbines: Axial turbine stages, stage velocity triangles, work, single stage impulse turbine, speed ratio, maximum utilization factor , compounding of turbines and its types, degree of reaction - reaction Stages. Inward Flow Radial turbine stages (IFR) - Working principle and performance characteristics.

Unit 5

Centrifugal Compressors: Constructional details, stage pressure rise, stage pressure coefficient, stage efficiency, degree of reaction, various slip factors, Introduction to Fans and Blowers, working principle, fan laws, performance characteristics.

Axial flow Compressors: general expression for degree of reaction; velocity triangles for different values of degree of reaction, blade loading and flow coefficient, static pressure rise, work done factor.

Textbooks:

1. Yahya S. M. - 'Turbines, Fans and Compressors' - Tata McGraw Hill Publishing Company Limited – 2002

Reference Books:

1. Cengel Y. A. & Cimbala J., "Fluid Mechanics -Fundamentals and Applications", 3/e, McGraw Hill Edition, 2013.
2. Dixon S. L. - 'Fluid Mechanics & Thermodynamics of Turbo machinery' - Elsevier - 2012 - 6th Edition
3. Kadambi V. and Manohar Prasad - 'Energy Conversion - Vol.III: Turbo Machinery' - New Age International Publishers – 1999

GAS DYNAMICS AND JET PROPULSION

Course Code: **L:T:P:**

Rationale:

- To discuss the effect of compressibility in gas flow
- To derive the steady one-dimensional isentropic flow equation
- To discuss the effects of friction and heat transfer on compressible flows through constant area duct
- To familiarize the occurrence of shocks and calculate property changes across a shock wave
- To derive the thrust equation and discuss its application in jet and rocket propulsion

Course Outcomes:

CO1	Apply the thermodynamics concepts in relation to compressible flows and derive relationships between various compressible flow parameters.
CO2	Understanding of isentropic compressible flows in variable area ducts and apply in design of static components like nozzles and diffusers
CO3	Solve for compressible flow characteristics with friction and heat transfer
CO4	Develop relationship for shocks and determine their characteristics under various conditions
CO5	Analyse the performance of aircraft and rocket propulsion engines

Course Contents:

Unit 1: Basic concepts:

Energy and momentum equations of compressible fluid flows - Stagnation states - Mach waves and Mach cone - Effect of Mach number on compressibility. Isentropic flows: Isentropic flow through variable area ducts. [10 hours]

UNIT 2: Isentropic Flow:

Nozzle and Diffusers, compressors and turbines - Use of Gas tables. Flow through ducts: Flow through constant area ducts with heat transfer (Rayleigh flow) and Friction (Fanno flow) - Variation of flow properties - Use of tables and charts - Generalized gas dynamics. [10 hours]

Unit 3: Normal and oblique shocks:

Governing equations - Variation of flow parameters across the normal and oblique shocks - Prandtl Meyer relations – Expansion of supersonic flow, Use of table and charts - Applications. [10 hours]

Unit 4: Jet propulsion:

Theory of jet propulsion - Thrust equation - Thrust power and propulsive efficiency - Operation principle - cycle analysis and use of stagnation state performance of ramjet, turbojet, turbofan and turbo-prop engines – Aircraft combustors. [7 hours]

UNIT 5: **Space propulsion**:

Types of rocket engines - Propellants - Ignition and combustion - Theory of rocket propulsion – Performance study - Staging - Terminal and characteristic velocity - Applications - Space flights. [8 hours]

Textbooks:

1.Yahya S. M. "Fundamentals of Compressible Flow with aircraft and rocket propulsion", 5/e,New Age International publishers, 2016

Reference Books:

1. Balachandran P. "Fundamentals of Compressible Fluid Dynamics", PHI Learning India Private Ltd., 2009.
2. John D. Anderson Jr. "Modern Compressible Flow with historical perspective", 2/e, McGraw Hill Publishing company, International Edition, 1990. S
3. Shapiro A. H. "Dynamics and Thermodynamics of Compressible Fluid Flow – Volume I", John Wiley, New York, 1953.

Fundamentals of HVAC Systems

Course Code: **L:T:P:**

Rationale:

- To learn climate variation and its effects on the building heat load.
- To learn building material characteristics and their influence on building heating /cooling load for all weather conditions.
- To study various conversation techniques related to build environment and codes for the same.
- To study various Testing and Balancing Air Systems.
- To study various techniques involved in industry air conditioning systems

Course Outcomes:

CO1	Estimate heating loads, space heat gains and space cooling loads using accepted engineering methods.
CO2	Determine the coil loads for cooling and heating systems
CO3	Select equipment and design systems to provide comfort conditions within the building.
CO4	Understand different testing and balancing air conditioning systems
CO5	To apply the principles of producing air conditioning for human comfort and industry applications

Course Contents:

UNIT I

Introduction to Air Conditioning and Refrigeration – Basic Thermodynamics of HVAC, Types of Refrigeration Systems, the Refrigeration Cycle, Refrigerants and their Properties, Plotting the Refrigeration Cycle, Piping and Tubing, Soldering and Brazing, Refrigerant Leak Testing, Refrigerant System Evacuation, Refrigerant System Charging, Control Systems.

UNIT II

Heating systems - Gas Furnaces, Gas Furnace Controls, Gas Furnace Installation, Troubleshooting Gas Furnaces, Oil Fired Heating Systems, Oil Furnace and Boiler Service, Residential Oil Heating Installation, troubleshooting of oil heating systems, Electric Heat, Electric Heat Installation, troubleshooting of electric heat, Heat Pump System Fundamentals, Heat Pumps Applications, Geothermal Heat Pumps, Heat Pump Installation, Troubleshooting of Heat Pump Systems.

UNIT III

Comfort and Psychometrics - Fundamentals: Psychometrics & Airflow, Air Filters, Ventilation and Dehumidification, Heat transmission in building structures -Solar radiation -Infiltration and Ventilation-Cooling/heating load calculations, Residential Load Calculations, Green Buildings and Systems, Indoor Air Quality (IAQ), Building energy calculations .

UNIT IV

Duct Installation, Duct Design, Zone Control Systems, Testing and Balancing Air Systems.

UNIT V

Chilled Water Systems, Cooling Towers, Commercial Refrigeration Systems, Supermarket Equipment, Ice Machines.

References:

1. Handbook of heating, ventilation and Air-conditioning, Jan. F. Kreider, CRC press.
2. Automotive heating and Air-conditioning, Mike Stubblefield and John H Haynes
3. Heating ventilation and air conditioning – Jan F. Kreider
4. Control systems for Heating, ventilating and air conditioning, Roger W. Haines, Springer
5. HVAC Equations, Data, and Rules of Thumb - Arthur A. Bell Jr., PE, McGraw-Hill

Fundamentals of Biomechanics

L:T:P-

Course Code:

Rationale:

- The principles of mechanics and their application in biomechanics.
- Biomechanics of skeletal joints and tissues.
- Solving equations of motion for simple models of human movement.
- Applying biomechanics principles to implant design and gait analysis.
- Developing skills in biomechanical analysis and problem-solving.

