



DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY COLLEGE OF ENGINEERING KAKINADA
JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
R23 COURSE STRUCTURE & SYLLABUS
M.TECH (THERMAL ENGINEERING)

VISION OF THE DEPARTMENT

To nurture the excellence in modeling and designing of modern mechanical engineering systems by imparting timeless core values to the learners and to mould the Department into a centre of academic excellence catering to the industrial needs through advanced research.

MISSION OF THE DEPARTMENT

1. To offer high quality graduate and post graduate programs in Mechanical Engineering in order to make the learners globally competitive technologists who are professionally capable and socially responsible.
2. The department enables the learners inculcate and imbibe theoretical and practical knowledge for exploration and deep insight for advanced technological innovations and inventions.

PROGRAM EDUCATIONAL OBJECTIVES

PEO1	To Prepare students with High Level of Technical Competency combined with Research and Complex Problem-Solving Ability to be globally competitive in the domains of Thermal Engineering.
PEO2	To Prepare students with good Experimental and Computational skills to develop energy efficient and eco-friendly systems for Sustainable Development.
PEO3	.To Exhibit Professionalism, communication skills, ethical attitude, social responsibility, teamwork in their profession and adapt to latest technologies by engaging in lifelong learning.

Dr N. Mohan Rao

Dr. B. Balakrishna

Dr. A. Swarna Kumari

Dr. E. Anil Kumar

Dr. S. Srinivasa Rao

Dr. P. Brahamara

Dr. B. Suresh

Dr. N. Jalaiah



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Mapping of PEOs with Mission statements:

	PEO1	PEO2	PEO3	PEO4
M1				
M2				
M3				
M4				

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PROGRAM OUTCOMES

PO1	An ability to independently carryout research/ investigation and development work to solve practical problem
PO2	An ability to write and present a substantial technical report / document
PO3	An Ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in appropriate bachelor program
PO4	Ability to develop proficiency in thermal engineering involving the problems of Heat Transfer, Fluid Dynamics, Renewable Energy Systems.
PO5	Ability to demonstrate the skills to use modern software tools and equipment of thermal engineering to analyse and solve complex engineering and inter disciplinary problems.
PO6	Students should be able to develop effective interpersonal communication skills and attitude of lifelong learning, to engage as leader in nurturing teams, with commitment to their ethical and social responsibilities.

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I-SEMESTER

S.No	Course Code	Courses	Category	L	T	P	C
1	MT-XXX-1101	Program Core-1 Advanced Heat Transfer (Advanced Heat Transfer Lab)	PC	3	0	3	4.5
2	MT-XXX-1102	Program Core-2 Advanced Fluid Mechanics	PC	3	0	0	3
3	MT-XXX-1103	Program Elective-1 Advanced Thermodynamics & Combustion Cryogenic Engineering Turbo Machines Mathematical Methods for Thermal Systems	PE	3	0	0	3
4	MT-XXX-1104	Program Elective-2 Renewable Sources of Energy Fuel Cells and Hydrogen Technologies Analysis of IC Engines	PE	3	0	0	3
5	MT-XXX-1105	Research Methodology and IPR	CC	2	0	0	2
6	MT-XXX-1107	Laboratory-2 Computational Laboratory	LB	0	0	3	1.5
7	MT-XXX-1108	Audit Course-1: English for Research Paper Writing	AC	2	0	0	0
Total Credits							17

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II-SEMESTER

S.No	Course Code	Courses	Category	L	T	P	C
1	MT-XXX-1201	Program Core-3 Computational Fluid Dynamics (Computational Fluid Dynamics Lab)	PC	3	0	3	4.5
2	MT-XXX-1202	Program Core-4 Experimental Analysis and Instrumentation	PC	3	0	0	3
3	MT-XXX-1203	Program Elective-3 HVAC Systems Fundamentals of Microfluidics Industrial Hydraulics and Pneumatics	PE	3	0	0	3
4	MT-XXX-1204	Program Elective-4 Thermal Management in EV Battery and Fuel Cell System Micro and Nano Scale Heat Transfer Design of Heat Transfer Equipment	PE	3	0	0	3
5	MT-XXX-1206	Laboratory-4 Thermal Simulation Lab	LB	0	0	3	1.5
6	MT-XXX-1207	Mini Project with Seminar	MP	2	0	0	2
7	MT-XXX-1208	Audit Course-2 Value Education	AC	2	0	0	0
Total Credits							17

Two months Mandatory Industrial Training/Internship during summer / semester break

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III-SEMESTER

S.No	Course Code	Courses	Category	L	T	P	C
1	MT-XXX-2101	Program Elective-5 1. MOOCs (NPTEL) - 12 Week Course recommended by the department 2. Energy Conservation, Management and Audit 3. Non-Newtonian Fluid Dynamics 4. Optimization Techniques	PE	3	0	0	3
2	MT-XXX-2102	Open Elective 1. MOOCs (NPTEL/SWAYAM)-Any 12 Week Course on Engineering/ Management/ Mathematics offered by other than parent department Courses offered by other departments in the college 2. Electronic Cooling Technologies 3. Renewable sources of Energy 4. Optimization Techniques	OE	3	0	0	3
3	MT-XXX-2104	Internship (Performed during summer / I year break)		-	-	-	2
4	MT-XXX-2103	Dissertation-Part I/ Industrial Project partI#	PJ	0	0	20	10
Total Credits							18

#Students going for Industrial Project/Thesis will complete these courses through MOOCs

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IV SEMESTER

S.No	CourseCode	Courses	Category	L	T	P	C
1	MT-XXX-2201	Dissertation-Part II/ Industrial Project part II	PJ	0	0	32	16
Total Credits							16

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ADVANCED HEAT TRANSFER

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

CO1	Develop the capacity to transform the physics of any heat conduction/thermal radiation problem into its equivalent mathematical model.
CO2	Demonstrate the ability to solve external forced and natural convection problems using analytical methods.
CO3	Develop the ability to analyze internal forced convection problems using analytical methods.
CO4	Apply the concepts of LMTD and NTU to solve Heat Exchanger Problems.
CO5	Evaluate radiant energy exchange in the presence of a participating medium.

UNIT-I:

INTRODUCTION: Review of basic concepts of conduction. Method of formulation: lumped, differential and integral formulations. Initial and boundary conditions

TRANSIENT HEAT CONDUCTION:

Differential formulation of transient heat conduction problems with time independent boundary conditions in different geometries and their analytical solutions: method of separation of variables, method of Laplace transforms. Differential formulation of steady two-dimensional heat conduction problems in different geometries and their analytical solutions: method of separation of variables, method of superposition.

UNIT II:

CONVECTION: Review of basics concepts and different non-dimensional numbers; Three-dimensional differential energy equation in Cartesian and Cylindrical coordinates.

FORCED CONVECTION: External flow:

External laminar forced convection for flow over a semi-infinite flat plate; Integral and similarity solutions for different thermal boundary conditions; Viscous dissipation effects in laminar boundary layer flow over a semi-infinite flat plate.

UNIT III:

FORCED CONVECTION: Internal flow:

Internal laminar forced convection: exact solutions to solution for rectilinear flows, axisymmetric rectilinear flows, and axisymmetric torsional flows; Solution for fully developed flow through a pipe with different thermal boundary conditions, Flow in the

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thermal entrance region of a circular duct: Graetz solution for uniform velocity, Graetz solution for parabolic velocity profile.

UNIT IV:

FREE CONVECTION:

External laminar free convection: integral and similarity solutions for semi-infinite vertical plate with different thermal boundary conditions

HEAT EXCHANGERS: Classification, LMTD and NTU methods

UNIT V:

RADIATION:

Basic definitions, Radiant energy exchange between two differential area elements. Radiation shape factor: properties and algebra. Radiant energy exchange between two surfaces. Reradiating surfaces. Radiation Shield.

Radiant energy exchange in enclosures: enclosures composed of black and diffuse-grey surfaces. Electrical network analogy. Radiation in participating media: Radiative heat transfer equation, Radiant energy exchange in presence of absorbing and transmitting media, radiant energy exchange in presence of transmitting, reflecting, and absorbing media.

TEXT BOOKS:

1. Myers, G.E., 1971, Analytical methods in conduction heat transfer, McGraw Hill, New York.
2. Kays, W. M. and Crawford, M. E., 2005, Convective Heat and Mass Transfer, 3rd ed., McGraw Hill.
3. Howell, J.R., Mengüç, M.P., Daun, K., and Siegel, R., 2020, Thermal radiation heat transfer, CRC press, New York.

REFERENCES:

1. Arpaci, V.S., 1966, Conduction heat transfer, Addison-Wesley, Reading, Massachusetts.
2. Janna, W.S., 2018, Engineering heat transfer, CRC press, Boca Raton.
3. Fundamentals of Heat and Mass Transfer, 5th Ed. / Frank P. Incropera/John Wiley
4. Sparrow, E.M., 2018, Radiation heat transfer, Routledge, New York.
5. Modest, M.F., and Mazumder, S., 2021, Radiative heat transfer, Academic press, New York.
6. Introduction to Heat Transfer/SK Som/PHI
7. Oosthuizen, P. H. and Naylor, D., 1999, Introduction to Convective Heat Transfer Analysis, International ed., McGraw Hill.
8. Kakac, S. Yener, Y., and Pramuanjaroenkij. A., 2014, Convective Heat Transfer, 3rd ed., CRC Press

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ADVANCED FLUID MECHANICS

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

CO1	Understand the principles of Inviscid flow of incompressible fluid flow
CO2	Develop the capability to transform the physics of viscous fluid flow problems into its equivalent mathematical model.
CO3	Attain the ability to solve laminar boundary layer problems for the flow over a flat plate.
CO4	Develop an ability to solve fundamental problems of turbulent flows
CO5	Understand principles and techniques for solving compressible flow problems.

UNIT -I:

INVISCID FLOW OF INCOMPRESSIBLE FLUIDS: Lagrangian and Eulerian descriptions of fluid motion, Path lines, Streamlines, Streak lines, stream tubes – velocity of a fluid particle, types of flows, Equations of three-dimensional continuity equation, Stream and Velocity potential functions, Condition for irrotationality, circulation & vorticity, accelerations in Cartesian systems, normal and tangential accelerations.

UNIT -II:

VISCOUS FLOW: Derivation of Navier-Stoke's Equations for viscous compressible flow – Exact solutions to certain cases: Plain Poiseuille flow, Couette flow with and without pressure gradient , Hagen Poiseuille flow.

UNIT -III:

BOUNDARY LAYER CONCEPTS : Prandtl's contribution to real fluid flows – Prandtl's boundary layer theory, Boundary layer thickness for flow over a flat plate, Blasius solution – Approximate solutions, Von-Karman momentum integral equation for laminar boundary layer — Expressions for local and mean drag coefficients for different velocity profiles.

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UNIT- IV:

INTRODUCTION TO TURBULENT FLOW: Fundamental concept of turbulence – Time Averaged Equations – Boundary Layer Equations, Prandtl Mixing Length Model, Universal Velocity Distribution Law: Van Driest Model, k-epsilon model, boundary layer separation and form drag – Karman Vortex Trail, Boundary layer control, lift on circular cylinders.

INTERNAL FLOW: Smooth and rough boundaries – Equations for Velocity Distribution and frictional Resistance in smooth and rough Pipes – Roughness of Commercial Pipes – Moody's diagram.

