DEPARTMENT OF MECHANICAL ENGINEERING

M.TECH. (THERMAL SYSTEMS DESIGN)

SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY
Ichchhanath, Surat-395007, Gujarat, India
www.svnit.ac.in

MISSION & VISION STATEMENT OF INSTITUTE

Vision statement

To be one of the leading technical institutes disseminating globally acceptable education, practical industrial training, and relevant research output.

Mission statement

To be a globally accepted centre of excellence in technical education catalysing absorption, innovation, diffusion, and transfer of high technologies resulting in enhanced quality for all the stakeholders.

MISSION & VISION STATEMENT OF THE DEPARTMENT

Vision statement

Department of Mechanical Engineering, Sardar Vallabhbhai National Institute of Technology, Surat perceived to be a globally accepted centre of quality technical education based on innovation and academic excellence.

Mission statement

Department of Mechanical Engineering, Sardar Vallabhbhai National Institute of Technology, Surat, strives to disseminate technical knowledge to its undergraduate, postgraduate, and research scholars to meet the intellectual, ethical, and career challenges for sustainable growth of humanity, nation, and global community.

Programme Educational Objectives (PEOs)

Master of Technology in Thermal Systems Design imbibes in student's excellent technical capabilities in thermal engineering and allied systems, practical communication skills, ensuring successful careers, and continuing their professional advancement through life-long learning.

The program educational objectives of the Master of Technology in Thermal Systems Design

PEO1: Prepare students with good analytical, computational, and experimental skills to solve thermal-engineering-related problems.

PEO2: Possess a high level of technical competency combined with research and problem-solving ability to generate innovative solutions in thermal engineering or related areas.

PEO3: Enjoy a successful career in industry and academia with an ethic for lifelong learning.

PEO4: Inculcate high professionalism and ethical standards, effective technical presentation, and writing skills, and work as a team on research projects.

Programme Outcomes (POs)

The graduates of M. Tech. (Thermal System Design) will demonstrate an ability to:

PO1	Carry out independent research /investigation and development work to solve practical problems
PO2	Write and express a substantial technical report/document
PO3	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 the appropriate bachelor program
PSO1:	Design, analyse and solve thermo-fluid problems using modern tools and techniques.
PSO2:	Formulate and devise innovative and sustainable solutions to thermal engineering and allied problems.

Teaching Scheme M. Tech.-I (Thermal Systems Design)

Semester-I

Sr. No.	Course	Code	Credits	Teaching Scheme			Examination Scheme			Total
				L	T	P	L	T	P	
1	**Core-1** Numerical Methods and Computations	METD101	4	3	1	0	100	25	0	125
2	**Core-2** Advanced Thermodynamics	METD102	4	3	1	0	100	25	00	125
3	**Core-3** Transport Phenomena -I	METD103	4	3	1	0	100	25	00	125
4	**Core Elective-1** • Design of Refrigeration and Air-conditioning systems • Bio-Mass Conversion Systems • Electro-Chemical Energy Storage Systems • Environmental Pollution and Control • Jet and Rocket Propulsion	METD110 METD111 METD112 METD113 METD114	3	3	0	0	100	0	00	100
5	**Core Elective-2** • Electric Vehicles and Advanced IC Engines • Gas Dynamics and Compressible Fluid Flow • Analysis and Design of Thermal Turbo Machines • Measurements and Data Analysis in Thermal Engineering • Finite Element Method in Thermal Engineering	METD120 METD121 METD122 METD123 METD124	3	3	0	0	100	0	00	100
6	Computational Laboratory – 1	METD104	2	0	0	4	0	0	100	100
7	Experimental Laboratory -1	METD105	2	0	0	4	0	0	100	100
	Total		**22**	**15**	**03**	**08**	**500**	**75**	**200**	**775**
	Total Contact Hours per week			**26**			**-**	**-**	**-**	**-**