Course Outcomes

CO1	Analyze and apply the principles of mechanics to solve problems in biomechanics and human movement analysis.
CO2	Assess the forces and stresses in human joints and tissues, using free-body diagrams and biomechanical analysis techniques to evaluate the functionality and limitations of different anatomical structures.
CO3	Model the mechanical properties of hard and soft tissues, such as bones, cartilage, tendons, ligaments, and muscles, and predict their behavior under various conditions and loads.
CO4	Design, develop, and evaluate prosthetic and orthopedic implants, considering biomechanical requirements, biocompatibility, and material characteristics to enhance patient outcomes.
CO5	Apply knowledge of cardiovascular and respiratory mechanics to interpret and predict the behavior of blood flow and respiratory dynamics, and to evaluate the performance of artificial heart valves and respiratory models.

Course Content

UNIT I

Introduction to Biomechanics- Review of the principles of mechanics, Vector mechanics, biomechanics, anatomical terminology, Anthropometry, motion in the human machine.

Biomechanics of Joints- Skeletal joints, forces and stresses in human joints, Analysis of rigid bodies in equilibrium, free body diagrams, types of joint, biomechanical analysis of elbow, shoulder, spinal column, hip knee and ankle, Introduction to bio fluid Mechanics, Rheological properties of blood, laminar flow, Couette flow and Hagen Poiseuille equation, turbulent flow.

UNIT II

Hard and Soft Tissue- Bone structure, composition mechanical properties of bone, cortical and cancellous bones, viscoelastic properties, maxwell & voight models, Structure and functions of Soft Tissues: Cartilage, Tendon, Ligament, and Muscle; Material Properties: Cartilage, Tendon, Ligament, and Muscle; Modeling of soft tissues, Hills's muscle model.

UNIT III

Cardiovascular and Respiratory Mechanics– Cardiovascular system, artificial heart valves, biological and mechanical valves development, testing of valves, Blood Flow Models, Blood Vessel Mechanics, Heart valve dynamics, prosthetic valve dynamics.

UNIT IV

Mechanism of air flow, respiratory cycle, lung ventilation model, methods of determining pressure, flow rate and volume spirometry.

Applied Biomechanics and Biomechanics of Implants- Engineering approaches to standing, sitting and lying, Biomechanics of gait, application of gait and locomotion analysis, Fluid mechanics and energetics: Forms of energy and energy transfer,

UNIT V

Design of orthopedic implant, specifications for a prosthetic joint, biocompatibility, requirement of a biomaterial, characteristics of different types of biomaterials, manufacturing process of implants, fixation of implants.

References

1.Ronald Huston, "Principles of Biomechanics", CRC Press - 1st Edition, 2019, ISBN: 978-0367452469

2.Susan J.Hall, "Basic Bio Mechanics", McGraw -Hill Publishing Co, Newyork - 8th Edition, 2019, ISBN: 978-1259913877.

3.Zatsiorsky and Prilutsky, Biomechanics of Skeletal muscles, Human Kinetics publishers, 2012.

4.Valdimir M. Zatsiorsky, "Kinetics of Human motion", Human Kinetics publishers, 2002, ISBN: 978-0736037785.

5.Vladimir M. Zatsiorsky, and Boris I. Prilutsky, "Biomechanics of Skeletal muscles", Human Kinetics publishers - 1st Edition, 2012, ISBN: 978-0736080200.

ADVANCED FORMING TECHNOLOGY

Course Code: **L:T:P:**

Rationale:

- To understand the fundamental concepts of different types of forming processes, plasticity theories, and material selection methods to optimize tooling design and improve formability.
- To inculcate the practical implications of advanced forming processes in real-world manufacturing scenarios.
- To attain the design skills required for forming processes to manufacture complex parts with quality assurance.
- To gain skills and hands-on experience with various forming processes through laboratory exercises and projects.

Course Outcomes:

CO1	Analyze material behavior during forming processes using plasticity theories
CO2	Design optimized parts and tooling for forming processes using CAD software and simulation tools
CO3	Apply advanced forming processes to produce complex parts
CO4	Evaluate formability using testing methods and formability limit diagrams
CO5	Conduct laboratory exercises and solve practical manufacturing problems with design considerations using advanced forming technology

Course Contents:

Unit 1: Fundamentals of Forming Processes

Overview of forming processes - Plasticity theories for forming processes - Material selection and material flow analysis - Tooling design and selection - Formability testing methods - Forming limit diagrams – Spring back effect. [8 Hours]

Unit 2: Advanced Forming Processes

High-energy rate-forming processes - Incremental forming processes - Hydroforming processes - Powder metallurgy forming – Flow forming - Innovative and hybrid forming processes. [8 Hours]

Unit 3: Design for Forming Processes and Manufacturing of Complex Parts

Design considerations for forming processes - Part and die design principles - Tolerance analysis and control - Computer-aided design (CAD) for forming processes - Simulation and modeling for forming processes - Design for manufacturing (DFM) principles - Manufacturing of complex parts and quality assurance. [14 Hours]

Unit 4: Laboratory Exercises and Projects

Laboratory exercises on various forming processes - Design and optimization of tooling for forming processes - Project on the application of advanced forming technology to solve a practical manufacturing problem with design considerations.

Textbooks:

1. Advanced Forming Technology: Principles, Applications, and Manufacturing Processes by Ming Wang Fu

Reference Books:

1. Fundamentals of Metal Forming Technology by Taylan Altan, Gracious Ngaile, and Gangshu Shen
2. Introduction to Materials Science for Engineers by James F. Shackelford
3. Metal Forming: Mechanics and Metallurgy by William F. Hosford and Robert M. Caddell
4. Advances in Metal Forming: Expert System for Metal Forming by Taylan Altan, M. Akif Ezan, and Faruk Birol
5. Fundamentals of Metal Forming" by Harold W. Paxton and Frank W. Koehler

ADDITIVE MANUFACTURING

Course Code: **L:T:P:**

Rationale:

- To provide comprehensive knowledge of the wide range of additive manufacturing processes, capabilities, and materials.
- To familiarize with materials science for additive manufacturing, process evaluation, applications, and quality and reliability.
- To impart knowledge about the software tools and techniques used for additive manufacturing.
- To create physical objects that facilitate product development/prototyping requirements.

Course Outcomes:

CO1	Illustrate the significance and principles of additive manufacturing
CO2	Select the suitable additive manufacturing process for a product/application and appropriate materials for the selected additive manufacturing process.
CO3	Demonstrate the methodology of CAD tools and CAD interface with additive manufacturing systems
CO4	Design and develop 3D-printed physical prototypes.

