DEPARTMENT OF MECHANICAL ENGINEERING

COURSE STRUCTURE

For

M.TECH

SPECIALIZATION

IN

HEAT POWER ENGINEERING

(Effective from 2019-20)

VEER SURENDRA SAI UNIVESITY OF TECHNOLOGY

BURLA, SAMBALPUR

PIN-768018

Vision

To be recognised as a centre of excellence in education and research in the field of mechanical engineering by producing innovative, creative and ethical mechanical engineering professionals for socio-economic upliftment of society in order to meet the global challenges.

Mission

Mechanical Engineering Department of VSSUT Burla strives to impart quality education to the students with enhancement of their skills to make them globally competitive through:

M1: Maintaining state of the art research facilities to provide conducive environment to create, analyze, apply and disseminate knowledge.

M2: Fortifying collaboration with world class R&D organizations, educational institutions, industry and alumni for excellence in teaching, research and consultancy practices to fulfil 'Make In India' policy of the Government.

M3: Providing the students with academic environment of excellence, leadership, ethical guidelines and lifelong learning needed for a long productive career.

Programme Educational Objectives (PEO)

PEO1	To enhance the fundamentals and the knowledge-base of students in thermal engineering and to make capable for effectively analyzing and solving the problems associated in this area.
PEO2	To encourage students to take up real life and research related problems and to create innovative solutions of these problems through systematic analysis and design.
PEO3	To inculcate teamwork, communication and interpersonal Skills adapting to changing environments of technology.

PEO-Mission Matrix

	M1	M2	M3
PEO1	1	1	3
PEO2	3	3	2
PEO3	1	2	3

Programme Outcomes (PO)

PO1	An ability to independently carry out research /investigation and development work to solve practical problems pertaining to heat power engineering.
PO2	An ability to write and present a substantial technical report/document.
PO3	An ability to demonstrate a degree of mastery over heat power engineering, a level higher than the requirements in the undergraduate program of mechanical engineering.
PO4	An ability to design various thermal systems to obtain optimal feasible solution considering safety, environment and other realistic constraints.
PO5	An ability to demonstrate skills in latest engineering tools, software and equipments to analyze and solve thermal engineering problems.
PO6	An ability to work as an individual and in a team with an understanding of the profession in ethical manner.

Programme Specific Outcomes (PSO)

On completion of M. Tech in Heat Power Engineering the students will be able to:

PSO1	critically analyze / synthesize, simulate and optimize mechanical systems, components and processes by applying the principles of heat power and thermal engineering.
PSO2	independently carry out research / investigation to solve practical industrial problems related to heat power and thermal engineering using advanced tools and techniques and write / present a substantial technical report/document.

Semester I

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-1	MMEHP101	Advanced Fluid Mechanics	3	0	0	3
2	Core-2	MMEHP102	Conduction and Radiation Heat Transfer	3	0	0	3
3	PE-1 (any one)	MHPPE101	Advanced Refrigeration Engineering	3	0	0	3
		MHPPE102	Finite Element Modeling in Thermal Engineering	3	0	0	3
		MHPPE103	Turbulence Modeling	3	0	0	3
4	PE-2 (any one)	MHPPE104	Gas Dynamics	3	0	0	3
		MHPPE105	Advanced IC Engines	3	0	0	3
		MHPPE106	Solar Engineering	3	0	0	3
5	Common	MMEHP103	Research Methodology & IPR	3	0	0	3
6	Lab-1	MMEHP104	Thermo-fluids Lab-I	0	0	3	2
7	Lab-2	MMEHP105	Numerical Simulation Lab	0	0	3	2
8	Audit -1						
Total Credits							19

Semester II

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Core-3	MMEHP201	Advanced Engineering Thermodynamics	3	0	0	3
2	Core-4	MMEHP202	Convective Heat and Mass Transfer	3	0	0	3
3	PE-3 (any one)	MHPPE201	Cryogenic Technology	3	0	0	3
		MHPPE202	Thermal System Simulation and design	3	0	0	3
		MHPPE203	Computational Fluid Dynamics	3	0	0	3
4	PE-4 (any one)	MHPPE204	Introduction to Two-Phase Flow	3	0	0	3
		MHPPE205	Air Conditioning Engineering	3	0	0	3
		MHPPE206	Micro fluidics	3	0	0	3
5	Common	MMEHP203	Minor project & Seminar	0	0	4	2
6	Lab-3	MMEHP204	Thermo-fluids Lab-II	0	0	3	2
7	Lab-4	MMEHP205	Research Seminar	0	0	3	2
8	Audit -2						
Total Credits							18

Semester III

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	PE-5 (any one)	MHPPE301	Experimental Techniques in Thermal Engineering	3	0	0	3
		MHPPE302	Computational Gas Dynamics	3	0	0	3
		MHPPE303	Gas Turbine and Jet Propulsion	3	0	0	3
2	OE-1 (any one)	MHPOE301	Non-conventional energy	3	0	0	3
		MHPOE302	Matrix Computation	3	0	0	3
		MHPOE303	Smart Materials	3	0	0	3
3	Project	MMEHP301	Dissertation (Phase-I)	0	0	20	10
Total Credits							16

Semester IV

Sl. No.	Core/ Elective	Subject Code	Subject Name	L	T	P	Credits
1	Project	MMEHP401	Dissertation (Phase-II)	0	0	32	16
Total Credits							16

GRAND TOTAL CREDITS: 1**9+**1**8+16+16**= **69**

<u>Audit course 1 & 2</u>

Sl.No.	Course Code	Subject Name
1.	BCAC1001	English for Research Paper Writing
2.	BCAC1002	Disaster Management
3.	BCAC1003	Sanskrit for Technical Knowledge
4.	BCAC1004	Value Education
5.	BCAC2001	Constitution of India
6.	BCAC2002	Pedagogy Studies
7.	BCAC2003	Stress Management by Yoga
8.	BCAC2004	Personality Development through Life Enlightenment Skills.

ADVANCE FLUID MECHANICS

L-T-P:3-0-0 Credit-3

Course Contents:

MODULE 1: **(8 Hours)**

Concept of continuum and definition of a fluid, Body and surface forces, stress tensor, principle of local stress equilibrium, Scalar and vector fields, Eulerian and Lagrangian description of flow. Motion of fluid element: translation, rotation and deformation; vorticity and strain-rate tensors. Continuity equation, Cauchy's equations of motion, Reynold's Transport theorem.Constitutive equations-Stokes law of viscosity. Derivation of N-S equations for compressible flow

MODULE 2: **(6 Hours)**

Exact solutions of N-S equations: plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between twoconcentric rotating cylinders, Stokes first and second problems,Pulsating Flow between Parallel Surfaces, stagnation-point flow, Flow in convergent-divergent channels. Flow over a Porous wall

MODULE 3: **(5 Hours)**

Slow viscous flow: Stokes and Oseens approximation, Uniform flow Past a Sphere, theory of hydrodynamic lubrication.

Introduction to hydrodynamic stability, Orr-Sommerfeld equation, neutral curve of linear stability for plane Poiseuille flow.

MODULE 4: **(5 Hours)**

The Boundary-Layer Equations, Blasius Solution, Falkner-SkanSolutions, Flow Over a Wedge, Stagnation-Point Flow, Approximate Solution for a Flat Surface, General Momentum Integral, Boundary-Layer Separation, Stability of Boundary Layers

MODULE 5: **(6 Hours)**

Physical and Mathematical Description of Turbulence, The Reynolds Equations of Turbulent Motion, The Two-Dimensional Turbulent-Boundary-Layer Equations, Velocity Profiles: The Inner, Outer, and Overlap Layers, Turbulent Flow in Pipes and Channels, The Turbulent Boundary Layer on a Flat Plate,Turbulence Modeling in Two-Dimensional Flow, Analysis of Turbulent Boundary layers with Pressure Gradient,Free Turbulence: Jets, Wakes, and Mixing Layers.

Text Book:

1. Viscous Fluid Flow by Frank M White (McGraw-Hill)
2. Fundamental Mechanics of Fluids by I.G Currie (CRC Press)

Reference Books:

1. Incompressible flow by R L Panton(John Wiley & Sons)
2. Fluid Mechanics, P.K. Kundu, I.M. Kohen& D.R. Dowling, Academic Press
3. An Introduction to Fluid Dynamics by G K Batchelor (Cambridge University Press)
4. Boundary Layer Theory by H Sctllichting (McGraw-Hill)

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Incorporate the fundamental concepts of fluid mechanics
CO2	Analyze exact solutions of NS equations for practical problems.
CO3	Analyze the concept hydrodynamic stability.
CO4	Analyze the concept of boundary layer theory
CO5	Implement various turbulence modelling on flow problems

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	1
CO2	3	1	3	3	1	1
CO3	3	1	3	3	1	1
CO4	3	1	3	3	1	1
CO5	3	1	3	3	1	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
Course	3	1	3	3	1	1

CONDUCTION AND RADIATION HEAT TRANSFER

L-T-P:3-0-0 Credit-3

Course Contents:

MODULE 1: (8 Hours)

Introduction to conduction: Derivation of energy equation for conduction in three dimensions – Initial and boundary conditions.