UNIT -V:

COMPRESSIBLE FLUID FLOW: Thermodynamic basics – Equations of continuity, Momentum and Energy, Acoustic Velocity, Derivation of Equation for Mach Number – Flow Regimes – Mach Angle – Mach Cone – Stagnation State, Area Variation, Property Relationships in terms of Mach number, Nozzles, Diffusers – Fanno and Raleigh Lines– Normal Compressible Shock, Oblique Shock: Expansion and Compressible Shocks – Supersonic Wave Drag.

TEXT BOOKS:

1. L. Victor Steeter, Fluid Mechanics, 10th Edition, Tata McGraw-Hill, 1996.
2. Frank M. White, Fluid Mechanics, 8th Edition, McGraw-Hill Education, 2016.

REFERENCES:

1. Modi and Seth, Fluid Mechanics and Machines, Standard Book House
2. Pijush K. Kundu, Ira M. Cohen, and David R. Dowling, Fluid Mechanics, 5th Edition, Elsevier
3. David R. Dowling, Ira M. Cohen, and Pijush K. Kundu, Fluid Mechanics, 5th Edition, Cengage Learning, 2011
4. William S Janna, Fluid Mechanics, CRC Press, 3rd Edition, 2019
5. Y.A Cengel and J.M Cimbala, Fluid Mechanics, MGH, 4th Edition, 2018
6. Schlichting H, Boundary Layer Theory, Springer Publications, 9th Edition, 2017
7. Shapiro, Dynamics & Theory and Dynamics of Compressible Fluid Flow, 2nd Edition
8. William F. Hughes & John A. Brighton, Fluid Dynamics, TMH, 2nd Edition, 2018
9. K.L Kumar, Fluid Mechanics, S Chand & Co., 6th Edition, 2019

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ADVANCED THERMODYNAMICS & COMBUSTION

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

CO1	Understand how to use the laws of thermodynamics to analyze complete thermodynamic systems and calculate energy and entropy balances.
CO2	Apply thermodynamic property relations to determine different thermodynamic parameters.
CO3	Identify and apply thermodynamic principles to determine thermodynamic properties of mixtures
CO4	Understand the Phase equilibrium of mixtures.
CO5	Apply the first and second law of thermodynamics to chemical reactions

UNIT-I

AVAILABILITY AND IRREVERSIBILITY:Quality of Energy, available and unavailable energy, availability, surroundings work, reversible work and irreversibility, availability in a closed system, availability in a SSSF process in an open system, second law efficiencies of processes, second law efficiency of cycles and exergy balance equations.

UNIT-II

THERMODYNAMIC PROPERTY RELATIONS:Helmholtz and Gibbs Functions, two Mathematical Conditions for Exact Differentials, Maxwell Relations, Clapeyron Equation, Relations for Changes in Enthalpy, Internal Energy and Entropy, Specific Heat Relations, Generalized Relations/Charts for Residual Enthalpy and Entropy, Gibbs Function at zero Pressure: A Mathematical Anomaly, Fugacity, Fugacity Coefficient and Residual Gibbs Function, The Joule, Thomson Coefficient and Inversion Curve, Thermodynamic similarity.

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UNIT-III

GAS MIXTURES: Mixtures of ideal Gases, Gas-Vapor Mixtures, Application of First Law to Psychometric Processes, Real Gas Mixtures.

THERMODYNAMIC RELATIONS FOR REAL MIXTURES: Partial Properties, Relation for Fugacity and Fugacity Coefficient in Real Gas Mixtures, Relations for Activity and Activity Coefficient in Real Liquid Mixtures/Solutions.

UNIT-IV

PHASE EQUILIBRIUM: VAPOR LIQUID EQUILIBRIUM OF MIXTURES: Phase Diagrams for Binary Mixtures, Vapor, Liquid Equilibrium in Ideal Solutions, Criteria for Equilibrium, Criterion for phase Equilibrium, Calculation of Standard State Fugacity of Pure Component, Vapor Liquid Equilibrium at Low to Moderate Pressures, Determination of Constants of Activity Coefficient Equations, Enthalpy Calculations.

UNIT-V

CHEMICAL REACTIONS AND COMBUSTION: Thermochemistry, Measures of Composition in Chemical Reactions, Application of First Law of Thermodynamics to chemical Reactions, the Combustion Process-Standard Heat/Enthalpy of Combustion, Reactions at actual Temperatures, adiabatic Flame Temperature, Entropy Change of Reacting Systems, Application of second Law of Thermodynamics to chemical Reactions, chemical equilibrium-Advancement of Chemical Reactions, Equilibrium Criterion in Chemical Reactions, equilibrium Constant and Law of Mass Action, Equilibrium Constant for Gas Phase Reactions in the standard state.

TEXT BOOKS:

1. P.K.Nag, Basic and Applied Thermodynamics, 2nd Edition, Tata McGraw-Hill, 2019.
2. J.P Holman, Thermodynamics, 10th Edition, McGraw Hill, 2017.
3. CP Arora, Thermodynamics: An Engineering Approach, 5th Edition, McGraw Hill Education (India) Pvt. Limited, 2016.

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1. Moran, M. J., Shapiro, H. N., Boettner, D. D., and Bailey, M. B., 2018, Fundamentals of Engineering Thermodynamics, 9th ed., Wiley.
2. Cengel, Y. A., 2010, Introduction to Thermodynamics and Heat Transfer, 2nd ed., McGraw-Hill Education.
3. Bejan, A., 2016, Advanced Engineering Thermodynamics, 4th ed., Wiley. 5. Nag, P.K, 2017, Engineering Thermodynamics, 6th ed., McGraw Hill Education.
4. Sonntag, R. E, Borgnakke, C and Wylen, G. J. V., and., 2023, Fundamentals of Classical thermodynamics, 6th ed., Wiley Eastern Ltd.
5. Jones, J. B. and Hawkins, G. A., 1986, Engineering Thermodynamics, John Wiley Sons.

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CRYOGENIC ENGINEERING

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

CO1	Understand the different fluid and material properties at low temperatures
CO2	Impart knowledge of the working principles of various cryo refrigerators, thermodynamic cycles for attaining low temperature, and gas separation and purification principles
CO3	Understand the fundamental principles of thermal design of storage vessels and insulation, transfer systems.
CO4	Understand the cool-down process and heat transfer in cryogenic fluids and the occurrence of two-phase flow and stratification in cryogenic systems.
CO5	Understand the importance of vacuum requirements in cryogenics, superconductivity, and special phenomena at very low-temperature engineering applications.

UNIT-I:

FLUID AND MATERIAL PROPERTIES AT LOW TEMPERATURE & APPLICATIONS OF CRYOGENICS:

Introduction to cryogenics: Cryogenic temperature scale, Properties of cryogenic fluids, super fluidity of He3 & He 4, properties of engineering materials at cryogenic temperatures, mechanical properties, thermal properties, electric & magnetic properties, super conducting materials. Applications of cryogenic systems: Super conductive devices, space technology, space simulation, cryogenics in biology and medicine, food preservation and industrial applications, nuclear propulsions, chemical propulsions

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UNIT-II:

CRYOGENIC GAS LIQUIFICATION:

Gas liquefaction systems: Introduction, thermodynamically ideal systems, Joule Thomson effect, liquefaction systems such as Linde Hampton, precooled Linde Hampton, Linde dual pressure, cascade system, Claude system, Kapitza system, Heyland systems using expanders, comparison of liquefaction systems and its performance evaluations.

UNIT-III:

CRYOGENIC AIR-SEPARATION:

Basics of Gas Separation, Ideal Gas Separation System, Gibbs Phase Rule, Phase Equilibrium Curves, Temperature Composition Diagrams, Raoult's Law, Gibbs – Dalton's Law, Distribution Coefficient, Enthalpy composition diagrams, Rectification Column Murphree efficiency, Theoretical Plate Calculations

UNIT-IV:

CRYOGENIC REFRIGERATOR AND CRYOCOOLERS:

Cryogenic Refrigeration System: Ideal isothermal and reversible isobaric source refrigeration cycles, Joule Thomson system, cascade or pre-cooled joule–Thomson refrigeration systems, expansion engine and cold gas refrigeration systems, Sterling refrigerators, Importance of regenerator effectiveness for the Sterling refrigerators, Gifford single volume refrigerator, Gifford double volume refrigerators analysis, Refrigerators using solids as working media: Magnetic cooling, magnetic refrigeration systems, thermal; valves, nuclear demagnetization, dilution refrigerator

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UNIT-V:

CRYOGENIC FLUID STORAGE, INSTRUMENTATION, AND INSULATION:

Dewar vessel for cryogenic fluid storage, Construction, Inner vessel design, outer vessel design, Temperature measurements, pressure measurements, flow measurements, liquid level measurements, fluid quality measurements, Cryogenic insulation – expanded foams, gas filled & fibrous insulation, vacuum insulation, evacuated powder & fibrous insulation, Opacified powder insulation, multilayer insulation, comparison of performance of various insulations.

TEXT BOOKS:

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

REFERENCES:

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

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TURBO MACHINES

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

CO1	Understand the fundamentals of Turbo machines to evaluate the performance.
CO2	Apply the knowledge in the design of steam nozzles.
CO3	Understand the basics of gas dynamics and centrifugal compressors.
CO4	Apply the knowledge in the design of axial flow compressors.
CO5	Apply the knowledge in the design of axial flow turbines.

UNIT – I:

FUNDAMENTALS OF TURBO MACHINES:

Classification, Application Thermodynamic analysis; Isentropic flow, Energy transfer; Efficiencies; static and Stagnation conditions; continuity equation; Euler's flow through variable cross-sectional area; unsteady flow in turbo machines.

UNIT –II:

STEAM NOZZLES: Effect of back – pressure on the analysis; Design of nozzles. Steam Turbines of C & C –D nozzles :Impulse Turbines: work done and velocity triangles; Efficiencies; Constant Reaction Blading; Design of blade passages, angles and height; Secondary flow; leakage losses; Thermodynamic analysis of steam turbines.

UNIT – III:

GAS DYNAMICS: Fundamentals thermodynamic concepts; Isentropic conditions; Mach number and Area – Velocity relation; Dynamic pressure; normal shock relations for perfect gas; supersonic flow, oblique shock waves ; normal shock recovery ; detached shocks ; Aerofoil theory. Centrifugal Compressor: Types; Velocity triangles and efficiencies; Blade passage design; Diffuser and pressure recovery; slip factor; Stanitz and Stodola's formulae; Effect of inlet Mach number; Pre-whirl; performance.

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UNIT – IV:

AXIAL FLOW COMPRESSORS: Flow analysis, work and velocity triangles ; Efficiencies; Thermodynamic analysis; stage pressure rise ; Degree of reaction ; stage loading ; general design, effect of velocity incidence ; performance. Cascade Analysis: Geometry and Terminology; Blade forces, Efficiency; losses; free and forced vortex blades.

UNIT – V:

AXIAL FLOW GAS TURBINES: Work done; velocity triangles and efficiencies; thermodynamic flow analysis; degree of reaction; Zweifel's relation; Design cascade analysis – Soderberg – Hawthorne – Ainley-correlations; secondary flow; Free-vortex blades; Blade angles for variable degree of reaction; Actuator disc theory; stresses in blades; Blade assembling; materials and cooling of blades; performance; Matching of compressor and turbine; off-design performance.