Course Contents:

Unit 1

Introduction: Methods and Systems

Introduction: Introduction to layered manufacturing, Importance of Additive Manufacturing, Introduction to reverse engineering: Traditional manufacturing vis Additive Manufacturing, Additive Manufacturing in Product Development, 3D Printers and Printable Materials, 3D Printer Workflow and Software. [3 hours]

Unit 2

Classification of additive manufacturing processes: Common additive manufacturing technologies: Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereo Lithography (SLA), Selection Laser Melting (SLM), Digital Laser Processing (DLP), Jetting, Laser Engineering Net Shaping (LENS), Laminated Object Manufacturing (LOM), Electron Beam Melting (EBM),

Wire Arc Additive Manufacturing (WAAM), Ultrasonic Additive Manufacturing, 4D Printing Capabilities, materials, costs, advantages and limitations of different systems. [7 hours]

Unit 3

Material and Process Evaluation

Material science for additive manufacturing: Mechanisms of material consolidation: FDM, SLS and SLM technologies. Polymers coalescence, sintering, photopolymerization, solidification rates, Meso and macro structures. [3 hours]

Unit 4

Process evaluation: process-structure relationships, structure-property relationships. [3 hours]

Post-processing: Defects in FDM, SLS, and SLM, Residual stress and distortion, Heat treatment, shot peening, HIPS, Micro finishing of AM parts, Support material removal, surface texture

improvements, property enhancement using thermal and non-thermal techniques; Critical process parameters: geometry, temperature, composition, phase transformation [4 hours]

Unit 5

CAD in Additive Manufacturing

CAD Modelling for 3D Printing: 3D Scanning and Digitization, data handling & Reduction Methods. [3 hours]

AM Software: data formats and standardization, Slicing algorithms: uniform flat layer slicing, adaptive slicing. [3 hours]

Process-path generation: Process-path algorithms, rasterization, part Orientation, and support generation. [4 hours]

Laboratory

CAD Modeling: Introduction to CAD environment, Sketching, Modeling and Editing features, Different file formats, Export/Import geometries, Part orientation, Slicing, Support generation-FDM/SLA, Process path selection, 3D Printing of prototypes using various technologies. [45 hours]

Session 1: Introduction to CAD package and basic sketching

Session 2: Introduction to basic 3D modeling

Session 3: Basic modeling exercise

Session 4: Complex modeling exercise

Session 5: CAD standard exchange formats and STL conversion

Session 6: Introduction to slicing software

Session 7: Support generation exercise

Session 8: Generation of G Code

Session 9: 3D Printing using FDM-exercise 1

Session 10: 3D Printing using FDM-exercise 2

Session 11: Demonstration of 3D printer – SLA and SLS

Textbooks:

1. Gibson, I., Rosen, D.W. and Stucker, B., "Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing", Springer, 2015.
2. Ben Redwood, Filemon Schoffer, Brian Garret, "3D Printing Handbook, Technologies design and Applications" 3D Hubs B. V., 2018.

Reference Books:

1. Joan Horvath, Rich Cameron, "Mastering 3D Printing in the Classroom, Library and Lab", Apress, 2018.
2. Chua, C.K., Leong K.F. and Lim C.S., "Rapid prototyping: Principles and applications", 2/e, World Scientific Publishers, 2010.
3. Liou, L.W. and Liou, F.W., "Rapid Prototyping and Engineering applications: A tool box for prototype development", CRC Press, 2011.
4. Kamrani, A.K. and Nasr, E.A., "Rapid Prototyping: Theory and practice", Springer, 2006.
5. Hilton, P.D. and Jacobs, P.F., Rapid Tooling: Technologies and Industrial Applications, CRC press, 2000.

Industrial Safety Engineering

Course Code: **L:T:P:**

Rationale:

- Effective Safety management system and BBS
- Accident reporting & investigation procedure
- Workplace, physical and chemical hazards
- Occupational physiological requirement of jobs.
- Fire safety and firefighting equipment

Course Outcomes:

CO1	Apply principles of safety management, its functions and technique in any organization
CO2	Classify and categorize the factors contributing to various hazards
CO3	Formulate accident investigation program in an organization, practice and develop accident reporting system within an organization
CO4	Apply material handling and machine guarding principles in industrial applications
CO5	Identify and analysis physical and chemical hazards and its control measures

Course Content:

UNIT I

Evolution of modern safety concept- Behaviour Based Safety (BBS) -Safety Culture-Effective Safety management system -Safety training.

UNIT II

Concept of an accident, reportable and non-reportable accidents, reporting to statutory authorities-principles of accident prevention – accident investigation and analysis– unsafe act and condition – Accident Causation Theories

UNIT III

Workplace Hazards - Machine Guarding, guarding of hazards, Machine Guarding types and its application – Safety in welding and Gas cutting – Safety in Manual and Mechanical material handling- Safety in use of electricity

UNIT IV

Occupational Hygiene - Chemical Hazards-Airborne particulate matters- TLV- Occupational Diseases-Physical hazards and its effects – Evaluation and control measures.

UNIT V

Occupational physiology-Man as a system component – allocation of functions – efficiency – occupational work capacity – aerobic and anaerobic work – evaluation of physiological requirements of jobs – parameters of measurements – categorization of job heaviness –fatigue – rest pauses.

Fire triangle- Types of fire - first aid firefighting equipment – flammability limit- LPG safety - Hazard identification and Risk Analysis.

Overview of factories act 1948 – ISO-45001

References

1. N.S.C., 1982. Accident Prevention Manual for Industrial Operations. Chicago: N.S.C. Blake, R.B., 1973. Industrial Safety. New Jersey: Prentice Hall, Inc..
2. Heinrich, H.W., 1980. Industrial Accident Prevention. New York: McGraw-Hill Company.
3. Krishnan, N.V., 1997. Safety Management in Industry. Bombay: Jaico Publishing House.
4. Ridley, J., 1983. Safety at Work. London: Butterworth & Co.
5. Deshmukh, L.M., 2017. Industrial Safety Management. New Delhi: Tata McGraw-Hill Education.

Open Elective-I

DESIGN OF THERMAL SYSTEMS

Course Code: **L:T:P:**

Rationale:

- To impart the knowledge about the concept of design of thermal systems.
- To know the design procedure of heat exchangers related to different thermal applications like condensers, evaporators, cooling towers etc.
- To know the design procedure of cooling of electronic components.

Course Outcomes:

CO1	Understand the types of heat exchanger and use LMTD and NTU approaches to solve problems.
CO2	Analyse the design procedures in double pipe and shell and tube heat exchangers.
CO3	Describe the working procedures and calculate the heat transfer aspects in condenser and evaporators.
CO4	Distinguishes the performance parameters in cooling tower performance and heat pipe applications.
CO5	Identify various techniques for cooling of electronic equipment.

Course Contents:

Unit 1

Classification of Heat Exchangers: Introduction- Recuperation & Regeneration-Tubular heat exchangers-Double pipe, Shell and Tube heat exchangers, Plate heat exchanger Exchangers-Plate fin and Tubular fin heat exchangers BASIC DESIGN METHODS OF HEAT EXCHANGERS: Basic equations in Design, Overall heat transfer coefficient-LMTD method and Effectiveness method (NTU) for heat exchanger analysis-Parallel flow, counter flow, Multi pass, Cross flow heat exchangers.