Semester-II

Sr. No.	Course	Code	Credits	Teaching Scheme			Examination Scheme			Total
				L	T	P	L	T	P	
1	**Core-4** Transport Phenomena -II	METD201	4	3	1	0	100	25	00	125
2	**Core-5** Energy conversion systems	METD202	4	3	1	0	100	25	00	125
3	**Core Elective -3** • Design of Heat Exchangers • Theory and Design of Cryogenic Systems • Combustion • Biofluidic and Bioheat Transfer • Turbulence and Turbulent Flows	METD230 METD231 METD232 METD233 METD234	3	3	0	0	100	0	00	100
4	**Core Elective-4** • Renewable Energy Systems • Flow and Flame Diagnostics • Transport in Porous Media • Nanofluid and Its Applications in Thermal Systems • Industrial Refrigeration	METD240 METD241 METD242 METD243 METD244	3	3	0	0	100	0	00	100
5	**Institute Elective** • Computational Fluid Dynamics • Optimization techniques • Energy Conservation, Management and Audit • Fundamentals of Electric Vehicles	METD210 METD211 METD212 METD213	3	3	0	0	100	0	00	100
6	Computational Laboratory – 2	METD203	2	0	0	4	0	0	100	100
7	Experimental Laboratory - 2	METD204	2	0	0	4	0	0	100	100
	Total		**21**	**15**	**2**	**8**	**500**	**50**	**200**	**750**
	Total Contact Hours per week			**25**			**-**	**-**	**-**	**-**

Semester - III

Sr. No.	Course	Code	Credit	Teaching Scheme			Examination Scheme			Total
				L	T	P	L	T	P	
1.	Dissertation Preliminaries	METD301	6	0	0	12	0	0	300	300
2.	Seminar	METD302	2	0	0	4	0	0	100	100
	Total		08	0	0	16	0	0	400	400

Semester - IV

Sr. No.	Course	Code	Credit	Teaching Scheme			Examination Scheme			Total
				L	T	P	L	T	P	
1.	Dissertation	METD401	12	0	0	24	0	0	600	600

Total Credits: 22 + 21 + 08 + 12 = 63 credits

Credit Matrix

Category	Credit to be earned				
	Sem - I	Sem – II	Sem – III	Sem – IV	Total
Core Courses	12	08	-	-	20
Elective Courses	06	09	-	-	15
Software/Laboratory	04	04	-	-	08
Seminar	-	-	02	-	02
Dissertation	-	-	06	12	18
Total Credits	22	21	08	12	**63**

DEPARTMENT OF MECHANICAL ENGINEERING

POOL OF ELECTIVES FOR ALL P.G. PROGRAMS

<table>
<tr><th colspan="2"><u>SEMESTER-I</u></th></tr>
<tr><th>CORE ELECTIVE-1</th><th>CORE ELECTIVE-2</th></tr>
<tr><td>1. Additive Manufacturing
2. Advanced Mechanical Vibrations
3. Advanced Mechanics of Solids
4. Advanced Welding Technology
5. Atomization and Sprays
6. Bio-Mass Conversion Systems
7. CAD for Manufacturing
8. Combustion
9. Concurrent Engineering: Tools, Techniques & Applications
10. Condition Monitoring and Fault Diagnosis of Rotating Machinery
11. Design of Reacting Systems
12. Electrical Vehicles and Advanced IC Engines
13. Electro-Chemical Engineering Storage
14. Environmental Pollution and Control
15. Industrial Tribology
16. Measurement and Data Analysis
17. Manufacturing Metallurgy
18. Material Characterization and Testing
19. Metal Cutting and Tool Design
20. Nonlinear Dynamics and Chaos
21. Power Plant Engineering
22. Product Design & Development
23. Theory of Plasticity</td><td>1. Advanced Metrology and Computer Aided Inspection
2. Analysis and Design of Thermal Turbo Machines
3. Computational Fluid Dynamics
4. Computer Aided Production Planning
5. Concurrent Engineering
6. Design of Pressure Vessels
7. Design of Refrigeration and Air Conditioning Systems
8. Electrical Vehicles and Advanced IC Engines
9. Energy and Exergy Analysis of Turbomachines
10. Failure Analysis & NDE
11. Finite Element Method in Thermal Engineering
12. Fracture Mechanics
13. Gas Dynamics and Compressible Fluid Flow
14. Hydrogen Energy Applications to Propulsion and Future Modes of Transport
15. Industrial Robotics
16. Jet and Rocket Propulsion
17. Measurements and Data Analysis in Thermal Engineering
18. Operation Planning and Control
19. Optimization Techniques
20. Rotor Dynamics, Vibration and Stress Analysis
21. Sensors in Manufacturing Systems
22. Unconventional Turbomachines</td></tr>
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DEPARTMENT OF MECHANICAL ENGINEERING