Solution of simple problems in steady state conduction with analytical solutions – Concept of electrical analogy – fin heat transfer and concept of fin efficiency and fin effectiveness.

Unsteady conduction: Concept of Biot number – Lumped capacitance formulation – simple problems – unsteady conduction from a semi-infinite solid- solution by similarity transformation method. Solution of the general 1D unsteady problem by separation of variables and charts.

MODULE 2: (8 Hours)

2D steady conduction and phase change problems: Laplace equation – solution by variable separable method – concept of superposition and homogeneous boundary conditions.

Phase change problems – The Stefan and Neumann problems – analytical solutions.

MODULE 3: (6 Hours)

Importance of radiation, Mechanism of radiation, Electromagnetic spectrum, Concept of black body, derivation of black body radiation laws from first principles – Planck's law, Stefan Boltzmann law, Wien's displacement law, Universal black body function, F function charts.

MODULE 4: (4 Hours)

Radiative properties of non-black surfaces: Spectral directional emissivity, definition of total and hemispherical quantities, hemispherical total emissivity. Spectral directional absorptivity, Kirchoff law, directional and hemispherical absorptivity, hemispherical total absorptivity, View factors.

MODULE 5: (4 Hours)

Enclosure with Transparent Medium – Enclosure analysis for diffuse-gray surfaces and non-diffuse, non-gray surfaces, net radiation method.

Enclosure with Participating Medium - Radiation in absorbing, emitting and scattering media. Absorption, scattering and extinction coefficients, Radiative transfer equation

Text Books:

1. Conduction Heat Transfer, D. Poulikakos, Prentice Hall, 1994.
2. Thermal Radiation Heat Transfer, R. Siegel and J. R. Howell, Taylor & Francis, 2002.

Reference Books:

1. Heat Conduction, S. Kakac and Y. Yener, Taylor and Francis, 1994.

2. Conduction Heat Transfer, V.S. Arpaci, Addison Wesley, 1996 (Abridged edition Ginn press 1998)
3. Heat Transfer, A.J.Chapman, Macmillan, 1984.

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Analyze heat transfer through extended surface.
CO2	Apply energy equation to evaluate temperature distribution in steady and unsteady heat conduction problem.
CO3	Develop analytical solutions for phase change problems.
CO4	Define mechanism of radiation and radiation properties of non-black surfaces.
CO5	Construct radiative transfer equation for enclosures with transparent and participating medium.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	1	3	3	2	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	2	1
CO5	3	1	3	3	2	1

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
Course	3	1	3	3	2	1

ADVANCED REFRIGERATION ENGINEERING

L-T-P: 3-0-0 Credit-3

Course Contents:

MODULE-1 (8 Hours)

Thermodynamic properties of pure and mixed refrigerants and their Selection:Recapitulation of thermodynamics of refrigeration systems, Refrigerants: Introduction, Desirable properties of an Ideal Refrigerant, Physical, Chemical & thermodynamic properties of a refrigerant, Classification of Refrigerants: Primary &

Secondary, Designation System of Refrigerants, Properties of Refrigerants, Uses of Important Refrigerants, Secondary Refrigerants – Brine

Vapour compression Refrigeration system: Analyis of Theoretical vapour Compression cycle, Types of vapour Compression cycles, Representation of the cycle on P-H, T-S and P-V diagrams, Simple Saturation Cycle, Sub-cooled cycles and superheated cycle, Effect of suction and discharge pressure on performance. Actual Vapour compression Cycle, Use of flash coolers, Advantages and disadvantages of Vapour Compression Systems

MODULE-2 (8 Hours)

Multistage compression systems: Introduction, Methods of improving C.O.P – Optimum Interstage, Pressure for Two-Stage Refrigeration System, Single load systems, Multi load systems with single Compressor, Multiple Evaporator and Compressor systems. Dual Compression systems

Vapour Absorption Refrigeration system: Introduction, simple vapour Absorption system, Practical Vapour Absorption System, Advantages of Vapour Absorption sytem over vapour compression system. Coefficient of Performance of an Ideal Vapour Absorption Refrigeration System. Electrolux (Ammonia-Hydrogen) Refrigerator, Lithium Bromide Absorption Refrigeration System

MODULE-3 (4Hours)

Ejector refrigeration systems: Principle and working, Advantages & disadvantage over existing systems, Alternative ejector types, Rotodynamic ejectors

Vortex tubes: Principle of working, Components, Phenomenon of energy transfer in vortex tubes, Analysis of temperature drop, adiabatic efficiency and COP, Advantages & applications

MODULE-4 (5Hours)

Principle of liquefaction of gases: Isentropic expansion, Free, Irreversible expansion, Joule Thompson co-efficient, Inversion temperature, Linde-Hampson System for liquefaction of air, hydrogen & helium, Low temperature applications

Solid ice production: Solid Carbon-dioxide as a refrigerant, Advantages & disadvantages, Manufacture of Solid Carbon-dioxide or dry Ice, , Use of water and flash intercooler for dry ice production

MODULE-5 (5 Hours)

Expansion devices - Capillary tubes, Automatic and thermostatic expansion valves, Design of capillary tubes

Thermal Design of evaporators & Condensers, Magnetic refrigeration systems, Analysis and thermal design of reciprocating centrifugal and screw compressors, Computer simulation of refrigerant compressors.

Textbooks:

1. C.P. Arora, Refrigeration & Air conditioning (TMH Publication)
2. Domkundwar&Arrora: Refrigeration & Air conditioning (DhanpatRai& Sons)

Reference Books:

1. Stoecker and Zones: Refrigeration & Air conditioning (McGraw Hill)
2. Monohar Prasad: Refrigeration & Air conditioning(EWP)
3. A text book of Refrigeration and Air-conditioning by R.S. Khurmiand J.K. Jai, S.Chand& Co.

Course Outcome:

Upon completion of the subject the students will be able to:

CO1	Give an overview of various refrigeration systems and describe about the principle and working of Vapour Compression refrigeration system in detail.
CO2	OutlineVapour Absorption and Multi-stage refrigeration systems.
CO3	Describe the working of other refrigeration systems.
CO4	Explain the process of Liquefaction of gases for low temperature applications
CO5	Implement theprinciples of thermodynamics and heat transfer to design various refrigeration systems.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	2	2	1	1	-
CO2	3	2	3	2	1	-
CO3	3	2	3	3	1	1
CO4	3	2	3	3	3	2
CO5	3	3	3	3	3	2

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	2	3	3	1	2

FINITE ELEMENT MODELING IN THERMAL ENGINEERING

L-T-P:3-0-0 Credit-3

Course Contents

Module-I (8 Hours)

Fundamental Concept: Strain displacement relation, stress-strain relation, Plane stress, Plane strain problem minimization of total potential energy.

Module-II (12 Hours)

Concept of an Element; Displacement model, Shape functions for one Dimensional and two Dimensional problems, Constant strain Triangle.Iso parametric representation, Generalized co-ordinates, Element stiffness Matrix: Assembly procedure, Treatment of Boundary condition. Elimination approach, Penalty approach, some practical application.

Module-III (8Hours)

Solution of Linear Equations: Gauss Elimination Method, Gauss Seidelmethod. Convergence criteria.Scalar field problems: Variation formulation.

Module-IV (8 Hours)

Application to steady state heat transfer in one and two dimension, simple problem on fluid flow, steam function formulation.

Module-V (4 Hours)

Computer method and Computer programs, Automatic mesh generation, Data input, stiffness generation, solution of equations.

Text Books:

1. Abel and Desai: Introduction to finite element method (EWP Publications)

2.Chandrupatla and Belegundu; Introduction to finite elements in Engineering (PHI Publications)

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Compile the basic understanding of stress-strain
CO2	Define the use of iso parametric formulation
CO3	Apply the concept of variation formulation in solving engineering problems.
CO4	To develop the finite element formulation for heat transfer.
CO5	Apply professional-level finite element software to solve engineering problems in Solid mechanics, fluid mechanics and heat transfer.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	3	1
CO2	3	1	2	2	3	1
CO3	3	1	2	2	3	1
CO4	3	1	2	3	3	1
CO5	3	1	2	2	3	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	**3**	**1**	**2**	**2**	**3**	**1**

TURBULENCE MODELING

L-T-P: 3-0-0 Credit 3

Course Contents:

Module-1: Introduction: (7 Hours)

Origin of turbulence, irregularity, diffusivity, three-dimensional motions, dissipation, wide spectrum, length scales; Statistical Description of Turbulence: Probability density, moments, correlations, integral micro scales, homogeneous and isotropic turbulence, Kolmogorov hypothesis, energy cascade, turbulence spectra; Turbulent Transport: Reynolds decomposition, turbulent stresses, Reynolds equations, mixing-length model, dynamics of turbulence

Module-2: Statistical Description of Turbulence: (7 Hours)

Random nature of turbulence, distribution function, probability density, moments, correlations, Taylor's hypothesis, integral micro scales, homogeneous and isotropic turbulence, Kolmogorov hypothesis, scales of turbulence, energy cascade, turbulence spectra.