Unit 2

Double Pipe Heat Exchanger: Film coefficient for fluids in annulus, fouling factors, calorific temperature, Average fluid temperature, Calculation of double pipe exchanger, double pipe exchangers in series parallel arrangements.

Shell & Tube Heat Exchangers: General design considerations, Construction details, Tube layouts, Baffles, Shell side and tube side film coefficients. Analysis of performance and design of shell & tube heat exchangers, Flow arrangements, Shell side pressure drop and Tube side pressure drop.

UNIT 3

Condensers & Evaporators: Types of Condensers-Air cooled condenser –Water-cooled condensers-Evaporative condensers Heat Transfer in condensers- Types of Evaporators-Heat transfer in Evaporators-Pool boiling – Heat transfer coefficient for nucleate pool boiling-Flow or forced convection boiling-Forced convection boiling correlations

UNIT 4

Direct Contact Heat Exchangers: Cooling towers, relation between wet bulb & dew bulb temperatures, and calculation of cooling tower performance. Heat Pipe: Gravity assisted thermo-syphons, micro heat pipes, pulsating heat pipes, loop heat pipe operation and working principles.

UNIT 5

Cooling of Electronic Equipment: Introduction-The chip carrier-Printed circuit boards-Cooling load of

Electronic equipment Conduction cooling: Conduction in chip carriers-conduction in printed circuit board heat frames. Air-cooling: Natural convection and radiation- Forced convection-Fan selection-cooling personal computers.

Textbooks:

1. Serth. R. W, Process Heat Transfer-Principles and Applications, Elsevier, 2007.

Reference Books:

1. Coulson & Richardson's series, Sinnott R. K., Chemical Engineering Design, Elsevier, 2005
2. Kern D, Q, Process Heat Transfer, McGraw-Hill, 1965
3. Shah R K and Sekulic D P, Fundamentals of Heat Exchanger Design, John Wiley and plyk\ vdfkpSons, 2002.
4. Kays W M and London A L, Compact Heat Exchanger, Krieger Publishing Company,1998
5. A.P. Frass and M.N. Ozisik, Heat Exchanger Design- John Wieley& Sons, New York

Optimization in Engineering Design

Course Code: **L:T:P:**

Rationale:

- Understand the need and origin of the optimization methods.
- Get a broader picture of the various applications of optimization methods used in engineering.
- Define an optimization problem and its various components
- Formulate optimization problems as mathematical programming problems.
- Briefly learn about classical and advanced techniques in optimizations.

Course Outcomes:

CO1	Enumerate the necessity of optimization in engineering design.
CO2	Identify the various optimization techniques pertaining to design-oriented problems.
CO3	Solve problems with single and multi – variable
CO4	Distinguish between integer and geometric specialized algorithm
CO5	Apply non-traditional algorithms for optimization of typical problems requiring their application

Course Contents:

UNIT I

Introduction to optimization. Classical optimization techniques. Single variable optimization, Unconstrained multivariable optimization.

UNIT II

Nonlinear programming: equality constraint, KKT conditions

Numerical optimization: Region elimination techniques, Fibonacci Method, Golden Section Method, Interpolation Methods

UNIT III

Unconstrained optimization techniques: Direct and indirect search method, Nonlinear programming: constrained optimization techniques, **Introduction to Geometric and integer Programming** Constrained Geometric Programming Problem

UNIT IV

Nontraditional algorithms: Introduction and Principles of Evolutionary Computation (EC), Binary-Coded Genetic (BCGA), Differential Evolution (DE), Particle Swarm Optimization (PSO).

UNIT V

Introduction to Multi-Objective Optimization: Introduction, Generalized Formulation,

Concept of Dominance and Pareto-optimality, Graphical Examples, Terminologies.

References:

1. Rao, Singiresu S. "Engineering optimization: theory and practice." John Wiley & Sons, 2019.
2. Deb, Kalyanmoy. "Optimization for engineering design: Algorithms and examples". PHI Learning Pvt. Ltd., 2012.
3. Chong EK, Żak SH. "An introduction to optimization". John Wiley & Sons; 2013
4. Nocedal, Jorge, and Wright, Stephen. Numerical "Optimization. Germany", Springer New York, 2006.
5. Belegundu, Ashok D., and Chandrupatla, Tirupathi R.. "Optimization Concepts and Applications in Engineering". India, Cambridge University Press, 2019.

Energy Conservation and Management

Course Code: **L:T:P:**

Rationale:

- To learn the present energy scenario and the need for energy conservation
- To understand the monitoring / targeting aspects of Energy
- To study the different measures for energy conservation of various thermal energy systems
- To learn economic analysis and project planning on energy conservation
- To understand the energy conservation principle with electrical equipment

Course Outcomes:

CO1	Apply energy conservation principles for practical devices
CO2	Assess the performance and energy efficiency of various thermal energy systems
CO3	Evaluate the energy loss with various electrical equipment
CO4	Perform energy audit in thermal and electrical systems
CO5	Execute techno-economic analysis and project planning on energy conservation

Course Contents:

UNIT I

Energy Scenario - Basics of Energy and its various forms - Energy Management and Audit - Material and Energy Balance -Energy Action Planning-Financial Management -Project Management -Energy Monitoring and Targeting -Global Environmental Concerns

UNIT II

Energy Efficiency in Thermal Utilities - Fuels and Combustion-Boilers-Steam System-Furnaces - Insulation and Refractory -FBC Boilers -Cogeneration -Waste heat recovery

UNIT III

Energy Efficiency in Electrical Utilities-Electrical Systems-Electric MotorsCompressed Air System-HVAC and Refrigeration System-Fans and Blowers-Pumps and Pumping System. Cooling Tower-Lighting System-Diesel Generating SystemEnergy Efficient Technologies in Electrical Systems

UNIT IV

Energy Performance Assessment for Equipment and Utility systems -BoilersFurnaces Cogeneration, Turbines (Gas, Steam)- Heat Exchangers-Electric Motors and Variable Speed Drives-Fans and Blowers-Water Pumps-Compressors

UNIT V

HVAC Systems-Lighting Systems-Performing Financial Analysis-Applications of Non Conventional and Renewable Energy Sources-Waste Minimization and Resource Conservation.

References

1. Guidebook for National Certification Examination for Energy Managers and Energy Auditors, Bureau of energy efficiencies, 2005.
2. Hamies, Energy Auditing and Conservation; Methods Measurements, Management and Case study, Hemisphere, Washington, 1980
3. Write, Larry C, Industrial Energy Management and Utilization, Hemisphere Publishers, Washington, 1988
4. Reay D.A, Industrial Energy Conservation, 1st edition, Pergamon Press, 1977.
5. Mehmet Kanoğlu, Yunus A. Çengel, Energy Efficiency and Management for Engineers, 1st Edition, McGraw-Hill Education, 2020.