TEXT BOOKS:

1. Shepherd, I. G., Fundamentals of Turbomachinery, 2nd Edition, John Wiley & Sons, 2005.
2. Yahya, S. M., Elements of Gas Dynamics, 2nd Edition, PHI Learning Pvt. Ltd., 2013.

REFERENCES:

1. Fluid Mechanics and Thermodynamics of Turbomachinery, Dixon, S.L, Elsevier, 2014, 7th Edition.
2. Gas Turbine Theory, Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Pearson Prentice Hall, 2017, 7th Edition.
3. G. Gopalakrishnan and D. Prithviraj, Practice on Turbomachines, SciTech Publishers, Chennai.

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MATHEMATICAL METHODS FOR THERMAL SYSTEMS

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

CO1	Apply the concepts of vector calculus.
CO2	Understand and Analyze Boundary Value Problems.
CO3	Develop the analytic approach for solving differential equations for different thermal and systems.
CO4	Understand the basics of weighted residual-based FEM methods and develop weak form from the strong form.
CO5	Analyze fluid flow, heat transfer, and coupled problems using FEM

UNIT-I:

Gradient, Divergence, Curl operators and their interpretation, Line Integrals, Surface Integrals, Volume Integral, Gauss-Divergence theorem, Green's Theorem, and Stokes' theorem with applications. First-order differential equations: Initial value problem, Solution techniques and applications, Second-order differential equations: homogeneous and nonhomogeneous cases.

UNIT-II:

Boundary value problem: Shooting methods, Applications of second-order differential equations, series solutions, Frobenius method, Sturm-Liouville problems, Bessel and Legendre equations; Systems of first-order differential equations, Partial differential equations: Cauchy problem, Method of characteristics, classification of second-order PDEs.

UNIT-III:

Solution to one-dimensional unsteady heat conduction equation, Solution to one-dimensional wave equation using variable separable methods, d'Alembert's solution, Solution to two-dimensional Laplace equation First and higher-order numerical methods for solving first-order differential equations, Implementation of higher order ordinary differential equations: boundary value problem: Shooting method, Datafitting, Interpolation, Least-squares, Numerical methods for scalar transport equation.

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UNIT-IV:

Mathematical Preliminaries for FEM; Introduction to method of weighted residuals; Finite Element Approximation; Weighted Integral Statements and Weak Forms; Fundamental concepts of FEM: Basics of numerical methods (stability, consistency; convergence, accuracy; types of errors); 1D Strong form, weak form, boundary conditions; Galerkin approximation; Matrix equation; Piecewise linear finite element space; local matrix and assembly of global matrix.

UNIT-V:

Iso-parametric element; linear and trilinear elements; Numerical Integration; Gaussian quadrature; Shape functions and their derivatives; 2D and 3D boundary value problems: Trial solutions and weighting functions; Strong form, weak form, boundary conditions; Finite element spatial discretization; Examples from Conduction Heat Transfer and Flows of Viscous Incompressible Fluids.

TEXT-BOOKS:

1. E. Kreyszig, Advanced Engineering Mathematics, Wiley.
2. Simmons, G. F., 2017, Differential Equations with Applications and Historical Notes, McGraw Hill.
3. Gartling, D., and Reddy, J.N., 2010, The Finite Element Method in Heat Transfer and Fluid Dynamics, CRC Press.

REFERENCES:

1. Ross, S. L., 2004, Differential Equations, 3rd ed., John Wiley & Sons, Inc.
2. Buchanan, J. R., and Shoude, Z., 2017, A First Course in Partial Differential Equations, World Scientific.
3. Butcher, J. C., 2003, Numerical Methods for Ordinary Differential Equations, Wiley.
4. Donea, J., and Huerta, A., 2003, Finite Element Methods for Flow Problems, John Wiley & Sons.
5. Pletcher, R., Tannehill, J. C., and Anderson, D. A., 2016, Computational Fluid Mechanics and Heat Transfer, 3rd ed., CRC Press.

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M.TECH (THERMAL ENGINEERING)

RENEWABLE SOURCES OF ENERGY

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

CO1	Identify the renewable energy sources, their utilization, and storage and evaluate the energy conversion from ocean thermal energy.
CO2	Understand the basic concepts of solar radiation and analyze the solar thermal systems for their utilization and the principle of working of solar cells.
CO3	Understand the Wind energy systems and its components with basic working principles.
CO4	Analyze Bio energy and Bio mass systems.
CO5	Narrate the importance and potential of geo thermal energy and Integrated power generation systems.

UNIT-I

INTRODUCTION: Energy and development, energy demand and availability, energy crisis, conventional and non-conventional sources, renewable and non-renewable energy resources, environmental impact of conventional energy usage, basic concepts of heat and fluid flow useful for energy systems.

ENERGY FROM THE OCEANS: OTEC systems, open and closed types; Wave energy conversion systems; Tidal energy conversion systems.

UNIT II

SOLAR ENERGY: Solar radiation at the earth's surface – solar radiation measurements – estimation of average solar radiation - solar thermal flat plate collectors - concentrating collectors – solar thermal applications - heating, cooling, desalination, drying, cooking, etc – solar thermal electric power plant - principle of photovoltaic conversion of solar energy, types of solar cells - Photovoltaic applications: battery charger, domestic lighting, street lighting, water pumping etc - solar PV power plant – Net metering concept.

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UNIT III

WIND ENERGY: Nature of the wind – power in the wind – factors influencing wind – wind data and energy estimation - wind speed monitoring - wind resource assessment - Betz limit - site selection - wind energy conversion devices - classification, characteristics, applications – offshore wind energy – Hybrid systems - safety and environmental aspects – wind energy potential and installation in India - Repowering concept.

UNIT IV

BIO-ENERGY: Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - direct combustion – biomass gasification - pyrolysis and liquefaction – biochemical conversion - anaerobic digestion - types of biogas Plants - applications - alcohol production from biomass – bio diesel production – Urban waste to energy conversion - Biomass energy programme in India.

UNIT-V:

MICRO AND SMALL HYDRO ENERGY SYSTEMS: Resource assessment of micro and small hydro power, micro, mini and small hydro power systems, economics, pump as turbine, special engines for low heads, velocity head turbines, hydrams, water mills.

GEO THERMAL ENERGY SYSTEMS: Vapor dominated, liquid dominated and petrothermal systems; Hybrid systems.

INTEGRATED ENERGY SYSTEMS: Concept of integration of conventional and non-conventional energy resources and systems; integrated energy system design and economics.

TEXT-BOOKS:

1. Non conventional Energy Resources, B.H.Khan, Tata McGraw Hill, New Delhi, 2017, 3rd edition.
2. Energy Technology: Non-Conventional, Renewable and Conventional, S.Rao and B.B.Parulekar, Khanna Publishers, 2010, 1st Edition.

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REFERENCES:

1. Duffie, J.A. and Beckman, W.A., “Solar Engineering of Thermal Processes”, John Wiley., 2006
2. Bungay, H.R., “Energy, the Biomass Option”, John Wiley. , 1981
3. Fowler, K.M., “Energy & Environment”, McGraw Hill. , 1984
4. Sukhatme, S.P. and Nayak, J.K., ”Solar Energy: principles of thermal collection and storage”, McGraw Hill., 2009
5. Boyle, G., “Renewable Energy – Power for a Sustainable Future”, 2nd Ed., Oxford University Press., 2010.

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M.TECH (THERMAL ENGINEERING)

FUEL CELLS AND HYDROGEN TECHNOLOGIES

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

CO1	Understand fuel cell fundamentals
CO2	Demonstrate the operation of different fuel cells
CO3	Analyse the performance of PEM fuel cell system
CO4	Understand the Production, Storage and Transportation systems of Hydrogen.
CO5	Understand the applications of Hydrogen in Stationary and Automotive applications.

UNIT-I:

Introduction to Fuel Cells – Fuel cell concept - key components - physical and chemical phenomena in fuel cells - advantages and disadvantages of fuel cells – different types of fuel cells and their characteristics – fuel cells for stationary applications – fuel cell vehicles.

UNIT-II

Thermodynamic analysis – systematic enthalpy change of a reacting system – systematic Gibbs free energy – change of a reacting system – ideal efficiency of the energy conversion – energy balance in fuel cells.

UNIT-III:

Electrochemistry – Nernst equation, relation of the fuel consumption versus output – stoichiometric coefficients and utilization percentages of fuels and oxygen – mass flow rate calculation for fuel and oxygen in single cell and fuel cell stack – total voltage and current for fuel cells in parallel and serial connection – over-potential and polarizations,

UNIT-IV:

DMFC operation scheme – general issues-water flooding and water management - polarization in PEMFC - optimization design of PEMFC – case studies.

Hydrogen economy – Introduction to hydrogen economy - production, storage and transportation systems – hydrogen from fossil fuels – electrolysis of water – thermochemical cycles – baseline and alternative thermochemical cycles.

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UNIT-V:

Hydrogen utilization – Hydrogen for stationary and automotive applications – transmission and infrastructure requirements – safety and environmental impacts - economics of transition to hydrogen systems – case studies.

TEXT BOOKS:

1. Vishwanathan B. and AuliceScibioh, “Fuel cells: Principles and Applications”, University Press, 2006.
2. Ram B. Gupta, “Hydrogen Fuel: Production, Transport and Storage”, CRC Press.

REFERENCES:

1. Peter Hoffman, “Tomorrow’s Energy – Hydrogen Fuel cells and the Prospects for Cleaner Planet”, MIT, 2002.
2. Prashukumar G.P., “Hydrogen – A Fuel for Automatic Engines” ISTE, 1999.
3. Hart A.B. and Womack G.J., “Fuel Cells – Theory and Applications”, Chapman and Hall, 1967.
4. Young G.J., “Fuel Cells”, Reinhold publishing Corp., 1960.
5. Veziroglu T., “Hydrogen Energy”, Springer publishing, 1975.

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ANALYSIS OF IC ENGINES

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

CO1	Analyze mixture systems for IC engines and describe different fuel supply systems in spark ignition and compression ignition engines.
CO2	Summarize the methods used to improve engine performance and estimate performance parameters.
CO3	Analyze the different fuels for SI and CI Engines.
CO4	Analyze the different combustion phenomenon in SI and CI engines.
CO5	Understand the basics of EV and Hybrid Engines.

UNIT-I:

Working principle - Constructional details - Classification and application of different types of I.C. engines - Two stroke engines - Wankel and other rotary engines - Stirling engine.

Mixture preparation systems for SI and CI engines – Carburetor – MPFI – Diesel fuel supply systems – fuel pumps - fuel injectors – unit injector - CRDI - Combustion chambers - Ignition.

Lubrication and Cooling Systems - Speed Governing systems - Intake and exhaust systems. Supercharging methods - Turbocharger matching - Aerothermodynamics of compressors and turbines.

UNIT-II:

Engine testing and performance – Effects of engine design and operating parameters on performance and emissions; Pollution formation in SI and CI engines - Factors affecting emissions - Control measures for evaporative emissions - Thermal reactors and catalytic converters.

Engine modifications to reduce emissions - Instrumentation to measure pollutants - Emission standards and testing - Review of basic thermodynamics and gaseous mixtures – Stoichiometry - Adiabatic flame temperature - First and Second Laws of Thermodynamics applied to combustion - Equilibrium products of combustion.