Module-3: Turbulent Transport of Moment and Heat: (6Hours)

Reynolds decomposition, turbulent stresses, vortex stretching, Reynolds equations, mixing-length model, Reynolds' analogy, dynamics of turbulence. Mixing Layer, Turbulent Wakes and Jets, Grid Turbulence.

Module-4: Wall-Bounded Turbulent Flows (5Hours)

Channel and pipe flows, Reynolds stresses, turbulent boundary layer equations, logarithmic-law of walls, turbulent structures.

Turbulence Modeling:

Introduction, eddy-viscosity hypothesis, algebraic model, k-ε and k-ω model, Reynolds-stress model, near-wall treatment, Introduction to LES and DNS.

Module-5: Experimental Methods (5Hours)

Introduction, hot wire anemometry, uncertainty analysis and laser doppler anemometry.

Text Books:

1. Turbulent Flows, Stephen B. Pope, Cambridge University Press
2. A First Course in Turbulence, H. Tennekes and J. L. Lumley, MIT Press

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Analyze limitations of the most commonly used modelling approaches.
CO2	Implement turbulence models for different fluid flow problems.
CO3	Analyze advanced modelling approaches related to Large Eddy Simulations.
CO4	Implement turbulence modelling for Free shear and wall-bounded flows
CO5	Analyze the use and limitations of Direct Numerical Simulations of turbulent flows.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	1
CO2	3	1	3	3	1	1
CO3	3	1	3	3	1	1
CO4	3	1	3	3	1	1
CO5	3	1	3	3	1	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	1	3	3	1	1

GAS DYNAMICS AND JET PROPULSION

L-T-P:3-0-0 Credit-3

Course Contents:

MODULE 1: (10 Hours)

Fundamental Aspects of Gas Dynamics: Introduction, Definition of Compressible Flow, Flow Regimes, Internal Energy and Enthalpy, First and second laws of thermodynamics, Entropy Calculation, Isentropic Relations,Integral form of Conservation Equations for Inviscid Flow: Continuity Equation, Momentum Equation, Energy Equation

MODULE 2: (10 Hours)

One-Dimensional Flow: One-Dimensional Flow Equations, Speed of Sound and Mach Number, Alternative Forms of the One-Dimensional Energy Equation, Normal Shock Waves: Normal Shock Relations, Hugoniot Equation, One-Dimensional Flow with Heat Addition, One-Dimensional Flow with Friction.

MODULE 3: (7 Hours)

Oblique Shock Wave: Oblique's Shock Relations, Supersonic Flow over Wedge and Cones, Regular Reflection from a Solid Boundary, Pressure- Deflection Diagrams, Mach Reflection, Detached Shock Wave in Front of Blunt Body, Prandtl-Mayer Expansion Waves.

MODULE 4:(7 Hours)

Quasi-One-Dimensional Flow: Governing Equations, Area-Velocity Relation, Isentropic Flow of a Calorically Perfect Gas through Variable-Area Ducts, Diffusers, Wave Reflection from a Free Boundary.

MODULE 5:(6 Hours)

Unsteady Wave Motion: Moving Normal Shock wave, Reflected Shock Wave, Incident and Reflected Expansion Wave, Shock Tube Relations, Finite Compression Waves

Text Books:

1. John D. Anderson, Jr. Modern Compressible Flow. Second Edition, McGraw-Hill Publishing Company, 1990

Reference Books:

1. F. M. White, Viscous Fluid Flow. 2nd ed. New York: McGraw-Hill, 1991.
2. A.H. Shapiro, Compressible Fluid Flow 1 and 2. Hoboken NJ: John Wiley.
3. L. D. Landau and E. M. Lifshitz, Fluid Mechanics. 2nd ed., Butterworth-Heinemann, 1995.
4. H. W. Liepmann, and A. Roshko, Elements of Gas Dynamics, Dover Pub, 2001.
5. P. H. Oosthuizen and W. E. Carscallen, Compressible Fluid Flow, NY, McGraw-Hill, 1997.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Formulate and solve problems in one -dimensional steady compressible flow
CO2	Apply conservation laws to fluid flow problems
CO3	Gain knowledge about main properties which are used for analyzing or modelling of compressible flow.
CO4	Solve flow problems with heat addition and with friction.
CO5	Simulation of One-dimensional flow in Shock tube

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	1	2	2
CO2	3	3	3	1	2	2
CO3	3	3	2	3	3	2
CO4	3	1	3	1	3	3
CO5	3	3	3	1	2	2

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	3	3	1	2	2

ADVANCED I.C. ENGINE

L-T-P:3-0-0 Credit-3

Course Contents:

MODULE – 1 (6 Hours)

Thermodynamics analysis of I C Engine cycles, Fuel-air cycles and actual cycles thermal efficiency and fuel consumption, Combustion in S.I engine and C.I engine, Use of combustion charts.Variable compression ratio engine; Theoretical analysis, method of obtaining variable compression ratio engine.

MODULE – 2 (8 Hours)

Super charging: Thermodynamic cycles with super charging, supercharging of S.I and C.I engines, effect of super charging on engine performance, limits of supercharging in C. I engines, method of super charging, superchargers. Stratified charge engines: Methods of charge stratification, stratification by fuel injection and positive ignition, swirl stratified charge engine, general characteristics of stratified charge engines.

MODULE – 3 (6 Hours)

Dual fuel and multi fuel engines: The working principle, combustion in dual fuel engines, super charge dual fuel engines, knock control in dual fuel systems, performance of dual fuel engines, characteristics of multi-fuel engine, performance of multi-fuel engines.

MODULE – 4 (5 Hours)

Engine Exhaust Emission Control: Formation of NOX, HC/CO mechanism, Smoke and Particulate emissions, Green House Effect, Methods of controlling emissions, Three way catalytic converter and Particulate Trap, Emission (HC,CO, NO and NOX) measuring equipments, Smoke and Particulate measurement, Indian Driving Cycles and emission norms.

MODULE – 5 (5 Hours)

Alternate Fuels: Alcohols, Vegetable oils and bio-diesel, Bio-gas, Natural Gas, Liquefied Petroleum Gas, Hydrogen, Properties, Suitability, Engine Modifications, Performance, Combustion and Emission Characteristics of SI and CI Engines using these alternate fuels.

Text books:

1. Internal Combustion Engines by Mathur and Sharma, DhanpatRai Publications.
2. Internal combustion engine fundamentals by J.B. Heywood, McGraw Hill Publications.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Understand the design and performance of IC Engines throughthermodynamic cycles
CO2	Analyze the supercharging effect on SI and CI Engines and their performance
CO3	Analyze fuel knocks and suggest controlling measures
CO4	Recognize emission control norms in SI and CI engines and to reduce harmful emission
CO5	Use alternate fuels in IC engines.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**2**	**2**	**3**	**-**	**-**
CO2	**1**	**-**	**2**	**2**	**-**	**-**
CO3	**2**	**2**	**2**	**1**	**-**	**-**
CO4	**2**	**2**	**2**	**1**	**-**	**-**
CO5	**3**	**2**	**3**	**2**	**-**	**-**

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	2	2	1	-	-

SOLAR ENGINEERING

L-T-P:3-0-0 Credit-3

Course Contents:

MODULE 1: Solar passive heating and cooling(8 Hours)

Thermal comfort - Heat transmission in buildings - Bioclimatic classification. Passive heating concepts - Direct heat gain, indirect heat gain, isolated gain and sunspaces. Passive cooling concepts - Evaporative cooling, radiative cooling, application of wind, water and earth for cooling, roof cooling, earth air-tunnel.Energy efficient landscape design - Concept of solar temperature and its significance, calculation of instantaneous heat gain through building envelope.

MODULE 2: Solar liquid and air heating system(6 Hours)

Flat plate collector – Liquid and air heating - Evacuated tubular collectors - Overall heat loss coefficient, heat capacity effect - Thermal analysis. Design of solar water heating systems, with natural and pump circulation. Solar dryers and applications.Thermal energy storage systems.

MODULE 3: Solar cooling and dehumidification (8 Hours)

Solar thermo-mechanical refrigeration system – Carnot refrigeration cycle, solar electric compression air conditioning, simple Rankine cycle air conditioning system.