Energy Storage Technology

Course Code: **L:T:P:**

Rationale:

- To understand the Need and Scope of Energy Storage Systems
- To analyse Thermal Energy Storage Systems.
- To evaluate Chemical Energy Storage Solutions
- To design and Optimize Battery Systems for Transportation.
- To master Electrochemical Storage Technologies

Course Outcomes:

CO1	Understand the necessity and various types of energy storage technologies, and effectively compare their applications and efficiency
CO2	Analyze and model thermal energy storage systems, including water, rock bed, and phase change storage units
CO3	Comprehend the fundamental concepts of batteries, including performance measurement, charging/discharging processes, and safety considerations
CO4	Explain the principles and types of fuel cells, assess their advantages and drawbacks, and conduct a detailed analysis of electrochemical storage systems
CO5	Understand the principles, methods, and applications of advanced energy storage technologies, including flywheels, super capacitors, and compressed air energy storage, as well as the concept and applications of hybrid storage systems

Course Contents:

UNIT I

Necessity of energy storage – types of energy storage – comparison of energy storage technologies – Applications

UNIT II

Thermal storage – Types – Modelling of thermal storage units – Simple water and rock bed storage system – pressurized water storage system – Modelling of phase change storage system – Simple units, packed bed storage units - Modelling using porous medium approach, Use of Transys

UNIT III

Fundamental concept of batteries – measuring of battery performance, charging and discharging of a battery, storage density, energy density, and safety issues. Types of batteries – Lead Acid, Nickel – Cadmium, Zinc Manganese dioxide and modern batteries for example (i) zinc - Air (ii) Nickel Hydride, (iii) Lithium Battery

UNIT IV

Fuel Cell – History of Fuel cell, Principles of Electrochemical storage – Types – Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, alkaline fuel cell, detailed analysis – advantage and drawback of each type.

UNIT V

Flywheel, Super capacitors, Principles & Methods – Applications, Compressed air Energy storage, Concept of Hybrid Storage – Applications

References:

1. Ibrahim Dincer and Mark A. Rosen, Thermal Energy Storage Systems and Applications, John Wiley & Sons 2002
2. Fuel cell systems Explained, James Larminie and Andrew Dicks, Wiley publications, 2003.
3. Electrochemical technologies for energy storage and conversion, Ru-shiliu, Leizhang, Xueliang sun, Wiley publications, 2012
4. Charles R. Russell, Elements of Energy Conversion, Permagon Press, 1967.
5. Hart A.B. and Womack, G.J., Fuel Cells: Theory and Application, Prentice Hall, 1989.

Low Temperature Technology

Course Code: **L:T:P:**

Rationale:

- To understand the fundamental principles of refrigeration, air conditioning and cryogenics.
- To select the right insulation for a particular cooling application
- To understand the behavior of properties of materials at different low temperatures
- To Select the cooling system for any given application and human comfort
- To Evaluate the merits of cooling systems and their usage

Course Outcomes:

CO1	Elucidate and implement the principles of refrigeration, air conditioning, and cryogenics.
CO2	Comprehend the characteristics of materials at reduced temperatures
CO3	Utilize various insulation and vacuum techniques for low-temperature systems.
CO4	Choose the appropriate cooling system for a specific application and human comfort.
CO5	Assess the advantages of various cooling systems and their applications.

Course Contents:

UNIT I

Basics of thermodynamic processes, Introduction to refrigeration, air conditioning and cryogenics.

UNIT II

Refrigeration, Vapor compression systems: Ideal and actual cycles, Vapor absorption systems: Refrigerant – absorbent combinations.

UNIT III

Psychrometry – Definitions for properties. Introduction to cooling load calculations. Comfort conditions. Air-conditioning systems.

UNIT IV

Cryogenic fluids, properties, behavior of cryogenics fluids, storage of cryogenic fluids,

UNIT V

Properties of materials at cryogenic temperatures, Insulation techniques, different types, vacuum techniques

References:

1. Arora, R.C., Refrigeration and Air Conditioning, PHI Pvt Ltd, 2010
2. Randall F. Barron, Cryogenic Systems, McGraw-Hill, 1985.
3. Klaus D. Timmerhaus and Thomas M. Flynn, Cryogenic Process Engineering, Plenum Press New York, 1989.
4. Herald Weinstock, Cryogenic Technology, 1969.

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5. Roy.J Dossat, Principles of Refrigeration, Pearson Education, 4th Edition , 2006

Welding Technology

Course Code: **L:T:P:**

Rationale:

- To study the different types of welding processes and understand the concept of weldability.
- To understand the principles of fusion welding processes.
- To acquire fundamental knowledge on principles of high energy density welding processes.
- To impart a sound understanding of principles of solid-state welding processes.
- To understand the effect of welding parameters on weld quality through modeling and optimization techniques.

Course Outcomes:

CO1	To learn basic principles and methods utilized for testing weldability.
CO2	To understand the impact of welding operations on environment and need for sustainable development
CO3	To select a suitable welding process for a particular application.
CO4	To acquire knowledge on modern developments in welding techniques
CO5	To get the knowledge about newly developed welding process and its parameters.

Course Contents:

UNIT I

Classification of welding processes: heat sources. Weld joint design - Weldability of steels and other materials - Weld defects.

UNIT II

Manual Metal Arc welding, TIG / A-TIG Welding, gas metal arc welding, Submerged arc welding.

UNIT III

Electron beam welding, Plasma arc welding, Laser beam welding - advantages and limitations, process variables and their effects.

UNIT IV

Friction welding and Friction stir welding processes – effects of speed and pressure – Explosive welding –Process Parameters – Resistance Welding – types and process capabilities.

UNIT V

Cold pressure welding - Ultrasonic welding - Recent Advances in welding - Modeling and optimization of welding process.

References:

1. Parmar, R.S., "Welding Engineering and Technology", Khanna Publishers, 2013, ISBN-13- 978-8174090287.
2. Lancaster J.F, 'The Physics of Welding: International Institute of Welding', Pergamon Press, 2013, ISBN-13- 978-0080340760
3. AWS, " Welding Handbook ", Vol. I to V. 1976
4. Weman, K., "Welding Processes Handbook", Woodhead Publishing, 2011, ISBN-13- 978-0857095107
5. Nadkarni S.V., 'Modern Arc Welding Technology', Ador Welding Ltd., 2008. ISBN-13-978812041676

Elementary Continuum Mechanics

Course Code: **L:T:P:**

Rationale:

- To introduce indicial notation and summation convention for vectorial and tensorial operations
- To introduce basic tensorial calculus for understanding continuum behavior of matters in cartesian coordinates.
- To familiarize the kinematics of continuum body deformation
- To familiarize the configuration dependent stress measures
- To understand the fundamental balance principles of continuum objects

Course Outcomes:

CO1	To apply indicial notation and Einstein's summation convention for tensor operation
CO2	To represent physical parameters in tensorial notations and perform tensor calculus.
CO3	To understand the unified theory of continuum body such as fluids and solids undergoing deformation.
CO4	To differentiate stress and strain measures on a material and spatial point
CO5	To represent linear momentum balance in material and spatial configuration

Course Contents:

UNIT I: Tensor - Introduction

Scalar, Vector, Second order Tensors, Indicial notation and summation convention, Dot, cross and dyadic products, Linear Transformation, Spherical & deviatoric projectors, Coordinate Transformation.