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UNIT-III:

Fundamentals of combustion kinetics – Elementary reaction rates. General characteristics of combustion flame – detonation – deflagration - Factors affecting flame velocity and thickness – Quenching - Flammability – Ignition - Flame stabilization Laminar premixed flames - Laminar diffusion flames - Turbulent premixed flames.

Fuels and their properties - Equivalence ratio – Self ignition temperature – Ignition lag - Role of fuel in engine combustion – Fuels for SI & CI engines – Octane number – Cetane number - Combustion generated pollutants.

UNIT-IV:

Normal combustion in SI Engines: Thermodynamic Analysis, Flame structure and speed, cyclic variations in combustion. Factors affecting combustion in SI engines – Effect of engine variables on flame propagation and ignition lag - Knocking - Effect of variables on knock – Detection of knock – Control of Knock - Pre-ignition - Normal combustion in CI Engines – Analysis of cylinder pressure data – Direct Injection and Indirect Injection, Fuel spray behavior - Variables affecting delay period - Factors affecting combustion in CI engines.

UNIT-V:

Electric Vehicles: Introduction: History of EVs, EV system, basic structure- Electric vehicle drivetrain-advantages and limitations, Components of EV Battery run EVs and Electric Motor run EVs- Brief treatment on types of electric machines for EVs (Power-Torque characteristics), regenerative braking system.

Hybrid Vehicles: Configurations of hybrids, advantages and limitations- basic structure of series, parallel and series-parallel configurations.

TEXTBOOKS:

1. Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, 1989.
2. Stephen R. T., An Introduction to Combustion, McGraw-Hill International Editions, 1996.
3. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi, CRC Press, 2018, II Edition.

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REFERENCES:

1. Kuo, K. K., Principles of Combustion, John Willey & Sons, 1986.
2. Strehlow, R. A., Combustion Fundamentals, McGraw-Hill, 1985.
3. Mukunda, H. S., Understanding Combustion, Macmillan India Ltd., 1992.
4. Ashley S. C., Thermodynamic Analysis of Combustion Engines, John Wiley, 1979.
5. Maleev, M. L., Internal Combustion Engines, Second edition, McGraw-Hill, 1989.
6. Mathur, M. L. and Sharma, R. P., Internal Combustion Engines, Dhanpath Rai & Sons, 2005.
7. Electric vehicle technology explained, John Lowry and James Larminie, John Wiley and Sons, 2012.

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RESEARCH METHODOLOGY & IPR

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

CO1	Understand the sources, characteristics, scope and objective of a research problem. Also learn data collection, analysis and interpretation.
CO2	Know about plagiarism, research ethics, and the contents of a research proposal.
CO3	Understand the types of intellectual property rights and the procedure for grant of patents.
CO4	Know about the licensing and transfer of the technology.
CO5	Understand the IPR of biological system and computer software.

UNIT-I

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

UNIT-II

Effective literature studies approaches, analysis Plagiarism, Research ethics, Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

UNIT-III

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT-IV

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

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UNIT-V

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies.

REFERENCES:

1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students”
2. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
3. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
4. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd, 2007.
5. Mayall, “Industrial Design”, McGraw Hill, 1992.

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ENGLISH FOR RESEARCH PAPER WRITING

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

CO1	To learn the basic structure and effectiveness of written English.
CO2	The student should learn to precisely and carefully present his findings in an organized manner.
CO3	The students should learn to identify the scope of his work plan to design the methods and present his results. He should also manually growth through the right up to avoid the errors that creep in by the spell checker.
CO4	The student should learn the necessary skills of writing from title to literature review making use of appropriate phrases in use.
CO5	The student should learn the necessary skills of writing methods, results, discussion and conclusion.

UNIT-I

Planning and Preparation, Word Order, Breaking up long sentences. Structuring Paragraphs and Sentences, Being concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

UNIT-II

Clarifying Who Did What, Highlighting your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction

UNIT-III

Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.

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UNIT-IV

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, useful phrases, how to ensure paper is as good as it could possibly be the first-time submission.

UNIT-V

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions.

REFERNCES:

1. Goldbort R (2006) Writing for Science, Yale University Press (available on Google Books)
2. Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press
3. Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM Highman's book.
4. Adrian Wallwork, English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011

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ADVANCED HEAT TRANSFER LAB

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

CO1	Estimate the thermal conductivity of liquids and gases.
CO2	Evaluate the performance of Solar Still and Flat Plate Collector.
CO3	Understand Wind Tunnel Equipment and determine pressure distribution and drag forces.
CO4	Estimate the performance of Air Compressor and VCR system.
CO5	Evaluate the performance of Variable compression Engine.

1. To fabricate and calibrate a thermocouple and illustrate its use in the temperature measurement.
2. To determine the LMTD, Effectiveness and Heat Transfer rate of a Shell and Tube Heat Exchanger.
3. To determine the Performance of a Solar Flat Plate Collector.
4. To determine the Performance of a Solar Still.
5. To determine the thermal conductivity of liquids and gases.
6. To determine the heat transfer rate in drop and film wise condensation.
7. To determine the critical heat flux of a wire.
8. To conduct the performance test on four stroke variable compression ratio diesel engine.
9. To conduct the performance test on a reciprocating air compressor
10. To determine the coefficient of performance in a Vapour Compression Refrigeration system.

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11. To conduct the flame propagation analysis of gaseous fuels.
12. To Evaluate the engine friction by Motoring/Retardation Test on an IC Engine.
13. Determination of Pressure Distribution over a Symmetric Aero foil.
14. Determination of Drag over the Sphere with different angle of attacks.

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M.TECH (THERMAL ENGINEERING)

COMPUTATIONAL LABORATORY
(MATLAB & PYTHON PROGRAMMING)

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

CO1	Develop essential programming skills in computer programming concepts like data types, containers apply the basics of programming in the MATLAB & Python language.
CO2	Solve the different methods for linear, non-linear and differential equations
CO3	Develop MATLAB & Python Codes to solve different Numerical Methods.

TO DETERMINE:

1. Roots of the equations using Bisection and Newton Raphson methods.
2. Solution of Simultaneous Linear equations using Gauss Elimination, Jacobi's, and Gauss-Seidel iterative methods.
3. Determination of Eigen values and Eigen vectors of a matrix.
4. Numerical Integration using Trapezoidal and Simpson's rules.
5. Solution of Ordinary differential equations using Eulers and Runge-Kutta methods.
6. Solution of Tri-Diagonal Matrix.
7. Best fit using the principle of least squares.

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M.TECH (THERMAL ENGINEERING)

COMPUTATIONAL FLUID DYNAMICS

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

CO1	Differentiate between different types of partial differential equations that govern fluid dynamics, such as conservation, continuity, momentum and energy equations.
CO2	Understand and Implement Finite Difference methods for Elliptical, Parabolic and Hyperbolic form of Partial Differential Equations.
CO3	Discretize the equations using Finite Volume Method applied to Diffusion and Convective-Diffusion Equations and understand the solution methodology.
CO4	Discretize the governing equations applied to Steady and Unsteady flows using Finite Volume Method.
CO5	Develop the ability for FEM discretization for simple one dimensional steady and unsteady problems in fluid flow and heat transfer.

UNIT-I:

A brief overview of the basic conservation equations for fluid flow and heat transfer, Boundary Conditions, classification of partial differential equations and pertinent physical behaviour, parabolic, elliptic and hyperbolic equations, role of characteristics. Over-View of Finite Element, Finite Difference and Finite Volume Methods.

Finite Difference Method: Derivation of Finite Difference Equations, Accuracy of Finite Difference Equations. Numerical Errors: Round-off, Truncation and Discretization Errors. Solution of discretized equations: Direct and Indirect or iterative methods, TDMA algorithm.

Elliptical Equations: Finite Difference Formulations, Iterative Solution Methods, Examples.

Parabolic Equations: Explicit Schemes and Von-Neumann Stability Analysis, Implicit Schemes, ADI Schemes, Approximate Factorization, Fractional Step Methods, Examples.

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UNIT-II:

Hyperbolic Equations: Explicit schemes and Von-Neumann stability analysis, Implicit schemes, multi-step methods, nonlinear problems, second order one-dimensional wave equations, Examples.

In-compressible Viscous Flows via FDM: Artificial Compressibility Method, Pressure Correction Methods and Vortex Methods, Examples.

UNIT-III:

FINITE VOLUME METHOD-I: DIFFUSION PROBLEMS: Solutions for 1-D and 2-D steady-state diffusion problems.

CONVECTION-DIFFUSION PROBLEMS: Solutions using Central Differencing Scheme, Upward differencing scheme, Hybrid differencing Scheme, Power Law scheme, Higher order differencing schemes, TVD schemes.

UNIT-IV:

FINITE VOLUME METHOD-II: STEADY FLOWS: Staggered grid, SIMPLE, SIMPLER, SIMPLEC and PISO algorithms.

UNSTEADY FLOWS: Solutions for Transient 1-D and 2-D Heat Conduction, Transient convection-diffusion problems, QUICK Scheme, Solutions using Transient SIMPLE and Transient PISO algorithms.

UNIT-V:

FINITE ELEMENT METHOD: Introduction. Weighted residual and variational formulations. Interpolation in one-dimensional case. Application of FEM to 1D steady and unsteady problems in fluid flow and heat transfer.

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TEXT BOOKS:

1. Chung, T. J., 2010, Computational Fluid Dynamics, 2nd ed., Cambridge University Press.
2. Versteeg, H. K., and Malalasekera, W., 2007, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd ed., Pearson Education Limited.
3. Gartling, D., and Reddy, J.N., 2010, The Finite Element Method in Heat Transfer and Fluid Dynamics, CRC Press.

REFERENCES:

1. Patankar, S. V., 2017, Numerical Heat Transfer and Fluid Flow, Special Indian ed., CRC Press.
2. Muralidhar K., and Sundararajan T. (Editors), 2017, Computational Fluid Flow and Heat Transfer, 2nd ed. tenth reprint, Narosa.
3. Anderson Jr., J. D., 2017, Computational Fluid Dynamics: The Basics with Applications, Indian ed., McGraw Hill Education.
4. Donea, J., and Huerta, A., 2003, Finite Element Methods for Flow Problems, John Wiley & Sons, Ltd.
5. Zienkiewicz, O. C, Nithiarasu, P., and Taylor, R. L, 2013, The Finite Element Method for Fluid Dynamics, 7th ed., Butterworth-Heinemann Ltd.

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M.TECH (THERMAL ENGINEERING)

EXPERIMENTAL ANALYSIS AND INSTRUMENTATION

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

CO1	Post-process the experimental data employing the standard statistical tools.
CO2	Analyze First and Second Order Systems applied different Thermal Systems.
CO3	Estimate uncertainties associated with the measurements.
CO4	Employ the knowledge for carrying out experiments in research labs and industries.
CO5	Design novel techniques for measurements of thermo-physical properties.

UNIT-I:

Concepts in dynamics measurements; system response; error analysis; uncertainty analysis; calibration; statistical analysis; probability distributions; goodness of data; method of least squares and multivariable regression.

UNIT-II:

Process control: Introduction and need for process control principles, transfer functions, block diagrams, signal flow graphs, open and closed-loop control systems – Analysis of First & Second-order systems with examples of mechanical and thermal systems. Control System Evaluation – Stability, steady-state regulations, and transient regulations.

UNIT-III:

Temperature measurements – by mechanical effects, electrical effects; thermistors; liquid crystal thermography; thermocouples – types, laws of thermocouple, thermopile, transient response of thermal systems; temperature measurement in cryogenics.