MODULE 4: Absorption refrigeration(4 Hours)

Thermodynamic analysis –Energy and mass balance of Lithium bromide-water absorption system, Aqua-ammonia absorption system, Calculations of HCOP and second law efficiency.Solar desiccant dehumidification.

Module 5: Solar thermal applications (4 Hours)

Solar systems for process heat production - Solar cooking – Performance and testing of solar cookers.Seawater desalination – Methods, solar still and performance calculations.Solar pond - Solar greenhouse.

Text Books:

1. Kalogirou S.A., “Solar Energy Engineering: Processes and Systems”, Academic Press, 2009.
2. Goswami D.Y., Kreith F., Kreider J.F., “Principles of Solar Engineering”, 2nd ed.,

Taylor and Francis, 2000, Indian reprint, 2003.

Reference books:

1. Duffie J. A, Beckman W. A., “Solar Engineering of Thermal Process”, Wiley, 3rd ed. 2006.
2. Khartchenko N.V., “Green Power: Eco-Friendly Energy Engineering”, Tech Books, Delhi, 2004.
3. Garg H.P., Prakash J., “Solar Energy Fundamentals and Applications”, Tata McGraw-Hill, 2005.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Recognize the significance of solar energy sources and the concept of solar temperature.
CO2	Carry out thermal analysis and design of solar heating, drying and thermal energy storage systems.
CO3	Employ solar energy technology in a given situation for cooling and dehumidification.
CO4	Develop and work on various solar refrigeration systems
CO5	Work for the future development of solar energy technologies as an efficient alternative to conventional sources of energy.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	1	3	2	1	1
CO2	3	2	3	3	3	1
CO3	3	2	3	3	3	1
CO4	3	2	3	3	3	2
CO5	3	3	3	3	3	2

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	2	3	3	3	1

SESSIONALS

Thermo-fluids Lab-I

Course Contents:

1. Determination of heat transfer coefficient in forced convection
2. Determination of thermal conductivity for a liquid
3. Determination of COP by using a refrigerator tutor
4. Determination of psychometric properties of air by using an air-conditioning tutor
5. Load Test on Twin Cylinder C.I. engine with Fraude's Hydraulic Dynamometer with Variable Injection Pressure
6. Load Test on Twin cylinder C.I. engine with Fraude's Hydraulic Dynamometer with Variable Speed
7. Performance Characteristics of BMC Petrol Engine with Variable Loading Conditions
8. Load Test on Variable Compression Ratio Engine with Variation of Spark Angle

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Describe the fundamentals of Heat transfer, IC engines, Fluid Mechanicsand Refrigeration and co-relate it to analysevarious thermodynamic systems.
CO2	Evaluatethe thermal conductivity in liquids and demonstrate the heat transfer process in forced convection.
CO3	Showcasean understandingof psychometry and refrigeration systemsby demonstration with the help of air-conditioning and refrigeration tutors.
CO4	Determine the efficiency, power outputas well as frictional losses in engines.
CO5	Evaluate experimental results of thermodynamic systemsand compare with the theoretical values for design, analysis and implementation for practical applications.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	1	-
CO2	3	1	3	3	2	-
CO3	3	1	3	3	2	1
CO4	3	3	3	3	2	2
CO5	3	3	3	3	3	2

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	1	3	3	2	2

Numerical Simulation Lab

Course contents

1. Develop code for a Lid driven cavity using FORTRAN, MATLAB or C.
2. Develop code for Natural Convectionin a rectangular cavity using FORTRAN, MATLAB or C.
3. Geometry, meshingfor various configurationsusingANSYS Workbench.
4. Fully developed laminar flow through a circular pipe using Workbench.
5. Natural Convectionthrough a vertical pipe using ANSYS Workbench.
6. Melting and solidification in a rectangular cavity.
7. Fully developed turbulentflow through circular pipe using ANSYS Workbench.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Develop knowledgein coding to simulate the flow in a Lid driven cavity.
CO2	Develop skillsin coding for natural convection heat transfer in enclosures.
CO3	Develop skills in making geometry and meshing for various configurations using ANSYS Workbench.
CO4	Develop knowledge in CFD simulation of Convective heat transfer and phase change problems using ANSYS Workbench.
CO5	Develop knowledge in simulation of turbulent flow using ANSYS Workbench.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	2	1	-	-	-	-	1
CO2	3	3	2	1	1	2	1	-	-	-	-	1
CO3	3	3	2	1	1	2	1	-	-	-	-	1
CO4	3	3	2	1	1	2	1	-	-	-	-	1
CO5	3	3	2	1	1	2	1	-	-	-	-	1

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
	3	3	2	1	1	2	1	-	-	-	-	1

2nd Semester

ADVANCED ENGINEERING THERMODYNAMICS

L-T-P: 3-0-0 Credit-3

Course Contents

Module-I (7 Hours)

Recapitulations of fundamentals, Analysis of simple closed and open systems, Properties of Pure substance, first law of Thermodynamics applied to closed systems, first law applied to steady flow processes, Analysis of variable flow process.

Module-II (7 Hours)

Second law of Thermodynamics, Entropy: Entropy generation, Relationship between entropy generation and viscous dissipation, Entropy balance for closed and open systems.

Module-III (10 Hours)

Exergy: Concept of reversible work and Irreversibility, second law efficiency, Exergy change of a system: Closed and open systems, Exergy transfer by heat, work and mass, Irreversibility and GouyStodola theorem, Application of GouyStodola Theorem, Exergy destruction, Exergy balance in closed and open systems.

Module-IV (6)

Properties of gas mixtures: equation of state and properties of ideal gas mixtures, Change in entropy of mixing, Real gases, Generalized compressibility charts, General conditions for Thermodynamic equilibrium, Criterion for equilibrium under various conditions of isolation.

Module-V (10)

Chemical equilibrium: Concept of fugacity and activity, Thermodynamic of reactive systems, stoichiometry, Enthalpy of formation and Enthalpy of combustion, First and Second Law analysis of chemical reactions.

Text Books:

1. Fundamentals of Engineering Thermodynamics (7^{th} Edition) by Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner, Margaret B. Bailey, Wiley Publication.
2. Fundamentals of Thermodynamics (6^{th} Edition)by Richard E. Sonntag, Claus Borgnakke, Gordon J. Van Wylen, Wiley Publication

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Express the fundamental concepts relevant to thermodynamics and apply the laws of thermodynamics to analyze boilers, heat pumps, nozzles, compressors, heat engines and refrigerators.
CO2	Apply the entropy balance for both closed and open systems.
CO3	Evaluate Availability, Irreversibility and the second law efficiency.
CO4	Express the general conditions for thermodynamic equilibrium.
CO5	Apply first and second law to the analysis of chemical reactions.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	2	1
CO4	3	1	3	3	1	1
CO5	3	1	3	3	2	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	1	3	3	2	1

CONVECTIVE HEAT AND MASS TRANSFER

L-T-P:3-0-0 Credit-3

Course Contents:

MODULE 1: **(8 Hours)**

Mass conservation, Momentum Equations, Derivation of Energy equation, Rules of scale analysis, Heat lines for visualizing Convection. Laminar Boundary layer Flow: Velocity and thermal boundary layers, Integral solutions, similarity solutions for uniform wall temperature and uniform wall heat flux, effect of longitudinal pressure gradient, effect of blowing and suction, Entropy generation minimization in laminar boundary layer flow.

MODULE 2: **(5 Hours)**

Heat transfer to fully developed duct flow: Uniform wall heat flux and Uniform wall temperature,Heat transfer to developing flow: Scale analysis, thermally developed uniform (slug) flow, thermally developing Hagen-Poiseuilleflow,heat lines in fully developed duct flow.External natural convection: Laminar boundary layer equations, scale analysis: High and low-Pr fluids, Integral solutions: High and low-Prfluids, Similarity solution, Internal natural convection in a rectangular enclosure.

MODULE 3: **(8 Hours)**

Transition to turbulence: Empirical transition data, scaling laws of transition, buckling of inviscid streams, Instability of inviscid flow. Turbulent boundary layer flow: Large scale structure,boundary layer equations, mixing length model, heat transfer in boundary layer flow. Turbulent Duct flow: Heat transfer rate for isothermal wall and uniform wall heating.

MODULE 4: (5 Hours)

Convection with Phase Change:-Condensation:Laminar film on a vertical surface, Drop condensation; Boiling: Pool boiling Regimes, nucleate boiling and peak heat flux, film boiling and minimum heat flux, flow boiling; Contact melting and lubrication: plane surfaces with relative motion, melting by natural convection.

MODULE 5: (4 Hours)

Mass Transfer: Properties of mixtures, mass conservation, massdiffusivity, boundary conditions, Laminar forced convection, impermeable surface model, external and internal forced convection, Naturalconvection: mass transfer driven flow and heat transfer driven flow.