POOL OF ELECTIVES FOR ALL P.G. PROGRAMS

<table>
<tr><th colspan="2"><u>SEMESTER-II</u></th></tr>
<tr><th>CORE ELECTIVE-3</th><th>CORE ELECTIVE-4</th></tr>
<tr><td>1. Advanced Welding Technology
2. Automation in Manufacturing
3. Bio fluidic and Bio Heat Transfer
4. Cascade Aerodynamics
5. Combustion
6. Composite Design and Manufacturing
7. Computational Fluid Dynamics
8. Computer Aided Tool Design
9. Condition Monitoring and Fault Diagnosis of Rotating Machinery
10. Design of Heat Exchangers
11. Design of Pressure Vessel & Piping
12. Finite Elements Methods
13. Industrial Tribology
14. Instrumentation and Experimental Methods
15. Laser Based Micro Manufacturing
16. Lifecycle Analysis of Turbomachines
17. Metal Cutting
18. Micro Hydro Turbine
19. Quality Engineering and Management
20. Renewable Energy Systems
21. Smart Materials & Manufacturing
22. Theory and Design of Cryogenic Systems
23. Turbulence and Turbulent Flows</td><td>1. Combustion
2. Concurrent Engineering
3. Design of Heat Exchangers
4. Flow & Flame Diagnostics
5. Fundamentals of Solid Propellant and Multi-Phase Combustion
6. Hydrodynamic Stability
7. Industrial Refrigeration
8. Industrial Tribology
9. Mechanics of Composite Laminates
10. Mechanics of Composite Materials
11. Nanofluids and its Applications in Thermal Systems
12. Non Destructive Techniques
13. Numerical Methods in Manufacturing
14. Operations Research
15. Optimization Techniques
16. Quality Engineering and Management
17. Surface Engineering
18. Theory of Elasticity and Plasticity
19. Thermo-Acoustic Instabilities
20. Transport in Porous Media
21. Turbulent Combustion</td></tr>
</table>

METD101	:	NUMERICAL METHODS AND COMPUTATIONS	L	T	P	Credits
			3	1	0	04

1. COURSE OUTCOMES (COs):

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

CO1	Understand the fundamental of numerical methods and applications in engineering problems
CO2	Implement solution procedures for solving linear and non-linear algebraic equations
CO3	Learn how to solve definite integrals using cubic spline, Romberg and initial value problems, and boundary value problems numerically.
CO4	Solve ordinary differential equations (ODEs) and partial differential equations (PDEs) on a computer.
CO5	Acquire working knowledge of computational complexity, accuracy, stability, and errors in solution procedures
CO6	Solve one-dimensional optimization problems using optimization algorithm.