UNIT II: Tensor - Calculus

Eigen values and eigen vectors, Transformation of Tensors, Tensor valued functions, gradient operators and Integral theorems.

UNIT III: Kinematics

Reference and deformed configurations, motion – velocity and acceleration in material & spatial representation, Deformation and displacement gradients, material and spatial stains measures, Line, area, and volume mappings, Nanson's formula, Polar decomposition - Rotation & stretch tensors, rate of deformation.

UNIT IV: Kinetics

Concept of stress, Cauchy's stress theorem, first and second PiolaKirchoff's & Cauchy's stress tensors, Normal and shear stress, Extremal stress values, stress states.

UNIT V: Balance Principles

Mass conservation, Reynold's transport theorem, Momentum and energy balances in references and current configuration, Weak and strong forms of balance equation, Continuum thermodynamics.

References:

1. Gerhard A. Holzapfel, Nonlinear solid mechanics: A Continuum approach for Engineering, Wiley, ISBN: 978-0-471-82319-3 ,2000.
2. W Michael Lai, David H. Rubin, Erhard Krempl, David Rubin, Introduction to Continuum Mechanics, Butterworth-Heinemann; 4th edition, ISBN: 978- 9380501581.
3. J.N. Reddy, An Introduction to Continuum Mechanics, Cambridge University Press; 2nd edition, ISBN: 978-1316614204.
4. George E. Mase, Schaum's Outline of Continuum Mechanics, McGraw Hill; First edition, ISBN: 978-9389691283
5. John W. Rudnick, Fundamentals of Continuum Mechanics, Wiley, ISBN: 978- 1-118-92767-0, 2014.

Modern Automotive Technology

Course Code: **L:T:P:**

Rationale:

- To impart knowledge on the constructions, functions and technological features of electric and hybrid vehicles.
- To imbibe the utilization of fuel cells and uses of alternative energy systems.
- To familiarize the various controls and safety features used in modern vehicles.
- To study the uses of modern peripheral systems and vehicle automated tracks used in automobiles.
- To understand the various modern features and developments in latest automobiles.

Course Outcomes:

CO1	To know the suitable control system for different electrical vehicles application.
CO2	To possess the knowledge about various alternative energy systems and fuel cells.
CO3	To identify various modern features for better functioning of vehicle
CO4	To demonstrate various safety features and equipment used in modern vehicle
CO5	To apply the fundamental knowledge in developing modern vehicle systems.

Course Contents:

UNIT I

Electric and Hybrid Vehicle Technology: Introduction, LEV, TLEV, ULV & ZEV, Basic components of Electric vehicles, Basic factors to be considered for converting automobiles to electric vehicle, electric hybrid vehicle, types - series and parallel hybrid, layouts, comparison, Power systems and control. Electric propulsion with cables – Magnetic track vehicles. Vehicle Operation and Control: Computer Control for fuel economy, pollution and noise.

UNIT II

Fuel Cells and Alternative energy systems: Proton exchange membrane fuel cells, alkaline electrolyte fuel cells, medium and high temperature fuel cells, fuel selection and processing, fuel cell stacks, fuel cell auxiliary systems. Recent Trends in Automotive Power Plants: Stratified charged / lean burn engines – Hydrogen Engines

UNIT III

Principle of Automobile Navigation and controls in the new generation cars. Capabilities of the navigation and control in future cars. Driver Assistance Systems in Automobiles: Vision in cars, A comprehensive driver assistance approach – Lane recognition, Traffic sign recognition, Stereo vision, road recognition, Object recognition – Traffic lights and signals, Building intelligent systems in new generation cars.

UNIT IV

Vehicle Automated Tracks: Preparation and maintenance of proper road network-National highway network with automated roads and vehicles-Satellite control of vehicle operation for safe and fast travel. Introduction to electronic traction control and stability control. Brief introduction to driverless cars.

UNIT V

Modem electronic and micro control systems in automobiles: Electronically controlled concealed headlight systems, Electro chromic mirrors, automatic review mirrors, Day time running lamps (DRL), Head up display, Travel information systems, On board navigation system, Electronic climate control, Electronic cruise control, Antilock braking system, Electronically controlled sunroof, Anti-theft systems, Automatic door locks (ADL), engine management system, chassis control system, Integrated system. Modern Developments in Automobiles

References:

1. Chris Mi, M. Abul Masrur, Electric Vehicles, 2nd Edition, Wiley, 2017.
2. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, Modern electric, hybrid electric, and fuel cell vehicles: fundamentals, theory, and design, CRC Press, 2004.
3. Tom Denton, Automobile Electrical and Electronics System, Routledge, 2017.
4. Tom Denton, Electric and Hybrid Vehicles, Routledge, 2020.
5. Barry Hollembeak, Automotive Electricity, Electronics and Computer Controls, S.Chand (G/L) & Company Ltd , 1998.

Hydrogen – Production Handling and Storage

Course Code: **L:T:P:**

Rationale:

- To understand the various methods of hydrogen production, including conventional and renewable approaches.
- To explore the technologies and safety measures involved in the handling and storage of hydrogen.
- To analyze the economic, environmental, and technical challenges associated with hydrogen as an energy carrier.
- To evaluate the role of hydrogen in the context of sustainable energy systems and its potential in various applications.
- To develop strategies for the implementation and optimization of hydrogen technologies in various sectors.

Course Outcomes:

CO1	Understand and explain various hydrogen production technologies, including both conventional and renewable methods.
CO2	Demonstrate knowledge of the safety considerations, handling, and storage technologies for hydrogen.
CO3	Perform economic and environmental assessments of hydrogen as an energy carrier, considering its production, storage, and application
CO4	Critically evaluate the potential and challenges of hydrogen in future sustainable energy systems and its applications in industry, transportation, and power generation.
CO5	Formulate and propose practical solutions for the adoption and enhancement of hydrogen production, handling, and storage systems.