Text Book:

1. Convective heat transfer by A. Bejan (Willey)

Reference Books:

1. Convective heat transfer byS. Kakaç (CRC Press)
2. Convective heat transfer byLouis C. Burmeister

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Analyze details of energy equation and develop models for physical problems.
CO2	Analyze heat transfer for duct flow with different boundary conditions.

CO3	Implement various turbulence models for heat transfer problems.
CO4	Analyze problems involving convection with phase changes.
CO5	Analyzemass transfer during convection for different physical problems.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	1
CO2	3	1	3	3	1	1
CO3	3	1	3	3	1	1
CO4	3	1	3	3	1	1
CO5	3	1	3	3	1	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	1	3	3	1	1

CRYOGENIC TECHNOLOGY

L-T-P: 3-0-0 Credit 3

Course Contents:

Module-1(10 Hours)

Introduction; Low temperature properties, Mechanical, Thermal, Electrical and Magnetic Properties of Cryogenic fluids.

Module-2 (10 Hours)

Gas liquefaction systems; Simple Linde – Hampson system, Pre-cooled LindeHampson systems for Neon, Hydrogen and Helium; Collins liquefaction systems, Critical components of liquefaction systems, Components and its efficiencies on system performance.

Module-3 (10 Hours)

Gas separation and purification systems ; Properties of mixtures , Principle of gas separation i.e., Simple condensation and evaporation , Rectification, Air separation systems, Argon separation systems, Helium separation systems, Gas purification methods, Cryogenic refrigeration systems (Liquid and gas as refrigerant); Joule Thomson refrigeration systems, Cascade or pre-cooled Joule–Thomson refrigeration systems, Cold gas refrigeration system (solid as working media)

Module-4 (5 Hours)

Magnetic cooling, its thermodynamic aspects, Magnetic refrigeration system, thermal valves, nuclear demagnetization, Measurement system for low temperature;

Cryogenic fluid storage and transfer systems, Thermal insulations for cryogenic applications in the order of increasing performance.

Module-5 (5 Hours)

Low temperature properties of engineering materials, superconductivity and superconducting devices, Special phenomenon at very low temperatures, Applications: Super conducting bearings, motors, Cryotrons, Chemical rockets, Space Simulation, Nuclear rockets , Blood and tissue preservation.

Text Books:

1. Barron, R., Cryogenic Systems, SI version, Oxford university press, 1985
2. Scott, R. B., Cryogenic Engineering, D'Van- Nostrand, 1962.

Reference Books:

1. Timmerhaus, K. D. and Flynn, T. M., Cryogenic Process Engineering, Plenum Press, 1989.
2. Vance, R. W. and Duke, W. M., Applied Cryogenic Engineering, John Wiley, 1962.
3. Marshall Sittig, Cryogenics Research and Applications, D. Van Nostrand Company, 1963
4. B.A.Hands, Cryogenic engineering, Academic press, 1986 7.Thomas M. Flynn, Cryogenic Engineering, Marcel Dekker Inc., New York, 2005.

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Define low temperature properties of cryogenic fluids.
CO2	Analyzegas liquefaction system.
CO3	Analyzegas separation and purification system.
CO4	Demonstrate cascade refrigeration system.
CO5	Evaluate storage systems used in cryogenic applications.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	2	1
CO2	3	1	2	3	2	1
CO3	3	1	2	2	2	1
CO4	3	1	2	2	2	1
CO5	3	1	2	2	2	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	1	2	2	2	1

THERMAL SYSTEM SIMULATION AND DESIGN

L-T-P: 3-0-0 Credit 3

Course Contents:

MODULE 1: (8 Hours)

Formulation of the design problem: design variables, constraints and limitations,requirements and specifications; Conceptual design, Steps in the design process (examples from thermal systems), Material selection.

MODULE 2: (10 Hours)

Modeling of thermal systems: types of models, mathematical modeling, physical modeling and dimensional analysis, curve fitting. Acceptable design of a thermal system: initial design, design strategies, some application illustrations (cooling of electronic equipment, heat transfer equipment, fluid flow systems etc.).

MODULE 3: (8 Hours)

Problem formulation for optimization: optimization in design, final optimized design, objective function, constraints, operating conditions, types of thermal systems, practical aspects in optimal design (choice of variables for optimization, sensitivity analysis, dependence on objective function and change of concept or model), Knowledge-based design and additional considerations, professional ethics.

MODULE 4: (7 Hours)

Optimization of unconstrained problems, optimization of constrained problems, applicability to thermal systems, search methods (single variable problem, unconstrained search with multiple variables and multivariable constrained optimization).

MODULE 5: (7 Hours)

Integer programming - penalty function method.Use of artificial intelligence techniques (neural network, fuzzy logic and genetic algorithm) in thermal systems design and optimization (simple examples).

Text Books:

1. Y. Jaluria, Design and Optimization of Thermal Systems, CRC Press, 2007.
2. S. S. Rao, Optimization methods, PHI, 1998

Reference Books:

1. W.F. Stoecker, Design of Thermal Systems - McGraw-Hill, 1971.

2. Bejan, G. Tsatsaronis, M.J. Moran, Thermal Design and Optimization - Wiley, 1996.
3. R. F. Boehm, Developments in the Design of Thermal Systems - Cambridge University

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Analyze theoretical concepts related to thermal energy systems.
CO2	Simulate and model various thermal systems.
CO3	Implement various optimization methods for thermal system design.
CO4	Implement various Optimization technique for unconstrained problems.
CO5	Implement integer programming methods for thermal system.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	1
CO2	3	1	3	3	1	1
CO3	3	1	3	3	1	1
CO4	3	1	3	3	1	1
CO5	3	1	3	3	1	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	1	3	3	1	1

COMPUTATIONAL FLUID DYNAMICS

L-T-P: 3-0-0 Credit 3

Course Contents:

MODULE 1: (7 Hours)

Introduction: Partial Differential Equations, Mathematical Classification, Systems of Partial Differential Equations,

MODULE 2: (10 Hours)

Finite Difference Discretization Methods: Various aspect of Finite Difference Methods, Truncation Error, Round-Off and Discretization Errors, Consistency, Stability, Convergence for Marching Problems, Conservation Form and Conservative

Property, Methods for obtaining Finite Difference Equations, Use of Taylor Series, Integral Method

MODULE 3: (8 Hours)

Finite Volume Discretization Methods: Various aspect of Finite Volume Methods, Use of Irregular Meshes, Irregular Mesh due to Shape of a Boundary, Irregular Mesh Not Caused by Shape of a Boundary, Fourier or von Neumann Analysis, Stability Analysis for Systems of Equations. Solution of conduction and Convection-Diffusion Problems

MODULE 4: (8 Hours)

Numerical Methods for Model Equations: Wave Equation:Upstream (First-Order and Second Order Upwind or Windward) DifferencingMethod,LaxMethod,Lax–Wendroff Method, Mac Cormack Method, Runge–Kutta Methods, Heat Equation:Richardson's Method, Crank–Nicolson Method, Burgers' Equation (Inviscid and Viscous):Godunov Scheme, Roe Scheme, FTCS Method, Allen–Cheng Method

MODULE 5: (7 Hours)

Solution of Simultaneous Equations: Direct Methods:Cramer'sRule,GaussianElimination,Thomas Algorithm, Advanced Direct Methods, Iterative Methods:Gauss–Seidel Iteration, Successive Overrelaxation, SOR by Lines, ADI Methods, Krylov Subspace Methods

Text Books:

1. Tannehill, J.C., Anderson, D.A., and Pletcher, R.H., Computational Fluid Mechanics and HeatTransfer, 3rded., Taylor & Francis, 2013.

Reference Books:

1. Hoffmann, K.A. and Chiang, S.T., Computational Fluid Dynamics for Engineers, Engineering Education Systems, 2000
2. Peyret, R. and Taylor, T. D., Computational Methods for Fluid Flow, Springer-Verlag, 1983.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Understand and be able to classify the governing equations for fluid flow
CO2	Understand and apply finite difference and finite volume methods to fluid flow problems
CO3	Solve Model Equations of Fluid Flow and Heat Transfer using various numerical schemes
CO4	Assess stability criteria and conduct a grid-convergence test

CO5	Able to numerical solve and implement code for Simultaneous Equations

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	1	2	2
CO2	3	3	3	1	2	2
CO3	3	3	2	3	3	3
CO4	3	3	2	3	2	2
CO5	3	3	2	3	3	3

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	3	2	2	2	2

INTRODUCTION TO TWO PHASE FLOW

L-T-P: 3-0-0 Credit 3

Course Contents:

Module – I (8 Hours)

Introduction to two phase flow, applications, methods of analysis, different terminologies, flow regimes in vertical and horizontal flow, flow regime mappings.