2. SYLLABUS:

- **INTRODUCTION** **(03 Hours)**
  Introduction to Computer-Aided Engineering Analysis, Measuring Errors, Sources of Error, Binary Representation of Numbers, Taylor Theorem Revisit

- **DIFFERENTIATION** **(04 Hours)**
  Primer on Differential Calculus, Differentiation of Continuous Functions, Differentiation of Discrete Functions

- **NONLINEAR EQUATIONS** **(04 Hours)**
  Solving Quadratic Equations Exactly, Solving Cubic Equations Exactly, Bisection Method, Newton-Raphson Method, Secant Method, False-Position Method

- **SIMULTANEOUS LINEAR EQUATIONS** **(05 Hours)**
  Introduction to Matrix Algebra, Systems of Equations, Gaussian Elimination, Gauss-Seidel Method, LU Decomposition, Gauss-Seidel Method, Adequacy of Solutions, Eigenvalues and Eigenvectors, Cholesky and LDLT Method

- **INTERPOLATION** **(04 Hours)**
  Background of Interpolation, Direct Method, Newton's Divided Difference Method, Lagrange Method, Spline Method

- **REGRESSION** **(04 Hours)**
  Primer on Statistical Terminology, Introduction to Regression, Linear Regression, Nonlinear Regression, Adequacy of Regression Models

- **INTEGRATION** **(04 Hours)**
  Primer on Integral Calculus, Trapezoidal Rule, Simpson's $1/3^{rd}$ Rule, Romberg Integration, Gauss-Quadrature Rule, Discrete Data Integration, Improper Integration, Simpson's 3/8 Rule

- **ORDINARY DIFFERENTIAL EQUATIONS** **(05 Hours)**
  Primer on Ordinary Differential Equations, Initial Value Problems, Euler's Methods, Runge-Kutta methods, Predictor - Corrector Method, Higher-Order/Coupled ODEs, Boundary Value Problems, Shooting Method, Finite Difference Method

- **PARTIAL DIFFERENTIAL EQUATIONS** **(05 Hours)**
  Introduction to Partial Differential Equations, Parabolic Partial Differential Equations, Elliptic Partial Differential Equations

- **OPTIMIZATION** **(04 Hours)**
  Golden Section Search Method, Newton's Method, Multidimensional Direct Search Method, Multidimensional Gradient Method, Simplex Method

Total Lectures (42 Hours)

3. BOOKS RECOMMENDED:

1. Chapra, S.C., Canale, R.P., "Numerical Methods for Engineers", 7th edition, Mcgraw hill, 2015.
2. Grewal, B.S., "Numerical Methods in Engineering & Science", 11th edition, Khanna Publication, 2013.
3. Cheney, W., Kincaid, D., "Numerical Mathematics and Computing", 7th edition, Cengage, 2013
4. Gerald, C., Wheatley, P., "Applied Numerical Analysis", 7th edition, Pearson Education India, 2007.
5. Isaacson, E., H. B. Keller, H.B., "Analysis of Numerical Methods", Dover Publications, 1994

METD102	:	ADVANCED THERMODYNAMICS	L	T	P	Credits
			3	1	0	04

1. COURSE OUTCOMES (COs)

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

CO1	Describe thermodynamics properties of pure fluids and mixtures
CO2	Illustrate kinetic theory of gases
CO3	Describe combustion characteristics and how these can be measured.
CO4	Analysis of stability in thermodynamic systems
CO5	Explain statistical thermodynamics.
CO6	Apply exergy analysis to various thermodynamic systems

2 SYLLABUS:

- **INTRODUCTION** **(07 Hours)**
  Review the first and second law of thermodynamics, Carnot theory, Principle of increase of entropy, and Application of the entropy principle. Entropy Evaluation— Ideal gas, Incompressible fluids, Solids, Entropy during phase change, Entropy of a Mixture of Ideal gases- Gibbs-Dalton's Law, Reversible Path Method. Entropy balance equation for different thermodynamic systems. Maximum Entropy and Minimum Energy— Maxima and Minima Principles- Entropy maximum, Internal Energy minimum, Enthalpy minimum, Helmholtz Free Energy Minimum, Gibbs Free Energy Minimum. Gibbsian Thermodynamics— Classical Rationale for Postulatory approach, Legendre Transformation, Generalized Relation for all Work Modes, Thermodynamic Postulates for Simple Systems.