Pressure measurements - bourdon-tube gage, diaphragm and bellows gage; inductive, piezoelectric and capacitive transducers; McLeod gage; Knudsen gage; ionization gage.

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UNIT-IV:

Flow measurements – flow obstruction meters – venturi, orifice, nozzle meters; turbine meters; coriolis flow meters; ultrasonic flow meters; magnetic flow meters. Hot-wire and hot-film anemometry; Laser Doppler Anemometer.

Acoustic measurements – microphones and sound level meters. Flow visualization - schlieren; shadowgraph; interferometer.

UNIT-V:

Measurement of thermal and physical properties – viscosity; thermal conductivity of solids and fluids – steady and unsteady state measurements; thermal conductivity of low-conducting and metallic solids; measurement of specific heat of solids and fluids; measurement of derived quantities – heat flux; heat transfer coefficient; measurement of calorific values, humidity.

Thermal radiation measurements – emissivity; reflectivity and transmissivity; pyrometry; solar radiation measurements.

TEXTBOOKS:

1. Eckert, E.R.G., and Goldstein, R.J., 1976, Measurements in Heat Transfer, 2nd ed. McGraw Hill.
2. Holman, J.P., 2012, Experimental Methods for Engineers, 8th ed., McGraw Hill.

REFERENCES:

1. Beckwith, T.G., Marangoni, R.D., and Lienhard V, J.H., 2007, Mechanical Measurements, 6th ed., Pearson Prentice Hall.
2. Sirohi, R.S., and Radha Krishna, H.C., 1991, Mechanical Measurements, 3rd ed., New Age International.
3. Venkateshan, S.P., Mechanical Measurements; 2nd ed., John Wiley & Sons.

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M.TECH (THERMAL ENGINEERING)

HVAC SYSTEMS

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

CO1	Understand the fundamentals of Psychrometry of Air-conditioning processes.
CO2	Apply human comfort indices and comfort charts to design indoor conditions of HVAC systems.
CO3	Estimate heating and loads for buildings according to ASHRAE procedures and standards.
CO4	Design and evaluate a complete air distribution system including fan, duct, and installation requirements for a typical HVAC system.
CO5	Understand the basic principles and applications of Heat Pumps.

UNIT-I:

INTRODUCTION: Brief history of air conditioning and impact of air conditioning. HVAC systems and classifications,

PSYCHROMETRY OF AIR CONDITIONING PROCESSES: Thermodynamic properties of moist air, Important Psychrometry properties, Psychrometric chart; Psychrometric process in air conditioning equipment, applied Psychrometry, air conditioning processes, air washers.

UNIT-II:

COMFORT AIR CONDITIONING: Thermodynamics of human body, metabolic rate, energy balance and models, thermoregulatory mechanism. Comfort & Comfort chart, Effective temperature, Factors governing optimum effective temperature, Design consideration. Selection of outside and inside design conditions.

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UNIT-III:

HEAT TRANSFER THROUGH BUILDING STRUCTURES: Solar radiation; basic concepts, sun-earth relationship, different angles, measurement of solar load, Periodic heat transfer through walls and roofs. Empirical methods to calculate heat transfer through walls and roofs using decrement factor and time lag method. Infiltration, stack effect, wind effect. CLTD/ETD method – Use of tables, Numerical and other methods, Heat transfer through fenestration – Governing equations, SHGF/SC/CLF Tables

UNIT-IV:

VENTILATION SYSTEM: Introduction- Fundamentals of good indoor air quality, need for building ventilation, Types of ventilation system, Air Inlet system. Filters heating & cooling equipment, Fans, Duct design, Grills, Diffusers for distribution of air in the workplace, HVAC interface with fire and gas detection systems - system requirements, devices and their functioning.

UNIT-V:

LOAD CALCULATIONS: Types of air-conditioning systems, General consideration, internal heat gains, system heat gain, cooling and heating load estimate.

HEAT PUMPS: General principles, appropriate conditions for using heat pumps, theoretical and practical COP, refrigerants, absorption heat pump, applications of heat pumps; gas driven heat pumps.

TEXT BOOKS:

1. Dossat, Roy J. and Horan, Thomas J., Principles of Refrigeration, 5th Edition, Prentice Hall, 2001.
2. Arora, R.C., Refrigeration & Air Conditioning, PHI, 2010.

REFERENCES:

1. Gosney W.B., Principles of Refrigeration, Cambridge University Press, 1982.
2. Threlkeld, J.L., Thermal Environmental Engineering, Prentice Hall, 1962.

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M.TECH (THERMAL ENGINEERING)

FUNDAMENTALS OF MICROFLUIDICS

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

CO1	Understand the fundamental theory of microfluidic systems.
CO2	Develop solutions to traditional and modern microfluidics problems.
CO3	Design, analyze, and evaluate microfluidic systems.
CO4	Understand the different fabrication essentials of micro fluidic systems.
CO5	Provide physical insights on the working of microfluidic devices and suggest system design improvements.

UNIT-I:

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

UNIT-II:

Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.

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

UNIT-III:

Active microfluidics- Electro-hydrodynamics. Electro-osmosis, Debye layer, Ideal electro-osmotic flow, Ideal electro-osmotic with back pressure, Cascade electro-osmotic micro pump. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size.

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UNIIT-IV:

Microfabrication essentials - Materials, Clean room, Silicon crystallography, Miller indices. Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding. Polymer microfabrication, PMMA/COC/PDMS substrates, micro-molding, hot embossing, fluidic interconnections. Experimental flow characterization.

UNIIT-V:

Microfluidics devices - Micropumps, Microvalves, Micro flow sensors, Micro mixers, Droplet generators, Microparticle separator, Microreactors. Current trends and applications of microfluidics.

TEXT-BOOKS:

1. Nam-Trung Nguyen and Steve Wereley, Fundamentals and Applications of Microfluidics, 2nd Edition, Artech House Inc., 2019.
2. Patrick Tabeling, Introduction to Microfluidics, 2nd Edition, Oxford University Press Inc., 2019.

REFERENCES:

1. Marc J. Madou, Fundamentals of Microfabrication, 2nd Edition, CRC Press, 2011.
2. Brian J. Kirby, Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
3. Henrik Bruus, Theoretical Microfluidics, 2nd Edition, Oxford University Press Inc., 2008.

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M.TECH (THERMAL ENGINEERING)

HYDRAULIC AND PNEUMATIC SYSTEMS

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

CO1	Illustrate the basic concepts of fluid power
CO2	Understand the functions of elements of Hydraulic and Pneumatic systems
CO3	Analyze the functions of hydraulic and Pneumatic circuits
CO4	Illustrate the working of various hydraulic and pneumatic devices.
CO5	Interpret the procedure of installation, maintenance

UNIT-1:

FLUID POWER: Power transmission modes, hydraulic systems, pneumatic systems, laws governing fluid flow: Pascal's law, continuity equation, Bernoulli's theorem, Boyle's, Charles', Gay-Lussec' laws, flow through pipes - types, pressure drop in pipes, Working fluids used in hydraulic and pneumatic systems- types, ISO/BIS standards and designations, properties.

UNIT-II:

HYDRAULIC AND PNEUMATIC ELEMENTS: Hydraulic pipes-Types, standards, designation methods and specifications, pressure ratings, applications and selection criteria, pumping theory, Hydraulic Pumps - types, construction, working principle, applications, selection criteria and comparison, hydraulic Actuators, Control valves, Accessories - their types, construction and working, pneumatic Pipes - materials, designations, standards, properties and piping layout, air compressors, Air receivers, air dryers, Air Filters, Regulators, Lubricators (FRL unit): their types, construction, working, specifications and selection criteria of following air preparation and conditioning elements, pneumatic Actuators and Control valves - types, construction, working, materials and specifications.

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UNIT-III:

HYDRAULIC AND PNEUMATIC CIRCUITS:

ISO symbols used in hydraulic and pneumatic circuit, basic Hydraulic Circuits – types (such as intensifier, regenerative, synchronizing, sequencing, speed control, safety), circuit diagram, components, working and applications, basic Pneumatic Circuits – types (such as speed control, two step feed control, automatic cylinder reciprocation, time delay, quick exhaust), circuit diagram, components, working and applications, pneumatic Logic circuit design - classic method, cascade method, step counter method, karnaughveitch maps and combinational circuit design.

UNIT-IV:

HYDRAULIC AND PNEUMATIC DEVICES:

Hydraulic and Pneumatic devices – Concept and applications, construction, working principle, major elements, performance variables of: Automotive hydraulic brake, Industrial Fork lift, Hydraulic jack, Hydraulic press, Automotive power steering, Automotive pneumatic brake, Automotive air suspension, Pneumatic drill, Pneumatic gun.

UNIT-V:

INSTALLATION, MAINTENANCE AND TROUBLE-SHOOTING:

Installation of hydraulic and pneumatic system causes and remedies for common troubles arising in hydraulic elements, maintenance of hydraulic systems, causes and remedies for troubles arising in pneumatic elements, maintenance of pneumatic systems.

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TEXT BOOKS:

1. S.R. Majumdar, Oil Hydraulic Systems: Principles and Maintenance, 3rd Edition, Tata McGraw-Hill Publication, 2013.
2. S.R. Majumdar, Pneumatic Systems: Principles and Maintenance, 3rd Edition, Tata McGraw-Hill Publication, 2013.

REFERENCES:

1. R. Srinivasan, Hydraulic and Pneumatic Controls, 2nd Edition, Vijay Nicole Imprints Private Limited, 2008.
2. T. Jagadeesha, Fluid Power Generation, Transmission and Control, 1st Edition, Universities Press (India) Private Limited, 2014.
3. T. Jagadeesha, Pneumatics Concepts, Design And Applications, 1st Edition, Universities Press (India) Private Limited, 2014.
4. Andrew Parr, Hydraulic And Pneumatics: A Technician's and Engineer's Guide, 2nd Edition, Jaico Publishing House, 2013.
5. K. ShanmugaSundaram, Hydraulic And Pneumatics Controls - Understanding Made Easy, 1st Edition, S. Chand Company Ltd., 2006.

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M.TECH (THERMAL ENGINEERING)

THERMAL MANAGEMENT IN EV BATTERY AND FUEL CELL SYSTEM

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

CO1	Understand the fundamentals of electric vehicles, battery management systems, and fuel cells.
CO2	Apply heat transfer principles to analyze and manage battery systems.
CO3	Understand the critical role of heat transfer in the successful functioning of fuel cells.
CO4	Understand different measurements for Battery Applications.
CO5	Design and implement effective thermal management strategies for modern applications involving batteries and fuel cells.

UNIT-I:

Introduction to battery management systems and devices, fuel Cells & Batteries, Nominal voltage and capacity, Energy and power.

BATTERY CELLS: Electrochemical and lithium-ion cells, Rechargeable cell, Charging and Discharging Process, Overcharge and Undercharge, Lithium-ion aging: Negative electrode, Lithium-ion aging: Positive electrode, Cell Balancing, Temperature Sensing, Current Sensing, BMS Functionality, High-voltage contactor control, Isolation sensing, Thermal control, Protection, Communication Interface, Range estimation, State-of charge estimation.

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UNIT-II:

Introduction – working and types of fuel cell – low, medium and high temperature fuel cell, liquid and methanol types, proton exchange membrane fuel cell solid oxide, hydrogen fuel cells – thermodynamics and electrochemical kinetics of fuel cells.