Module– II (10 Hours)

Homogenous flow: One-dimensional steady homogenous equilibrium flow, conservative equations, pressure drop, homogenous friction factor for laminar and turbulent flow , pressure drop in bends, tees, orifices and valves. Homogenous theory extended to unsteady flow

Module– III (10 Hours)

Separated flow: Introduction, steady homogenous flow with different velocities, condition for choking, evaluation of wall shear stress and void fraction, empirical correlations, Governing equations for separated flow, Comparison with homogenous model

Module– IV (6 Hours)

Measurement techniques for two phase flow: Flow regime identification, pressure drop, void fraction and flow rate measurement.

Module– V (6 Hours)

Hydrodynamics of gas-solid flows, suspension of particles in fluids, particulate fluidization, fluidized bed

Text Book:

1. One dimensional two phase flows by Graham B Wallis, McGraw Hill, 1969.

2. Two-Phase Flow: Theory and Applications by ClKleinstreuer, CRC Press.

3. Two-phase flow and heat transfer by P. B. Whalley, Oxford University Press, USA.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Understand flow patterns and flow mapping.
CO2	Perform mathematical modelling for two phase flows
CO3	Predict pressure drop for a homogenous flow
CO4	Predict void fraction and pressure drop in two phase flow experiments
CO5	Understand the hydrodynamics of particulate flow in fluids

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	3	2	3
CO2	3	3	3	3	2	3
CO3	3	3	2	3	2	3
CO4	3	3	2	3	2	3
CO5	3	3	2	3	2	3

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	3	2	3	2	3

AIR-CONDITIONING ENGINEERING

L-T-P: 3-0-0 Credit 3

Course Contents:

Module-I (10 Hours)

Psychometry: Definition, Psychometric terms, Degree of saturation, Humidity, Absolute Humidity, Relative humidity, dry bulb temperature, wet bulb temperature, wet bulb depression, Dew point temperature, Dew point depression, Dalton's law of Partial pressure, Psychometric Relations, Humidity ratio, Psychometer, Psychometric chart, Psychometric Processes, Sensible heating, Sensible cooling, By-pass factor of heating and cooling coils, Dehumidification and humidification , Methods of humidification and dehumidification.

Module-II (08 Hours)

Air-conditioning systems: Introduction, Air conditioning system and equipments used in air-conditioning system, Various types of air-conditioning systems, Comfort Air-conditioning, Factors affecting effective optimum temperature, Factors affecting comfort air-conditioning, Room Sensible heat factor and Grand sensible heat factor.

Module-III (08 Hours)

Cooling Load estimation: Air-conditioning calculations, Comfort scales and measures concepts of effective temperatures, Solar heat gains through gains through glass, buildings, heat storage, diversity and stratification, Internal heat gains: Sensible heat, Latent heat.

Module- IV (07 Hours)

Cooling towers, spray chambers, Cooling and humidifying coils, Design of air-duct system, Room air distribution principles, Temperature, pressure and humidity controls, Various types of system controls, Building automation systems.

Module-V(07 Hours)

Ducts: Introduction, Classification, Material of duct, construction, shape, pressure in ducts, Continuity equation and Bernoulli's equation for ducts, Pressure losses inducts: Frictional losses & Dynamic losses, Duct design, pressure loss due to enlargement in area and static regain

Textbooks:

1. C. P. Arora, Ref & Air Conditioning (TMH Publication)

2. A text book of Refrigeration and Air-conditioning by R.S. Khurmi and J.K. Jai, S.Chand& Co.

Reference Books:

3. Stoecker and Zones: Refrigeration and Air Conditioning (McGraw Hill)
4. Manohar Prasad: Refrigeration and Air Conditioning (EWP)
5. W.P. Zones: Air Conditioning Engg. (Edward Arnold Press)

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Apprehend principles of Psychometry and Air-conditioning.
CO2	Showcasean understanding of the principles and practice of thermal comfort by Cooling load estimation for air conditioning systems.
CO3	Demonstrate and develop techniques for building envelope loads.
CO4	Apply the HVAC theory to design a HVAC system.
CO5	Analyze and design fan and duct systems.

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	1	-
CO2	3	1	3	3	1	-
CO3	3	1	3	3	1	1
CO4	3	3	3	3	2	2
CO5	3	3	3	3	2	2

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	1	3	3	1	2

MICROFLUIDICS

L-T-P: 3-0-0 Credit 3

MODULE 1: (5 Hours)

Introduction: Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws.

MODULE 2: (15 Hours)

Micro-scale fluid mechanics: Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere,

MODULE 3: (07 Hours)

Capillary flows: Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect.

MODULE 4: (10 Hours)

Electrokinetics:Electrohydrodynamics fundamentals. Electro-osmosis, Debye layer, Thin EDL limit, Ideal electroosmotic flow, Ideal EOF with back pressure, Cascade electroosmoticmicropump, EOF of power-law fluids. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size.Dielectrophoresis,

MODULE 5: (03 Hours)

Few applications of microfluidics: Drug delivery, Diagnostics, Bio-sensing.

Text Books:

- Fundamentals and applications of Microfluidics, by Nguyen and Werely, Artech house Inc., 2002.
- Introduction to microfluidics by Tabeling, Oxford University Press Inc., 2005.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Understand the physics of fluid flow in microchannels
CO2	Understand the surface force dominating in the microscale
CO3	Solve simple problems of gas and liquid flows in microchannels
CO4	Perform electrokinetic analysis of microchannel flows
CO5	Understand the drug delivery system and bio-sensing

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	3	3	2

CO2	3	3	3	3	3	3
CO3	3	3	2	3	3	2
CO4	3	3	2	3	2	2
CO5	3	3	2	3	2	2

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	3	2	3	3	2

<u>SESSIONALS</u>

Minor project & Seminar

Thermo-fluids Lab-II

8. Determination the sensitivity of multi tube inclined tube manometer.
9. Determination of the total and static pressure using Pitot static tube.
10. Demonstration of application of Bernoulli's theorem to flow along a convergent-divergent passage.
11. Determination of drag on cylindrical bodies.
12. Determination of the boundary layer thickness for flow over a flat plate.
13. Determination of the pressure coefficient for flow around a bend apparatus.
14. Demonstration of Jet attachment to a wall.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Demonstrate the sensitivity of multi tube inclined tube manometer.
CO2	Demonstrate the use of Pitot static tube.
CO3	Demonstrate the application of Bernoulli's theorem.
CO4	Evaluate drag on cylindrical bodies.
CO5	Evaluate boundary layer thickness for flow over a flat plate.

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	2	1	1	2	1	-	-	-	-	1

CO2	3	3	2	1	1	2	1	-	-	-	-	1
CO3	3	3	2	1	1	2	1	-	-	-	-	1
CO4	3	3	2	1	1	2	1	-	-	-	-	1
CO5	3	3	2	1	1	2	1	-	-	-	-	1

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
	3	3	2	1	1	2	1	-	-	-	-	1

Research Seminar

3rd Semester

EXPERIMENTAL TECHNIQUES FOR THERMAL ENGINEERING

L-T-P: 3-0-0 CREDIT: 3

Course Contents:

Module-I (10 Hours)

Measurement: Introduction, Basic concepts of measurement methods, single and multi-point measurement in space and time, Processing of experimental data, Process of Measurement, Methods of measurement, Primary, Secondary & Tertiary Measurement, Types of measuring instruments, Scale Range & Scale span, Static Calibration, Error Calibration Curve, Static & Dynamic characteristics of measurement, Accuracy, Sensitivity, Reproducibility, Repeatability, Drift, Static error, Dead zone, Error analysis and estimation, Types of errors, Random error, Systematic error, True value, Absolute error, Relative static error, Error analysis and numerical.

Module-II (10 Hours)

Statistical error analysis: Curve fitting, Regression analysis, Analog and Digital instruments, Noise, Signal to Noise ratio, various sources of Noise, Numericals related to errors and noise

Measurement of temperature: Thermocouple, analysis of effect of bead size and shielding on time constant and frequency response characteristics of thermocouples, Errors due to conduction and radiation in well type thermocouple, thermocouple installations, resistance and resonant quartz thermometer, Pyrometry, Low temperature measurement, Measurement of heat flux and thermal conductivity.