- **KINETIC THEORY OF GASES** **(04 Hours)**
  Introduction, basic assumption, molecular flux, equation of state for an ideal gas, collisions with a moving wall, principle of equipartition of energy, classical theory of specific heat capacity. Transport phenomena-intermolecular forces, The Van der Waals equation of state, collision cross-section, mean free path. Three Parameter Equations of State, Generalized Equation of State, Empirical Equations of State, State Equations for Liquids/ Solids.

- **THERMODYNAMIC PROPERTIES OF PURE FLUIDS AND MIXTURES** **(07 Hours)**
  Ideal Gas Properties, James Clark Maxwell Relations, Second Maxwell Relation, Third Maxwell Relation, Fourth Maxwell Relation, Generalized Relations, Evaluation of Thermodynamics Properties, Pfizer Effect, Kesler Equation of State and Kesler Tables, Fugacity, Vapor/Liquid Equilibrium Curve, Throttling Process. Thermodynamics Properties of Mixtures —Partial Molal Property – Introduction, generalized relations,

Euler and Gibbs-Duhem Equations, Relationship between Molal and Pure Properties, Ideal Gas Mixture, Ideal solution, Fugacity, Molal Properties using Equations of State.

- **PHASE EQUILIBRIUM FOR A MIXTURE AND STABILITY (06 Hours)**
Phase Equilibrium-Two and Multiphase systems and Gibbs phase rule. Simplified criteria for Phase Equilibrium, Pressure and Temperature Diagrams- Completely Miscible Mixtures, Immiscible Mixture, Dissolved Gases in liquids, Derivations from Raoult's Law. Types of equilibrium and stability, Stability Criteria, Mathematical Criterion for Stability multi-component and multi-phase systems, Application to Boiling and Condensation, Entropy Generation during irreversible transformation.

- **STATISTICAL THERMODYNAMICS (04 Hours)**
Introduction, energy states and energy levels, macro and microscales, thermodynamic probability, B-E, F-D, M-D statistics, distribution function, partition energy, statistical interpretation of entropy, application of statistics to a gases-mono-atomic ideal gas.

- **EXERGY ANALYSIS (14 Hours)**
Concepts of exergy, exergy applied to control region, classification of exergy forms, exergy concepts for a control region, physical exergy, chemical exergy, and exergy concepts for closed system analysis. Control mass analysis, control region analysis, pictorial representation of exergy balance, and exergy-based property diagrams. Exergy Analysis for Various Processes—Exergy analysis for Expansions process, Compression process, Heat transfer process, Mixing and Separation Process, Chemical process mainly combustion, Combustion process. Energy Analysis of Systems — Gas turbine plant, Thermal power plant, Cogeneration plant, Captive power plant, Combined cycle power plant, Refrigeration plant, Chemical plant, Linde air liquefaction plant, Heat exchanger. Exergy Analysis For Steam Power Plant—Introduction to steam power plant systems, balance equations of exergy, exergy values, process description, exergy efficiency, simplified process diagrams, exergy losses, environmental impact, and sustainability.

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Bejan, A., "Advanced Engineering Thermodynamics," 3rd edition, John Wiley and Sons, 2006.
2. Sears, F.W., Salinger, G.L., "Thermodynamics, Kinetic Theory, and Statistical Thermodynamics", 3rd edition, Narosa Publishing House, New Delhi, 1998.
3. Moran, M.J., Shapiro, H.N., "Fundamentals of Engineering Thermodynamics", John Wiley and Sons, 2014.
4. Kotas T.J., "The Exergy Methods of Thermal Plant Analysis," 2nd edition, Krieger Publ. Corp. U.S.A., 2000.
5. Ibrahim Dincer, Marc A. Rosen, "Exergy – Energy, Environment and Sustainable Development," Elsevier Publications, 2021.