Basic Convective heat transfer and fluid flow, The fundamental of BTMS: Liquid cooling and Air cooling, Thermoelectric cooling, Heat Transfer Fluids in phase change materials, Heat Pipe (HP), Vapor compression, Direct refrigerant cooling Electric Motor Cooling.

UNIT-III:

Heat dissipations dependence on cold plate's channel's pattern, Heat dissipations dependence on the cold plate's number of channels and their shape, Heat dissipations dependence on the placement of the cooling plate.

High temperature batteries for back-up applications, Flow batteries for load levelling and large-scale grid application, Ni-Hydrogen batteries for space and marine applications.

UNIT-IV:

PHEV and BEV Battery Systems, Thermal Conductivity Measurements for EV Battery Applications, Battery State Estimation. EV Battery Cooling- challenges and solutions. Heat Exchanger Design and Optimization Model for EV Batteries using PCMs-system set up, selection of PCMs. Chevrolet Volt Model Battery, Thermal Management System - Case study. Modeling Liquid Cooling of a Li-Ion Battery Pack with software- simulation concepts.

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UNIT-V:

Fuel cell system-balance of plant-components required. Fuel cell power plant sizing problems-Fuel Cell Electric Vehicle, Fuel economy calculations-Battery EVs Vs Fuel Cell EVs, High pressure hydrogen tank, Boost convertor, NiMH Battery, Internal circulation system, Case studies-Battery and fuel cells, Challenges and Risks.

TEXT BOOKS:

1. Dincer, I., Hamut, H. S. and Javani, N., Thermal Management of Electric Vehicle Battery Systems, Wiley Network, 2017.
2. Hart A.B. and Womack G.J., "Fuel Cells – Theory and Applications", Chapman and Hall, 1967.

REFERENCES:

1. Andrea, D., Battery Management Systems for Large Lithium-Ion Battery Packs, Artech, 2010.
2. Söffker D., and Moulik, B., Battery Management System for Future Electric, Mdpi AG, 2020.
3. Linden D., and Reddy, T.S., Handbook of Batteries, 3rd Edition, McGraw-Hill, 2002.
4. Kiehne, H.A., Battery Technology Handbook, Marcel Dekker, NYC, 2003.
5. Nazri G.A., and Pistoia G., Lithium Batteries, Science and Technology, Kluwer Academic Publisher, 2003.
6. Husain, I., Electric and Hybrid Vehicles, Design: Fundamentals, 3rd Edition, CRC press, 2021.
7. Jiang, J., and Zhang, C., Fundamentals and Applications of Lithium-Ion Batteries in Electric Drive Vehicles, John Wiley & Sons, 2015.
8. Revankar, S.T., and Majumdar, P., Fuel Cells: Principles, Design, and Analysis, CRC press, 2014.
9. Sammes, N. ed., Fuel Cell Technology: Reaching Towards Commercialization, Springer Science & Business Media, 2006.

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M.TECH (THERMAL ENGINEERING)

MICRO AND NANO SCALE HEAT TRANSFER

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

CO1	Understand physics involved in fluid flow in micro scale fabricated systems and its applications.
CO2	Understand the conduction in integrated circuits and their constituent films.
CO3	Analyze the convective heat transfer in micro tubes and channels.
CO4	Analyze the heat transport at the nanoscale.
CO5	Understand the different analytical methods in nano scale heat transfer.

UNIT-I:

Introduction to microscale heat transfer - Observations on deviations from conventional theory – experimental and theoretical findings – Overview of studies and comparison of results – Introductory ideas about single phase, multiphase and gas flow in small channels – Contradictory observations and viewpoints in microchannel heat transfer- Applications of microscale heat transfer – basic ideas on micro heat exchangers and microscale heat sinks – applications in electronics cooling, biotechnology and MEMS.

UNIT-II:

Conduction in integrated circuits and their constituent films – current trends and future challenges – Microscale thermometry techniques – electrical and optical methods – thermo-reflectance thermometry – Thermal properties of amorphous dielectric films – Thermal characterization and heat transport in dielectric films – Heat conduction in crystalline silicon films – Phonon dispersion - heat conduction in semi-conductors at high temperatures – phonon transport equations – hot phonon effects.

UNIT-III:

Fundamentals of convective heat transfer in microtubes and channels – Thermodynamic concepts, general laws and particular laws - Governing equations and size effects. Single phase forced convection in microchannels – Flow structure – entrance length – experimental observations on flow and heat transfer characteristics – Theoretical investigations – Forced convection in mixtures - Gas flow in microchannels. Boiling and two- phase flow heat transfer in small channels – Boiling curve and critical heat flux - flow patterns – Bubble dynamics and thermodynamic aspects – Mathematical modeling and measurement of

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microscale convective boiling; Applications of microchannel heat transfer – microchannel heat sinks – micro heat pipes and micro heat spreaders – integration of microchannel heat sinks and heat spreaders to silicon structures – experimental and theoretical investigations.

UNIT-IV:

Fundamentals of heat transport at the nanoscale – characteristic lengths and heat transfer regimes – Nanoscale heat transfer phenomena – Conduction, radiation and convection in the nanoscale – Applications of nanoscale heat transfer in microelectronics, energy, nanomaterial synthesis, nano fabrication and biotechnology – Experimental methods in nanoscale heat transfer – thermophysical property measurement – heating and sensing based on microheaters and microsensors – Photothermal methods – Mixed optical and electrical heating methods.

UNIT-V:

Nanowires and carbon nanotubes – Thermal imaging – Analytical methods – Boltzmann equation approach and Monte Carlo Simulation for Boltzmann transport equation – The wave mechanisms - quantized incoherent transport, molecular dynamics simulation and the fluctuation-dissipation theorem approach – Multicarrier and Multidimensional Transport – coupled electron-phonon transport, multi length-scale and multidimensional transport – Challenges and Future applications.

TEXT BOOKS:

1. Ju, Y.S., and Goodson, K. , Microscale Heat Conduction in Integrated Circuits and their Constituent Films, Kluwer Academic Publishers, Boston, 1999.
2. Satish, K., Srinivas, G., Dongqing, L., Stephane, C., and Michael R. K., Heat Transfer and Fluid Flow in Minichannels and Microchannels, First Edition, Elsevier, 2005.

REFERENCES:

1. Garimella, S. V. and C. B. Sobhan, C. B., Transport in Microchannels – A Critical Review, in Annual Review of Heat Transfer, Begell House, NY, 2004.
2. Chen, G., Nanoscale Energy Transport and Conversion, Oxford University Press, 2005.
3. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2005.

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DESIGN OF HEAT TRANSFER EQUIPMENT

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

CO1	Understand different types of Heat Exchangers, and their applications in the process industry and be able to analyze their thermal performance.
CO2	Design various single-phase heat exchangers.
CO3	Design various Plate Type Heat Exchangers.
CO4	Apply the principles of boiling and condensation in the design of boilers and condensers.
CO5	Understand the principles and workings of various types of heat pipes.

UNIT-I:

Classification of heat exchangers and applications, Concept of overall heat transfer coefficient, fouling factor, LMTD, effectiveness, film coefficients for tubes and annuli, equivalent diameter of annuli, caloric temperature, true temperature difference. Regenerators and recuperates. Various methods in use: ϵ -NTU, P-NTU, MTD methods, ψ -P and P1-P2 methods, Δ -II Method.

Thermal design of regenerators, compact heat exchangers. Design calculation of double pipe heat exchanger, double pipe exchangers in series-parallel arrangement.

UNIT-II:

Shell and Tube Heat Exchangers-Tube layouts, baffles, classification of shell and tube heat exchangers, TEMA standards. Design calculation of shell and tube heat exchangers-shell side film coefficient, shell-side equivalent diameter, True temperature difference in a 1-2 exchanger, shell and tube sides pressure drops; Performance analysis of 1-2 heat exchangers, flow arrangements for increased heat recovery.

UNIT-III:

PLATE HEAT EXCHANGERS: Mechanical features-plate pack and the frame. Plate types; Advantages and performance limits, passes and flow arrangements, Heat transfer and pressure drop calculations. Basics of compact heat exchangers: heat transfer enhancement, plate-fin heat exchangers, tube-fin heat exchangers.

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UNIT-IV:

PRINCIPLES OF CONDENSERS AND BOILERS: Condensers, Types of condensers, Heat transfer fundamentals of condensers, Nusselt theory of laminar film wise condensation; Thermal design of shell and tube condensers, Condensation outside and inside of horizontal tubes, Condensation outside and inside vertical tubes, Empirical correlations;

BOILERS- fundamentals and types of boiling, Various empirical correlations pertaining to flow boiling.

UNIT-V:

HEAT PIPES: Types and applications, operating principle, Working fluids, Wick structures, Pressure balance, Effective thermal conductivity of wick structures, Heat pipe limits, Heat pipe design procedure, Nonconventional heat pipes, Micro heat pipes, cryogenic heat pipes, pulsating heat pipes.

TEXT BOOKS:

1. Kern, D.Q., and Kern, D.Q., Process Heat Transfer, McGraw-Hill, 1950.
2. Shah, R.K., and Sekulic, D.P., Fundamentals of Heat Exchanger Design, John Wiley & Sons, 2003.

REFERENCES:

1. Kakac, S., Liu, H., and Pramuanjaroenkij, A., Heat Exchangers: Selection, Rating, and Thermal Design, CRC Press, 2020.
2. Chi, S. W., Heat Pipe Theory and Practice- A Source Book, McGraw-Hill, 1976.
3. Fraas, A. P., Heat Exchanger Design, John Wiley & Sons, 1989.
4. Dunn, P.D., and Reay, D.A., Heat Pipes, Pergamon, 1994.

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VALUE EDUCATION

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

CO1	Understand the importance of values and self-development.
CO2	Learn the importance of Human value and Discipline
CO3	Develop the overall personality and behavior.
CO4	Imbibe good values in student and emerge as responsible citizens.
CO5	Understand the different religious faiths, knowing the importance of character, self-management and contribute in building a healthy nation.

UNIT I

Values and self-development –Social values and individual attitudes, Work ethics, Indian vision of humanism, Moral and non- moral valuation. Standards and principles, Value judgments.

UNIT II

Importance of cultivation of values, Sense of duty. Devotion, Self-reliance. Confidence, Concentration.

Truthfulness, Cleanliness, Honesty, Humanity, Power of faith, National Unity, Patriotism, Love for nature, Discipline

UNIT III

Personality and Behavior Development - Soul and Scientific attitude, Positive Thinking. Integrity and discipline, Punctuality, Love and Kindness, Avoid fault Thinking, Free from anger, Dignity of labour, Universal brotherhood and religious tolerance, True friendship.

UNIT IV

Happiness Vs suffering, love for truth, Aware of self-destructive habits, Association and Cooperation. Doing best for saving nature.

UNIT V

Character and Competence –Holy books vs Blind faith, Self-management and Good health, Science of reincarnation, Equality, Nonviolence ,Humility, Role of Women, All religions and same message, Mind your Mind, Self-control, Honesty, Studying effectively.