Module-III (8 Hours)

Measurement of pressure: Measurement of pressure, Very low pressure measurement, Pirani gauge, McLeod Gauge, and other gauges

Measurement of flow rate and velocity: Measurement of Incompressible flow: Venturi-meter, Nozzle, Orifice-meter, Measurement of Compressible flow: Principle and theory of Pitot tube, Rotameter

Module-IV (4 Hours)

Principle and theory of measurement of concentration & humidity: Hygrometers, Chromatography, Calorimetry

Module-V (8 Hours)

Advanced Measurement techniques and analysis Non-intrustive measurement, Hot-wire anemometer,gas chromatography, Shadograph, Schliren Technique, Interferometer, Spectrometry

Textbooks:

1. J.P.Holman, Mechanical Measurements (McGraw Hill – 1989)
2. Mechanical Measurement by R.S. Sirohi, S.C. Radhakrishna (Wiley,1993)
3. Mechanical Measurements and Instrumentation by R.K.Rajput (S.K.Kataria& Sons, 2009)

Reference Books:

1. E.O. Doeblin, Mechanical Measurements (Int. Edition, 1983)
2. Doeblin, Measurement System Application and Design, McGraw-Hill, 1978
3. Prebrashensky. V., Measurement and Instrumentation in Heat Engineering, Vol.1 and 2 MIR Publishers, 1980
4. Morris, A. S, Principles of Measurements and Instrumentation Prentice Hall of India, 1998.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Define general concepts and terminology of measurement systems in engineering.
CO2	Perform Error analysis, calibration of measuring instruments and measurement of temperature.
CO3	Explain the importance ofexperimental techniques of measurement of pressure, velocity and flow rate.
CO4	Elaborate on concentration & humidity in thermal systemsand carry out uncertainty analysis while designing various thermal systems.
CO5	Apply advanced Measurement techniques for selection and design of measuring instruments.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	2	1	1	-
CO2	3	1	3	3	2	-
CO3	3	1	3	3	2	-
CO4	3	2	3	3	2	1
CO5	3	3	3	3	3	1

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	1	3	3	2	1

COMPUTATIONAL GAS DYNAMICS

L-T-P: 3-0-0   Credit 3

Cours Outcomes:

Module – I (8 Hours)

Governing Equation of Gas Dynamics: Integral form of Euler equations, The Conservation form of Euler equations, Primitive variable form of Euler equations, Other form of Euler equations.

Module– II (8 Hours)

Scalar Conservation Laws: Integral Form, Conservation Form, Characteristic Form, Expansion Waves, Compression Waves and Shock Waves, Contact Discontinuity, Linear Advection Equation, Burgers' Equation, Non-Convex Scalar Conservation Laws, Entropy Condition, Waveform Preservation, Destruction and Creation

Module– III (8 Hours)

The Riemann Problem: Riemann problems for Euler equations and Linear systems of equations, Roe's Approximate Riemann solver for Euler equations. One wave Linear Approximation, Other Approximate Riemann solvers, Riemann problems for Scalar Conservation Law.

Module– IV (10 Hours)

Computational Gas Dynamics: Conservative finite volume methods, Conservative finite difference methods, Transformation to conservation form, The CFL Condition, Upwind and Adaptive Stencils, Introduction to Flux Averaging, Introduction to Flux Splitting, Flux Split Form, Introduction Flux reconstructions. Artificial Viscosity, Total Variation Diminishing(TVD), Essentially Nonoscillatory (ENO).

Module– V (6 Hours)

Basic Numerical Methods for Scalar Conservation Laws: Lax-Friedrichs Methods, Lax-Wendroff Methods, First-Order Upwind Method, Beam-Warming Second-Order Upwind Methods, Boundary Treatments, Solid Boundaries and Far-Field Boundaries.

Text Book:

1. Culbert B. Laney. Computational Gasdynamics (2007). Cambridge University Press.
2. Anderson, D.A., Tannehill, J.C. and Pletcher, R.H. (1997). Computational Fluid Mechanics and Heat Transfer. Taylor & Francis.

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Ability to understand conservation form of Euler equations of gas dynamics.
CO2	Understand scalar conservation laws
CO3	Solve Riemann Problem using various scheme
CO4	Understand and implement conservative finite volume methods for solving Euler equations
CO5	Implement various numerical methods for conservation laws

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	1	2	2
CO2	3	3	2	1	2	2

CO3	3	3	2	1	3	3
CO4	3	3	2	2	3	3
CO5	3	3	2	1	2	2

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	3	2	1	2	2

GAS TURBINE AND JET PROPULSION

L-T-P:3-0-0 Credit-3

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Course Contents:

Module-I (7 Hours)

Gas Dynamics Of Passive Components Of Turbo-engine fundamentals Of Gas Dynamics: Energy equation for a non-flow process, Energy equation for a flow process, The adiabatic energy equation, Momentum Equation, Moment of Momentum equation, Stagnation Velocity of Sound, Stagnation Pressure, Stagnation Density, Stagnation State, Velocity of sound - Critical states – Mach number - Critical Mach number - Various regions of flow.

Module-II (8 Hours)

Analysis Of Diffusers And Nozzles: Introduction -study of intakes for subsonic and supersonic engines, Comparison of isentropic and adiabatic processes, Mach number variation, Area ratio as function of Mach numbers, Mass flow rates, Flow through nozzles, Flow through diffusers, Effect of friction, Analysis of intakes for supersonic engines, Intakes with normal shock, Oblique shocks.

Module-III (7 Hours)

Study Of Compressors: Design and Analysis of compressors - Classification - analysis of centrifugal compressors - velocity triangles. Analysis of axial flow compressor, analysis of stage, characterization of stage.Design of multistage axial flow compressor.

Module-IV (6 Hours)

Study Of Turbines: Concept of gas turbine - analysis of turbine stage – velocity triangles and characterization of blades and stages.

Module-V (12 Hours)

Propulsion: Aircraft Propulsion - introduction - Early aircraft engines -Types of aircraft engines - Reciprocating internal combustion engines - Gas turbine engines - Turbo jet engine - Turbo fan engine - Turbo-prop engine. Aircraft propulsion theory: thrust, thrust power, propulsive and overall efficiencies.

Thermodynamic Analysis Of Ideal Propulsion cycles: Thermodynamic analysis of turbojet engine - Study of subsonic and supersonic engine models - Identification and Selection of optimal operational parameters. Need for further development - Analysis of Turbojet with after burner. Thermodynamic analysis of turbofan engine - Study of subsonic and supersonic systems - Identification and selection of optimal operational parameters.Design of fuel efficient engines - Mixed flow turbo fan engine - Analysis of Turbofan with after burner.

Text Books:

1. Gas turbine theory by V VGanesan
2. Gas turbines and propulsive systems by P.R.Khajuria and S.P.Dubey
3. Fundamentals of compressible fluid flow by S.M.Yahya

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Express the momentum and energy equation and classify the various regions of flow using Mach number.
CO2	Analyze the flow through nozzles and diffusers.
CO3	Construct velocity triangles of compressors.
CO4	Analyze the velocity triangles of turbine
CO5	Express thermodynamic analysis of propulsion cycles.

Course Articulation Matrix

Course Outcomes	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**2**	**2**	**2**	**1**
CO2	**3**	**1**	**2**	**2**	**2**	**1**
CO3	**3**	**1**	**2**	**2**	**2**	**1**
CO4	**3**	**1**	**2**	**2**	**2**	**1**
CO5	**3**	**1**	**2**	**2**	**2**	**1**

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	**3**	**1**	**2**	**2**	**2**	**1**

NON-CONVENTIONAL ENERGY

L-T-P: 3-0-0   Credit-3

Course Contents:

Module-I (8 Hours)

Introduction to energy sources: Renewable and non-renewable energy sources, energy consumption as a measure of Nation's development; strategy for meeting the future energy requirements, Global and National scenarios, Prospects of renewable energy sources.

Solar Energy: Solar radiation- beam and diffuse radiation, solar constant, earth sun angles, attenuation and measurement of solar radiation, local solar times, derived solar angles, sunrise, sunset and day length. Flat plate collectors, concentrating collectors, solar air heater-types, solar driers, storage solar energy-thermal storage, solar pond, solar water heaters, solar distillation, solar still, solar cooker, solar heating and cooling of buildings, photovoltaic-solar cells and its applications.

Module-II (8 Hours)

Wind Energy: Principle of wind energy conversion; Basic components of wind energy conversion systems; wind mill components; various types and their constructional features; design considerations of horizontal and vertical axis wind machines; analysis of aerodynamic forces acting on wind mill blades and estimation of power output; wind data and site selection considerations.

Energy from Biomass: Biomass conversion technologies; Biogas generation plants: Classification, advantages and disadvantages, constructional details site selection, digester design consideration, filling a digester for starting, maintaining biogas production, fuel properties of biogas, utilization of biogas.

Module-III (8 Hours)

Geothermal Energy: Estimation and nature of geothermal energy, geothermal sources and resources like hydrothermal, geo-pressured hot dry rock, magma. Advantages, disadvantages and application of geothermal energy, prospects of geothermal energy in India.

Energy from the Ocean: Ocean Thermal Electric Conversion (OTEC) systems like open cycle, closed cycle, Hybrid cycle, prospects of OTEC in India, Energy from tides, basic principle of tidal power, single basin and double basin tidal power plants, advantages, limitations and scope of tidal energy. Wave energy and power from wave, wave energy conversion devices, advantages and disadvantages of wave energy.