Course Contents:

UNIT I

Historical Perspective and Evolution of Hydrogen Use, Hydrogen's Role in the Energy Transition, Physical and Chemical Properties of Hydrogen, Hydrogen Handling and Safety: Hydrogen Properties and Hazard Identification, Safety Protocols for Handling Hydrogen, Hydrogen Leak Detection and Mitigation. Materials Compatibility and Hydrogen Embrittlement, Codes, Standards, and Regulations for Hydrogen Safety

UNIT II

Hydrogen Production Technologies- Conventional Methods: Steam Methane Reforming, Coal Gasification, Partial Oxidation of Hydrocarbons. Renewable Methods: Water Electrolysis (Alkaline, PEM, Solid Oxide), Biomass Gasification, Photoelectrochemical Water Splitting, Thermochemical Water Splitting, Biological Hydrogen Production. Emerging Technologies: Plasma-Assisted Hydrogen Production, Green Hydrogen via Wind and Solar Integration

UNIT III

Hydrogen Storage Technologies: Physical Storage: Compressed Gas Storage, Liquid Hydrogen Storage, Cryogenic Storage Systems. Material-Based Storage: Metal Hydrides, Chemical Hydrides, Carbon-Based and Novel Materials for Hydrogen Adsorption. Advanced Storage Solutions: Solid-State Storage Technologies, Challenges in Scaling Up Hydrogen Storage Solutions

UNIT IV

Hydrogen Transportation and Infrastructure: Hydrogen Pipelines and Distribution Networks, Road and Rail Transport of Hydrogen, Marine Transport of Liquid Hydrogen, Development of Hydrogen Refueling Infrastructure. Case Studies: Global

Hydrogen Infrastructure Projects, Economic and Environmental Aspects of Hydrogen, Cost Analysis of Hydrogen Production Methods, Life Cycle Assessment of Hydrogen Production and Use, Carbon Footprint and Environmental Impact, Hydrogen Economy: Opportunities and Barriers, Policy and Incentives for Hydrogen Deployment

UNIT V

Applications of Hydrogen, Hydrogen in Fuel Cells: PEMFC, SOFC, and MCFC. Hydrogen as a Fuel for Transportation, Industrial Applications of Hydrogen, Hydrogen in Power Generation and Grid Integration, Hydrogen for Energy Storage and Backup Power Systems. Research Directions: Advances in Hydrogen Production and Storage Technologies, Hydrogen Blending in Natural Gas Grids, Potential for Hydrogen in Decarbonizing Hard-to-Abate Sectors, Research and Development Priorities in Hydrogen Technology

References:

1. S.A. Sherif, D. Yogi Goswami, E.K. (Lee) Stefanakos, Aldo Steinfeld, “Handbook of Hydrogen Energy”, 1st Edition, 2014.
2. zimas, E., Filiou, C., Peteves, S.D., &Veyret, J.B. “Hydrogen storage: state-ofthe-art and future perspective. Netherlands”: European Communities, 2003.
3. Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009.
4. Michael Hirscher, “Handbook of Hydrogen Storage”, Wiley-VCH, 2010.
5. Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009
6. Anand Ramanathan, Babu Dharmalingam, Vinoth Thangarasu, “Advances in Clean Energy Production and Application”, Taylor & Francis, CRC Press, 2020
7. Anand Ramanathan, Meera Begum, Amaro Pereira, Claude Cohen, “A Thermo-economic Approach to Energy from Waste”, Elsevier, 2021.

Alternative Sources of Energy

Course Code: **L:T:P**

Rationale:

Course Outcomes:

CO-1	Identify renewable energy sources and their utilization.
CO-2	Understand basic concepts of solar radiation and analyze solar thermal systems for its utilisation.
CO-3	Understand working of solar cells and its modern manufacturing technologies.
CO-4	Understand concepts of Fuel cells and their applications
CO-5	Identify methods of energy storage.
CO-6	Compare energy utilization from wind energy, geothermal energy, biomass, biogas and hydrogen.

Course Contents:

UNIT I:

Introduction: Overview of the course; Examination and Evaluation patterns; Global warming; Introduction to Renewable Energy Technologies

Energy Storage: Introduction; Necessity of Energy Storage; Energy Storage Methods

UNIT II:

Solar Energy: Fundamentals; Solar Radiation; Estimation of solar radiation on horizontal and inclined surfaces; Measurement of solar radiation data

Solar Thermal systems: Introduction; Basics of thermodynamics and heat transfer; Flat plate collector; Evacuated Tubular Collector; Solar air collector; Solar concentrator; Solar distillation; Solar cooker; Solar refrigeration and air conditioning; Thermal energy storage systems

UNIT III:

Solar Photovoltaic systems: Introduction; Solar cell Fundamentals; Characteristics and classification; Solar cell: Module, panel and Array construction; Photovoltaic thermal systems.

Wind Energy: Introduction; Origin and nature of winds; Wind turbine siting; Basics of fluid mechanics; Wind turbine aerodynamics; wind turbine types and their construction; Wind energy conversion systems

UNIT IV:

Fuel cells: Overview; Classification of fuel cells; operating principles; Fuel cell thermodynamics Biomass Energy: Introduction; Photosynthesis Process; Biofuels; Biomass

Resources; Biomass conversion technologies; Urban waste to energy conversion; Biomass gasification.

UNIT V:

Other forms of Energy: Introduction: Nuclear, ocean and geothermal energy applications; Origin and their types; Working principles

Text Books:

1. Sukhatme S.P. and J.K.Nayak, Solar Energy - Principles of Thermal Collection and Storage, Tata McGraw Hill, New Delhi, 2008.
2. Khan B.H., Non-Conventional Energy Resources, Tata McGraw Hill, New Delhi, 2006.
3. J.A. Duffie and W.A. Beckman, Solar Energy - Thermal Processes, John Wiley, 2001.

Other Suggested Readings:

1. NPTEL Courses

MIT Open Course Ware, etc.

3D Printing

Course Code: **L:T:P:**

Rationale:

Course Outcomes:

CO-1	Develop preprocess data for the 3D Printing
CO-2	Identify properties of 3DP materials and their influence on final part quality
CO-3	Describe the working principles of each 3D Printing technology
CO-4	Apply suitable 3D Printing technology for any given industrial application
CO-5	Select the postprocessing and testing method for the given application
CO-6	Develop preprocess data for the 3D Printing

Course Contents:

UNIT I

Computer Aided Design (CAD) and Preprocessing Data for 3D Printing: Introduction to Geometric Modelling of Curves, Parametric Representation of Freeform Surfaces and Solids. CAD Data Exchange Formats, Input File Sources and Characteristics, 3D Printing Data File Formats and Software, STL File

Errors and Manipulation, 3D Printing Process Chain, Part Orientation and Support Generation, Model Slicing and Contour Data Organisation, Hatching Strategies, 3D Printing Toolpaths Generation and Process Plan, Build Preparation and 3D Printing Process Simulation.

UNIT II

3D Printing Materials and Characterisation: Nature of Thermoplastics and Thermosetting Polymers, Properties of Metal and Ceramics. *3DP Liquid Materials:* Rheology and Wetting Behaviour. *3DP Solid*

Materials: Filament Diameter Consistency, Density, Porosity, Moisture Content, Thermal Properties,

Microstructure of Composite Filament, Mechanical Properties of Filament. *3DP Powder Materials:* Powder Size Measurements, Morphology, Chemical Composition, Flow Characteristics, Density, Energy Absorption Characteristics of Powder.

UNIT III

3D Printing Processes: Classification of 3D Printing Processes. Description, Process Parameters, Material Selection and Characterisation, Applications, Strengths and Weaknesses of Vat Photopolymerization,

Material Jetting, Binder Jetting, Material Extrusion, Sheet Lamination, Powder Bed Fusion and Directed Energy Deposition Processes; *Other Processes:* Aerosol Printing and Bio-plotter.

Construction of DIY Printers: Motion System, Frame/Chassis, Print Bed, Extruder, Electronics.