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TEXT BOOK:

1 Chakroborty, S.K. “Values and Ethics for organizations Theory and practice”, Oxford University, Press, New Delhi

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COMPUTATIONAL FLUID DYNAMICS LAB

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

CO1	Develop codes for solution of algebraic and differential equations
CO2	Develop skills in the actual implementation of CFD methods with their own codes
CO3	Analyze real-life engineering applications with the help of CFD.
CO4	Design thermal engineering equipment using CFD

Using any Programming Language, code the following methods with an example:

1. Solution of 1-D parabolic equations
 Explicit (FTCS, DuFort-Frankel)
 Implicit (Laasonen)
2. Fin problem with insulated and Convective end
3. Couette Problem with and without pressure Gradient
4. Solution of Elliptic Equations
 With Point Gauss-Seidel method
 With Point Successive Over Relaxation Method

 ■ Examples: (i) Temperature Distribution over a rectangular plate with different Boundary conditions on the sides.
5. Solution of Parabolic Equations
6. Solution of Linear Hyperbolic Equations.
 Using upwind and Lax explicit methods
 Using BTCS and Crank-Nicolson implicit methods

 ■ Examples: Wave propagation at a high altitude

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7. Solution of Nonlinear Hyperbolic Equations.

Lax Method

MacCormack Method

- Examples: Shock Tube Problem ➤ Solution of Incompressible NSEs Vorticity-Stream function formulation

8. Primitive Variable Formulation

- Examples:

- Lid Driven Cavity Problem
- Mass entering and leaving a square chamber

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THERMAL SIMULATION LABORATORY

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

CO1	Formulate problems in fluid flow and heat transfer
CO2	Analyse the influence of non-dimensional parameters for heat transfer problems
CO3	Solve real life thermal engineering problems using CFD package
CO4	Design thermal engineering equipment using CFD package

LIST OF EXPERIMENTS: To perform the Simulation of the following using a CFD Package:

1. Couette flow and draw the velocity profiles
2. Hagen-Poiseuille flow and draw the velocity profiles
3. Unsteady simulation of compressible flow of air through 2D a convergent – Divergent nozzle
4. **HEAT CONDUCTION THROUGH A SLAB:** To analyze the temperature distribution and hot spot temperature for a slab with different boundary conditions.
5. **LUMPED HEAT CAPACITY MODEL:** To revisit the concept of lumped heat capacity analysis via numerical analysis and predict the temperature with time.
6. **LAMINAR PIPE FLOW:** To list out the assumptions, governing equations and non-dimensional parameters for laminar flow through the pipe. Develop the numerical solution using the CFD package and compare the results with analytical solutions.
7. **LID DRIVEN CAVITY:** To list out the assumptions, governing equations and non-dimensional parameters for lid driven flow in a cavity. Develop the numerical solution using the CFD package and compare the results with published research articles.
8. **NATURAL CONVECTION IN A CAVITY (STEADY STATE):** To list out the assumptions, governing equations and non-dimensional parameters for differentially heated cavity and analyze buoyancy induced flow. Develop the numerical solution using the CFD package and compare the results with published research articles.
9. **NATURAL CONVECTION IN A CAVITY (UNSTEADY):** To list out the assumptions, governing equations and non-dimensional parameters for differentially heated cavity and analyze buoyancy induced flow with time. Develop the numerical solution using the CFD package and compare the results with published research articles.

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10. **TURBULENT PIPE FLOW:** To understand the basics of turbulence and turbulence flow models. To list out the assumptions and governing equations for turbulent flow
11. through the pipe. Develop the numerical solution using the CFD package and compare the results with the literature.
12. **FLOW OVER CYLINDER:** To understand the basics of external flows and flow separation. To list out the assumptions, governing equations and non-dimensional parameters for laminar flow over the cylinder. Develop the numerical solution using the CFD package and analyze the phenomena of vortex shedding by comparing the results with published research articles.
13. **HEAT TRANSFER IN POROUS MEDIA:** To understand the basics and formulations of porous media. To list out the assumptions, governing equations and non-dimensional parameters for buoyancy induced flow in a differentially heated porous cavity. Develop the numerical solution using the CFD package and compare the results with the literature.
14. **CONJUGATE HEAT TRANSFER PROBLEM:** To analyze the thermal transport for the combined solid and fluid domains.

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ENERGY CONSERVATION, MANAGEMENT AND AUDIT

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

CO1	Identify and assess the energy conservation/saving opportunities in Global and National Energy Scenario.
CO2	Identify and assess energy conservation opportunities in different Thermal systems.
CO3	Demonstrate skills required for energy audit and management
CO4	Understand the different energy policies of the industry.
CO5	Suggest cost-effective measures towards improving energy efficient and energy conservation.

UNIT 1:

GLOBAL AND NATIONAL ENERGY SCENARIO: Energy consumption in various sectors, Energy resources like Coal, Oil, and Natural Gas –their demand and supply management, Indian energy scenario, Indian Coal & LPG scenario, Primary and Secondary Sources of Energy, Commercial and Non-Commercial Sources, India's installed energy capacity, per capita energy consumption. General aspects of Energy conservation and management, Roles of energy auditors, Roles of an energy manager, Energy policy of industry, Energy Conservation Act and its amendments, PAT Scheme

UNIT 2:

ENERGY EFFICIENCY IN BOILER, STEAM, AND FURNACE SYSTEM UTILITIES: Energy conservation opportunities in boiler systems, retrofitting of FBC in conventional boilers, Steam line distribution standard practices including sizing and layouts, selection, operation, maintenance of steam traps, and energy-saving opportunities in steam systems.

UNIT 3:

ENERGY EFFICIENCY IN FURNACES AND REFRACTORIES: (06 Hours) Sankey diagram, Fuel economy measures in furnaces Insulation and Refractories: Types of insulations, Economic thickness of insulation, Typical refractories for industrial applications. Benchmarking in Glass and Steel Industries.

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UNIT 4:

COGENERATION: Principle of cogeneration, Technical options for cogeneration, Factors influencing cogeneration choice, Important technical parameters for cogeneration, case study on savings with and without cogeneration

UNIT 5:

ENERGY CONSERVATION IN FANS, BLOWERS COMPRESSORS, AND PUMP SYSTEMS: Energy-saving opportunities, performance evaluation and efficient system operation. Air Systems: Efficient operation of the compressed air system, Leakage tests. Pumps and Pumping Systems: Pump curves, factors affecting pump performance, Energy loss in throttling, Effects of impeller diameter change, Flow control strategy, Variable speed drives, and Energy conservation opportunities. Energy Conservation in HVAC and Cooling Towers

TEXT BOOKS:

1. General Aspects of Energy Conservation, Management and Audit: Guide Book for Energy Managers and Energy Auditors; Bureau of Energy Efficiency, Ministry of Power
2. Energy Efficiency in Electrical Utilities: Guide Book for Energy Managers and Energy Auditors; Bureau of Energy Efficiency, Ministry of Power

REFERENCES:

1. Energy Efficiency in Thermal Utilities: Guide Book for Energy Managers and Energy Auditors; Bureau of Energy Efficiency, Ministry of Power
2. Roosa, S. A., Energy Management Handbook, 2018, Publisher: Fairmont Press.
3. Turner, W. C., Energy Management Handbook, 3rd Edition, Publisher: Prentice Hall, 2000.

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NON-NEWTONIAN FLUID DYNAMICS

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

CO1	Understand the physics behind the flow behavior of various non-Newtonian fluid systems.
CO2	Apply fundamentals of rheology to examine non-Newtonian fluid flow problems.
CO3	Understand the theory behind mechanical rheometry, perform standard rheology tests, and interpret experimental data.
CO4	Formulate and solve the governing equations applicable to generalized non-Newtonian and viscoelastic fluids.
CO5	Understand the complex fluid flow in different devices

UNIT-I:

NON-NEWTONIAN FLUID BEHAVIOUR: Time-independent fluid behaviour, Time-dependent fluid behaviour, Viscoelastic fluid behavior, Dimensional considerations for viscoelastic fluids.

COMPLEX FLUIDS: examples, Pertinent length scales, Common features & applications.

Basic forces, Energies and timescales in complex fluids: Van Der Waals interactions, electrostatic interactions, hydrogen bonding, excluded volume interactions, relaxation phenomena in complex fluids.

UNIT-II:

RHEOLOGY FUNDAMENTALS: rheological properties, flow behaviour and viscosity, elastic behaviour and shear modulus.

TYPICAL RHEOLOGICAL BEHAVIOURS: shear-thinning/thickening, yield stress, visco-plastic models, linear viscoelasticity, nonlinear viscoelasticity, Maxwell model, Kelvin-Voight model.

UNIT-III:

FLOW PHENOMENA IN COMPLEX MATERIALS AND MICROSTRUCTURE:

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stress and strain rate, velocity gradient and strain rate Relevant basics of Tensor calculus, Constitutive equations: general principles, inelastic models and linear viscoelasticity, steady visco-metric flows, mechanical models (Kelvin, Maxwell), general linear viscoelastic model, generalized Maxwell model.

NONLINEAR VISCOELASTICITY: scalar invariants of the stress tensor, frameinvariance, simple nonlinear viscosity models.

UNIT-IV:

FINITE MEASURES OF STRAIN: Cauchy and Finger tensor, Oldroyd's constitutive equation: convected time derivatives, upper-convected Maxwell model, Computational Methods.

SHEAR RHEOMETRY: drag flows, pressure-driven flows, Extensional rheometry: free-surface flows, confined flows. Rheometer design, rotational rheometer demonstration, different measurement systems, Inverse problems in rheometry.

UNIT-V:

COMPLEX FLUID RHEOMETRY: Rotational tests, relaxations tests, oscillatory tests. Applications of non-Newtonian fluid rheology: suspension rheology, rheology of polymer solutions, rheology of printing inks in additive manufacturing. Flow of complex fluids in microfluidic devices, Rheo-optics, Rheo-chemistry.

TEXT BOOKS:

1. Macosko, C. W., Rheology: Principles, Measurements, and Applications, Wiley-VCH, 1994.
2. Phan-Thien, N., and Mai-Duy, N., Understanding Viscoelasticity: An Introduction to Rheology, 3rd Edition, Springer, AG, 2017.

REFERENCES:

1. Larson, R. G., The Structure and Rheology of Complex Fluids, Oxford University Press, 1999.
2. Barnes, H.A., Hutton, J.F. and Walters, K., An Introduction to Rheology, Elsevier, 1989.
3. Mewis, J. and Wagner, N.J., Colloidal Suspension Rheology, Cambridge University Press, 2012.

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OPTIMIZATION TECHNIQUES

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

CO1	Understand the classification of Optimization problem and solution of one dimensional optimization methods.
CO2	Understand Multi variable non-linear optimization.
CO3	Solve integer programming problem by either geometry cutting plane algorithm or branch and bound method.
CO4	Formulate and Solve Geometric Programming model.
CO5	Solve the optimization problem by Non-Traditional Algorithms.

UNIT- I:

INTRODUCTION: Engineering Applications of optimization- statement of an optimization problem – Classification of optimization problems. Single Variable Non-Linear Unconstrained Optimization: One dimensional Optimization methods:- Uni-modal function, elimination methods, Fibonacci method, golden section method, interpolation methods – quadratic and cubic interpolation methods.

UNIT- II:

MULTI VARIABLE NON-LINEAR UNCONSTRAINED OPTIMIZATION: Direct search method – Univariate method - pattern search methods – Powell's- Hook -Jeeves, Rosenbrock search methods- gradient methods, gradient of function, steepest descent method, Fletcher Reeves method, variable metric method. Linear Programming – Graphical method- Simplex method- Dual simplex method, Revised simplex method- Parametric linear programming- Goal Programming Simulation- types of simulations- Applications of simulations to inventory, queuing and thermal systems.