Module-IV (8 Hours)

Magneto Hydro Dynamic (MHD) Power generation: Principle of MHD power generation, MHD system, Design problems and developments, gas conductivity, materials for MHD generators and future prospects.

Fuel Cells: Introduction, Design principle and operation of fuel cell, Types of fuel cells, conversion efficiency of fuel cell, application of fuel cells.

Module-V (8 Hours)

Hydrogen Energy: Introduction, Hydrogen production methods, hydrogen storage, hydrogen transportation, utilization of hydrogen gas, hydrogen as alternative fuel for vehicles.

Energy management: Energy economics, energy conservation, energy audit, general concept of total energy system, scope of alternative energy system in India.

Text books:

1. Non-Conventional Energy Sources ,G.D. Rai
2. Non-Conventional Energy, Ashok V Desai,Wiley Eastern.

Reference books:

2. K M, Non-Conventional Energy Systems, Wheeler Publishing Co. Ltd, New Delhi, 2003.
3. Ramesh R & Kumar K U, Renewable Energy Technologies, Narosa Publishing House, New Delhi, 2004
4. Wakil MM, Power Plant Technology, McGraw Hill Book Co, New Delhi, 2004.

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1	Understand the environmental aspects of non-conventional energy resources in Comparison with various conventional energy systems, their prospects and limitations.
CO2	Identify the need of renewable energy resources, historical and latest developments.
CO3	Understand the use of solar energy and the various components used in the energyproduction with respect to applications like - heating, cooling, desalination,

	power generation, drying, cooking etc.
CO4	Appreciate the need of Wind Energy and the various components used in energy generation and know the classifications.
CO5	Understand the concept of Biomass energy resources and their classification, types of biogas Plants- applications

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	1	-	-	-
CO2	3	3	2	-	-	-
CO3	3	2	3	1	-	1
CO4	2	2	2	-	-	1
CO5	2	3	1	-	-	1

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	2	2	1	-	1

MATRIX COMPUTATIONS

L-T-P: 3-0-0   Credit-3

Course contents:

Module - I: Gaussian Elimination and Its Variants (10Hours)

Overview of matrix computations, Matrix Multiplication, Systems of Linear Equations, Triangular Systems, Positive Definite Systems; Cholesky Decomposition, Banded Positive Definite Systems, Sparse Positive Definite Systems, Gaussian Elimination and the LU Decomposition

Module - II: Solution of Linear Systems (8Hours)

Vector and Matrix Norms, Condition Numbers, Perturbing the Coefficient Matrix, A Posterior Error Analysis Using the Residual, Round off Errors; Backward Stability, Component wise Sensitivity Analysis

Module - III: Solution of Least Squares of Problem (7Hours)

The Discrete Least Squares Problem, Orthogonal Matrices, Rotators, and Reflectors, Solution of the Least Squares Problem

Module - Iv: The Singular Value Decomposition (7Hours)

Some Basic Applications of Singular Values, The SVD and the Least Squares Problem

Module - IV: Solution of Eigen-value Problem (4Hours)

Systems of Differential Equations, Basic Facts, The Power Method and Some Simple Extensions, The QR Algorithm, Implementation of the QR algorithm, Use of the QR Algorithm to Calculate Eigenvectors

Module - V: Iterative Methods for Solution of Linear Systems (4Hours)

Overview of iterative methods, Jacobi, Gauss-Seidel and successive over relaxation methods, Pre-conditioners, The Conjugate-Gradient Method

Text Books:

1. D. S. Watkins, Fundamentals of Matrix Computations, 2nd. ed., Wiley Interscience, 2002.

Reference Books:

1. J. W. Demmel, Applied Numerical Linear Algebra, SIAM, 1997
2. G. H. Golub and C. F. Van Loan, Matrix Computations, 3rd Edition, John Hopkins University Press, 1996
3. L. N. Trefethen and D. Bau III, Numerical Linear Algebra, SIAM, 1997

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Understand the algorithms underlying matrix computations
CO2	Solve solution of linear systems
CO3	Solve least squares problem and singular value decomposition
CO4	Implement QR algorithms
CO5	Understand the difference between iterative methods for linear systems and direct methods

Course Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	3	2
CO2	3	3	2	2	2	2
CO3	3	3	2	2	3	2
CO4	3	3	2	2	3	3
CO5	3	3	2	2	3	3

Program Articulation Matrix row for this course

	PO1	PO2	PO3	PO4	PO5	PO6
CO	3	3	2	2	3	2

SMART MATERIALS

L-T-P: 3-0-0   Credit 3

Course Outcomes:

Module-I (10 Hours)

Introduction: Types of materials, Composites: Introduction to composites and their classification, Types of fibers, Particulate composites, Hybrid composites, Long aligned fiber composites, properties, application and morphology of fibre reinforced composites, metal matrix composites and ceramic composites.

Reinforcements: Glass fibers, Boron fibers, Carbon fibers, Organic fibers, Ceramic fibers, Non-oxide fibers, Comparison of different types of fibers.

Matrix Materials: Polymers, metals, Ceramic matrix materials and their properties

Module -II (8 Hours)

Processing of Composites: Hand lay-up, Pre-peg processing, Press-molding, Vacuum molding, Filament winding, extrusion, Pultrusion, liquid metal infiltration process, Diffusion bonding and powder metallurgy methods, joining of composites, Basic properties of GRP, CFRP, Al-B, Casting and Particulate composites.

Interfaces: Wettability, Crystallographic nature of interface, Interactions at the interface, Types of bonding at the interface, Test for measuring interfacial strength.

Module-III (8 Hours)

Properties and Applications: Modulus, Strength, Thermal characteristics, Aging, Fatigue, Creep, Transport properties, Matrix connectivity, Aerospace application, Structural, Defense biomedical application, Machine tools, Automobiles applications, finite element method for simulation and optimization.

Failure/ Fracture of Composites: Tensile strength, Compressive strength, Fractures modes in composites.

Module-IV (7 Hours)

Smart materials: Introduction to smart materials, Structure, characteristics and application of polymers, Structure, properties and applications of thermosetting (epoxy resin and akelite) and thermoplastics (polyvinyl chloride and polytetrafluoroethylene), Compounding of plastics injection and extrusion moulding. sensor applications based on required properties optical fibers, actuators, and methods of analyses employed in smart materials.

Module-V (7 Hours)

Need of materials characterization and available techniques:

Optical Microscopy: Optical microscope - Basic principles & components, Different examination modes (Bright field illumination, Oblique illumination, Dark field illumination, Phase contrast, Polarised light, Hot stage, Interference techniques), Specimen preparation, Applications.

Electron Microscopy: Interaction of electrons with solids, scanning electron microscopy Transmission electron microscopy and specimen preparation techniques, Scanning transmission electron microscopy, Energy dispersive spectroscopy, Wavelength dispersive spectroscopy.

Diffraction Methods: Fundamentals of crystallography, X-ray diffraction techniques, Electron diffraction, Neutron diffraction. Surface Analysis: Atomic force microscopy, scanning tunneling microscopy, X-ray photoelectron spectroscopy. Spectroscopy: Atomic absorption spectroscopies, UV/Visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy.

Thermal Analysis: Thermogravimetric analysis, Differential thermal analysis, Differential Scanning calorimetry, Experimental methods for characterization of composite materials

Text Books:

1. Gandhi M V and Thompson B S, Smart Materials and Structures, Chapman & Hall, Madras, 1992. 2. Meirovitch L., Dynamics and Control of Structures, John Wiley, 1992.
2. Smallman, R.E., and Bishop, R.J., Metals and Materials – Science, Processes, Applications, Butterworth-Heinemann (1995).
3. Sibilia J.P., A Guide to Materials Characterisation and Chemical Analysis, VCH (1988).

Reference Books:

1. Gabriel, B. SEM- A Users's Manual, Plenum Press (1985).
2. Cullity, B.D. Elements of X-Ray Diffraction, Addison Wesley (1967).

Course Outcomes:

Upon completion of the subject the students will be able to:

CO1	Identify and describe the properties of fibre reinforcements, matrix materials and composites.
CO2	Asses the applicability of a composite material and developing practical skills for selection of appropriate processing technique for manufacture of composite materials.
CO3	Analyse elastic properties and mechanical performance for prediction of failure behaviour in fibre-reinforced composites.
CO4	Comprehend the principles of operation of optical fibers, actuators, sensors and methods of analyses for application in Smart materials.
CO5	Examine and interpret mechanical and thermal characteristics of Smart materials for different applications.

Course Articulation Matrix

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	1	1	1	1	1
CO2	3	3	3	2	2	1
CO3	3	3	3	3	3	1
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2

Program Articulation Matrix row for this course

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	3	3	3	3	1

SESSIONALS

Dissertation (Phase-I)

4th Semester:

SESSIONALS

Dissertation (Phase-II)