UNIT IV

3D Printing Applications: An Overview of 3D Printing Applications, *Aerospace:* Aerospace Materials and their Requirements, Qualification and Certification of Parts, Aerospace Case Studies. *Medical:* Medical Scanning Technologies, Biomaterials, Planning and Simulation of Complex Surgeries, Design and Fabrication of Customized Implants, Medical Case Studies. *Automobile:* Prototyping, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. *Other Applications of 3DP:* Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

UNIT V

Postprocessing and Testing of 3DP Parts: Need for Postprocessing in 3DP, *Surface Treatment Methods:* Subtractive Machining Methods, Thermal-based Methods, Abrasive-based Methods, Chemical Methods. *Surface Protection, Functionalization, and Decorative Methods.* Heat Treatment and Aging. Establish a

Relationship between Processing Parameters, Resulting Microstructure, Mechanical Properties, Fatigue,

Creep and Corrosion Resistance of 3DP Parts. *Testing of 3DP Parts:* Metrology Measurement Methods, Porosity and Density, Dimensions, Mechanical Measurement Methods, NDT Methods of 3DP Parts, 3DP Safety, 3DP Standards.

Text Books:

1. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TataMcGrawHill, 2008.
2. Damir Godec, Joamin Gonzalez-Gutierrez, Axel Nordin, Eujin Pei, Julia Urena Alcazar, A Guide to Additive Manufacturing, Springer, 2022.
3. Ian Gibson, David Rosen, Brent Stucker, and Mahyar Khorasani, Additive Manufacturing Technologies, 3rd Edition, Springer, 2021.
4. Diegel, Olaf, Axel Nordin, and Damien Motte, A Practical Guide to Design for Additive Manufacturing, Springer, 2020.
5. Zafar Alam Faiz Iqbal, Dilshad Ahmad Khan, Post-processing Techniques for Additive Manufacturing, CRC Press, 2024.

Reference Books:

1. Michael E.Mortenson, Geometric Modeling, McGrawHill, 2013.
2. Patri K. Venuvinod and Weiyin Ma, Rapid Prototyping: Laser-based and Other Technologies, Springer, 2004.

3. Sanjay Joshi, Richard P. Martukanitz, Abdalla R. Nassar, Pan Michaleris, Additive Manufacturing with Metals: Design, Processes, Materials, Quality Assurance, and Applications, Springer, 2023.
4. L.Lu, J. Y. H. Fuh and Y.S.Wong, Laser-Induced Materials and Processes for Rapid Prototyping, Springer, 2001.
5. Chua Chee Kai, Leong Kah Fai, Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, World Scientific, 5th Edition, 2019.
6. Gurminder Singh, Ranvijay Kumar, Kamalpreet Sandhu, Eujin Pei, and Sunpreet Singh, Handbook of Post-Processing in Additive Manufacturing: Requirements, Theories, and Methods, CRC Press, 2024.

Composite Materials

Course Code: **L:T:P:**

Rationale:

Course Outcomes:

CO-1	Understand composite material and their reinforcements
CO-2	Select constituent materials for preparing appropriate composites
CO-3	Analyze interfaces of composites for predicting their mechanical properties.
CO-4	Develop metal matrix, ceramic matrix and polymer matrix composites with given proportions of constituents

Course Contents:

UNIT I:

Introduction: Overview of the course, history and basic concept of composites, Types and constituents, reinforcement and matrices, interface and mechanism of strengthening.

UNIT II:

Fundamental concepts: Definition and Classification of Composites, particulate and dispersion hardened composites, continuous and discontinuous fibre reinforced composites MMC, PMC, CMC.

UNIT III:

Metal Matrix Composites Processing: Liquid state processes, solid state processes and in situ processes.

UNIT IV:

Polymer Matrix Composites Processing: Hand lay-up and spray technique, filament winding, pultrusion, resin transfer moulding, bag and injection moulding, sheet moulding compound. Matrix resins-thermoplastics and thermosetting matrix resins. Reinforcing fibres-Natural fibres (cellulose, jute, coir etc), carbon fiber, glass fiber, Kevlar fiber, etc. Particulate fillers-importance of particle shape and size. Coupling agents-surface treatment of fillers and fibres, significance of interface in composites. short and continuous fibre reinforced composites, critical fibre length, and anisotropic behaviour.

UNIT V:

Ceramic Matrix Composites Processing: Cold pressing & sintering, hot pressing reaction bonding processes, infiltration, in-situ chemical reaction, Sol-Gel and polymer pyrolysis, self- propagating high temperature synthesis. Carbon- carbon composites, Interfaces.

Rule of mixtures. Stress, strain transformations.

Text Books:

1. Chawla, Composite Materials Science and Engineering, Springer
2. Hull, An introduction to composite materials, Cambridge
3. Steven L. Donaldson, ASM Handbook Composites Volume 21, 2001.
4. Krishan K. Chawla, Composite Materials, Science and Engineering, Springer, 2001.
5. Suresh G. Advani, E. Murat Sozer, Process Modelling in Composites Manufacturing, 2nd Ed. CRC Press.

Industrial Management

Course Code: **L:T:P:**

Rationale:

Course Outcomes:

CO-1	Understand the evolutionary development of management thought and general principles of management
CO-2	Apply marketing concepts and tools for successful launch of a product
CO-3	Understand the role of productivity in streamlining a production system
CO-4	Apply the inventory management tools in managing inventory
CO-5	Apply quality engineering tools to the design of the products and process controls
CO-6	Apply project management tools to manage projects

Course Contents:

UNIT I:

General Management: Evolution of industry and professional management; functions of management; design of an organization structure, Hawthorn experiments, primary groups and informal organizational structures, leadership styles and characteristics of effective leadership, Mc Gregor's Theory X and Theory Y, Maslow's and Hertzberg's motivational theories, Japanese Management.

UNIT II:

Marketing Management: Marketing management process and the four Ps of marketing mix; market segmentation, targeting and positioning; product life cycle and marketing strategies in different stages of product life cycle.

UNIT III:

Productivity and Work Study: Productivity definition, its role in the economy, techniques for improving productivity, method study procedure, flow process chart and flow diagram, two handed process chart, principles of motion economy, work sampling, stop watch time study.

UNIT IV:

Quality Management: control charts - and R, p & c charts, Sampling plan –design of single sampling plan using OC curve, rectifying inspection and AOQL; Taguchi's method of total quality control, Quality function deployment, Introduction to TQM

UNIT V:

Inventory Management: Purposes of inventories, inventory costs, ABC classification, EOQ,P and Q systems of inventory control.

Project Management: Network diagrams, critical path method, total slack and free slack, crashing of activities and resource levelling, PERT.

Text Books:

1. Donald J clough. "Concepts in Management science", Prentice Hall of India.
2. Philip Kotler, "Marketing Management", Prentice Hall of India, New Delhi, 2020.
3. Koontz, H. et. al., "Essentials of Management" - Mc Graw Hill Book Co., New York, 2019.
4. Chase and Aquilano - Operations Management -Mc Graw Hill Pub. Books Co. New York, 2019.