UNIT- III:

Integer Programming- Introduction – formulation – Gomory cutting plane algorithm – Zero or one algorithm, branch and bound method Stochastic Programming: Basic concepts of probability theory, random variables distributions-mean, variance, correlation, co variance, joint probability distributions stochastic linear, dynamic programming.

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UNIT- IV:

GEOMETRIC PROGRAMMING: Posynomials – arithmetic - geometric inequality – unconstrained G.P- constrained G.P

UNIT- V:

NON-TRADITIONAL OPTIMIZATION ALGORITHMS: Genetics Algorithm-Working Principles, Similarities and Differences between Genetic Algorithm and Traditional Methods. Simulated Annealing- Working Principle-Simple Problems. Application in production problems.

TEXT BOOKS:

1. S.S. Rao, Optimization Theory and Applications, 2nd Edition, New Age International Publishers
2. Kalyanmoy Deb, Optimization for Engineering Design, PHI Publishers

REFERENCES:

1. S.D.Sharma ,Operations Research.
2. H.A.Taha ,Operation Research,TMH
3. R.LRardin ,Optimization in operations research.
4. Belagundu&Chandraputla, Optimization Techniques, Pearson Asia.
5. M.C.Joshi, K.M.Moudgalya ,Optimization Techniques theory and practice, Narosa Publications

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M.TECH (THERMAL ENGINEERING)

ELECTRONIC COOLING TECHNOLOGIES
(OPEN ELECTIVE)

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

CO1	Understand the basics of heat transfer and analyze heat transfer through fins
CO2	Acquire the knowledge on Free and forced convective systems
CO3	Understand the air cooling and single phase liquid cooling systems with case studies
CO4	Demonstrate the concepts of Two phase cooling and heat pipes
CO5	Understand thermo electric coolers, mini and micro channels

UNIT 1:

INTRODUCTION OF HEAT TRANSFER: Modes – Conduction, Convection and Radiation – Basic Laws – Applications of Heat Transfer

BASICS OF CONDUCTION –Conduction equation – Thermal analogy – Lumped heat capacity analysis - Heat conduction with phase change - Thermal Resistance – Extended Surfaces – Uniform cross section fins – Fin efficiency – Selection and design of fins

UNIT 2:

FORCED AND FREE CONVECTION – Heat transfer coefficient - Parameters effecting heat transfer – Thermal Properties of fluids - Combined Modes

RADIATION – Stefan- Boltzmann Law – Kirchoff's law and Emissivity – Radiation between Black Isothermal Surfaces – Radiation between Grey Isothermal Surfaces – Extreme Climatic conditions - Radiation at normal ambient Temperature measurement and its Instrumentation

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UNIT 3:

PRINTED CIRCUIT BOARDS – Chip packaging – thermal Resistance – Board Cooling methods – Board thermal Analysis – Equivalent thermal Conductivity

Air Cooling – Fans – Heat transfer Enhancement – Air handling systems - Blowers

Single Phase Cooling – Coolant Selection – Natural Convection – Forced Convection - Air Cooling - Convective cooling in Small systems – Forced cooling in medium and large systems – Liquid cooling in high power modules – Case Studies

UNIT 4:

Two-Phase Cooling – Direct Immersion Cooling – Basics of Pool Boiling – Enhancement of Pool Boiling – Flow Boiling

Heat Pipes – Operation Principles – Useful Characteristics – Operating Limits and Temperatures – Operation Methods – Applications – Micro Heat Pipes.

UNIT 5:

THERMOELECTRIC COOLERS: Basics theories – Thermo electric effect – Operation Principles

Phase change materials, Thermal Interface materials, Heat Spreaders and Heat Sinks – Working Principles Mini and Micro Channels. Use of nano fluids in electronic cooling

TEXT BOOKS:

1. Allan D. Kraus and Avram Bar Cohen, Thermal Analysis and Control of Electronic Equipment ,1983, McGraw Hill, New York, NY.

REFERENCES:

1. Rao Tummala(ed), Fundamentals of Microelectronics Packaging ,2001, McGraw Hill, New York, NY.
2. James W. Dally, Packaging of Electronic Systems ,1990, McGraw Hill, New York, NY.

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RENEWABLE SOURCES OF ENERGY
(OPEN ELECTIVE)

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

CO1	Identify the renewable energy sources, their utilization, and storage and evaluate the energy conversion from ocean thermal energy.
CO2	Understand the basic concepts of solar radiation and analyze the solar thermal systems for their utilization and the principle of working of solar cells.
CO3	Understand the Wind energy systems and its components with basic working principles.
CO4	Analyze Bio energy and Bio mass systems.
CO5	Narrate the importance and potential of geo thermal energy and Integrated power generation systems.

UNIT-I

INTRODUCTION: Energy and development, energy demand and availability, energy crisis, conventional and non-conventional sources, renewable and non-renewable energy resources, environmental impact of conventional energy usage, basic concepts of heat and fluid flow useful for energy systems.

ENERGY FROM THE OCEANS: OTEC systems, open and closed types; Wave energy conversion systems; Tidal energy conversion systems.

UNIT II

SOLAR ENERGY: Solar radiation at the earth's surface – solar radiation measurements – estimation of average solar radiation - solar thermal flat plate collectors - concentrating collectors – solar thermal applications - heating, cooling, desalination, drying, cooking, etc – solar thermal electric power plant - principle of photovoltaic conversion of solar energy, types of solar cells - Photovoltaic applications: battery charger, domestic lighting, street lighting, water pumping etc - solar PV power plant – Net metering concept.

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UNIT III

WIND ENERGY: Nature of the wind – power in the wind – factors influencing wind – wind data and energy estimation - wind speed monitoring - wind resource assessment - Betz limit - site selection - wind energy conversion devices - classification, characteristics, applications – offshore wind energy – Hybrid systems - safety and environmental aspects – wind energy potential and installation in India - Repowering concept.

UNIT IV

BIO-ENERGY: Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - direct combustion – biomass gasification - pyrolysis and liquefaction – biochemical conversion - anaerobic digestion - types of biogas Plants - applications - alcohol production from biomass – bio diesel production – Urban waste to energy conversion - Biomass energy programme in India.

UNIT-V:

MICRO AND SMALL HYDRO ENERGY SYSTEMS: Resource assessment of micro and small hydro power, micro, mini and small hydro power systems, economics, pump as turbine, special engines for low heads, velocity head turbines, hydrams, water mills.

GEOTHERMAL ENERGY SYSTEMS: Vapor dominated, liquid dominated and petrothermal systems; Hybrid systems.

INTEGRATED ENERGY SYSTEMS: Concept of integration of conventional and non-conventional energy resources and systems; integrated energy system design and economics.

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TEXT-BOOKS:

1. Non conventional Energy Resources, B.H.Khan, Tata McGraw Hill, New Delhi, 2017, 3rd edition.
2. Energy Technology: Non-Conventional, Renewable and Conventional, S.Rao and B.B.Parulekar, Khanna Publishers, 2010, 1st Edition.

REFERENCES:

1. Duffie, J.A. and Beckman, W.A., "Solar Engineering of Thermal Processes", John Wiley., 2006
2. Bungay, H.R., "Energy, the Biomass Option", John Wiley. , 1981
3. Fowler, K.M., "Energy & Environment", McGraw Hill. , 1984
4. Sukhatme, S.P. and Nayak, J.K., "Solar Energy: principles of thermal collection and storage", McGraw Hill., 2009
5. Boyle, G., "Renewable Energy – Power for a Sustainable Future", 2nd Ed., Oxford University Press., 2010.

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OPTIMIZATION TECHNIQUES
(OPEN ELECTIVE)

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

CO1	Understand the classification of Optimization problem and solution of one dimensional optimization methods.
CO2	Understand Multi variable non-linear optimization.
CO3	Solve integer programming problem by either geometry cutting plane algorithm or branch and bound method.
CO4	Formulate and Solve Geometric Programming model.
CO5	Solve the optimization problem by Non-Traditional Algorithms.

UNIT- I:

INTRODUCTION: Engineering Applications of optimization- statement of an optimization problem – Classification of optimization problems. Single Variable Non-Linear Unconstrained Optimization: One dimensional Optimization methods:- Uni-modal function, elimination methods, Fibonacci method, golden section method, interpolation methods – quadratic and cubic interpolation methods.

UNIT- II:

MULTI VARIABLE NON-LINEAR UNCONSTRAINED OPTIMIZATION: Direct search method – Univariate method - pattern search methods – Powell's- Hook -Jeeves, Rosenbrock search methods- gradient methods, gradient of function, steepest descent method, Fletcher Reeves method, variable metric method. Linear Programming – Graphical method- Simplex method- Dual simplex method, Revised simplex method- Parametric linear programming- Goal Programming Simulation- types of simulations- Applications of simulations to inventory, queuing and thermal systems.

UNIT- III:

Integer Programming- Introduction – formulation – Gomory cutting plane algorithm – Zero or one algorithm, branch and bound method Stochastic Programming: Basic concepts of probability theory, random variables distributions-mean, variance, correlation, co variance, joint probability distribution stochastic linear, dynamic programming.

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UNIT- IV: GEOMETRIC PROGRAMMING: Posynomials – arithmetic - geometric inequality – unconstrained G.P- constrained G.P

UNIT- V:

NON-TRADITIONAL OPTIMIZATION ALGORITHMS: Genetics Algorithm-Working Principles, Similarities and Differences between Genetic Algorithm and Traditional Methods. Simulated Annealing- Working Principle-Simple Problems. Application in production problems.

TEXT BOOKS:

1. S.S. Rao, Optimization Theory and Applications, 2nd Edition, New Age International Publishers
2. Kalyanmoy Deb, Optimization for Engineering Design, PHI Publishers

REFERENCES:

1. S.D.Sharma ,Operations Research.
2. H.A.Taha ,Operation Research,TMH
3. R.LRardin ,Optimization in operations research.
4. Belagundu&Chandraputla, Optimization Techniques, Pearson Asia.
5. M.C.Joshi, K.M.Moudgalya ,Optimization Techniques theory and practice, Narosa Publications

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R23 M.Tech (THERMAL ENGINEERING)**

MINUTES OF BOS MEETING.

The meeting was held on 11-09-2023 through online mode

Resolutions:

1. The BoS members reviewed and finalized the Program Educational Objectives of the Thermal Engineering Specialization. The PEO's and Mission Statements of the Department are mapped.
2. The BoS board of Thermal Engineering discussed the modifications in R23 regulations with respect R19 regulations. The main modifications are:
 - (i) Integrated course is introduced in I and II Semester in place of a subject and a Laboratory.
 - (ii) Compulsory internship is introduced in the summer break of First year.
3. Advanced Heat Transfer and Computational Fluid Dynamics are finalised as the integrated courses in I and II Semesters respectively.
4. English for Research Paper writing and Value Education are the Audit courses finalised for I and II Semester Subjects.
5. The Program Core subjects, Program Electives, Open Elective Subjects and the laboratories are decided, and Course structure is finalised.
6. For the finalised course structure, detailed discussion happened to construct the appropriate syllabus, modified thoroughly taking the industrial and academic feedback into consideration and finalised the syllabus for all the subjects.

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