METD103	:	TRANSPORT PHENOMENA-I	L	T	P	Credits
			3	1	0	04

1. COURSE OUTCOMES (COs):

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

CO1	Recall fundamentals of fluid dynamics and heat transfer.
CO2	Develop a mathematical model for fluid dynamics and heat conduction problems.
CO3	Extend modelling approach to turbulence and multiphase flow problem.
CO4	Classify various turbulent flow modelling approaches.
CO5	Evaluate multi-dimensional heat conduction problems.
CO6	Formulate a numerical heat conduction model and compare it with its analytical solution.

2. SYLLABUS:

MOMENTUM TRANSPORT **(22 Hours)**

- **Governing Equations of Fluid Motion** **(16 Hours)**

Lagrangian and Eulerian description, Reynolds transport theorem, Integral and differential forms of governing equations: mass, momentum, and energy conservation equations, Cartesian Tensors, Stokes hypothesis for stress tensor, Navier-Stokes equations, Energy equation, Euler's equation, Bernoulli's Equation, Exact solutions of Navier-Stokes equations in the Cartesian and cylindrical domain, Flow between concentric rotating cylinders, Parallel flow of power-law fluids, Stratified flow of two fluids, modeling of multiphase flow.

- **Turbulence And Turbulent Flow Modelling** **(06 hours)**

Mechanism of turbulence, Kolmogorov scale, Kinetic energy of the mean flow and fluctuations, turbulent intensity, Reynolds Averaged Navier-Stokes (RANS) equations, Turbulent stresses, Eddy viscosity, Prandtl mixing length model, K-Epsilon model of turbulence, Universal velocity distribution law and friction factor, Laminar–turbulent boundary layer transition, Turbulent boundary layers, Concept of Large Eddy Simulations (LES) and Direct Numerical simulations (DNS).

DIFFUSION TRANSPORT BY HEAT **(20 hours)**

- **Introduction to steady-state and unsteady-state Conduction** **(10 Hours)**

Introduction to three modes of heat transfer- conduction, convection, and radiation, Fourier's law of heat conduction in cartesian, cylindrical, and spherical systems, heat conduction in Isotropic and anisotropic material, various boundary conditions, Fixed and moving Fin heat transfer, Concept of fin efficiency and fin effectiveness, heat conduction in the porous medium, Concept of Biot number, Lumped system transients, 1-D transient problems-distributed system, Multidimensional transient problem-Heisler charts, Semi-infinite solid solution, Penetration depth

- **Multi-Dimensional steady-state conduction and phase change problems** **(05 Hours)**

Laplace equation, Solution by variable separable method, Concept of superposition and homogeneous boundary conditions, Phase change problems, Stefan and Neumann problems, analytical solutions

- **Numerical solution to heat conduction problems** **(05 Hours)**

Basic ideas of finite difference method, Forward, backward, and central differences, uniform and non-uniform grid, Discretization for the steady and unsteady heat equation with and without heat generation, 1-D and 2-D heat conduction in cartesian and cylindrical system

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Mauri, R., "Transport Phenomena in Multiphase Flows", Springer Publication, 2015.
2. White, F.M., "Fluid Mechanics", McGraw Hill Publications, 2016.
3. Hahn, D.W., Özişik, M.N., "Heat Conduction", John Wiley & Sons, Inc., 2012.
4. Jiji, L.M., "Heat Conduction", Springer Science & Business Media, 2009.
5. Ghoshdastidar, P.S., "Heat Transfer", Oxford University Press, 2012.

METD110	:	DESIGN OF REFRIGERATION AND AIR CONDITIONING SYSTEMS	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Describe the properties of refrigerants and evaluate the performance of the actual vapor compression refrigeration systems.
CO2	Evaluate the performance of compound vapor compression refrigeration systems for various applications.
CO3	Describe the vapor absorption system for large cooling load applications and evaluate its performance.
CO4	Explain the working principles of non-conventional refrigeration systems and evaluate the performance of steam jet refrigeration systems.
CO5	Compute cooling/heating loads for designing air conditioning systems for residential and commercial buildings.
CO6	Design the air duct systems for large commercial buildings.

2. SYLLABUS:

- **VAPOUR COMPRESSION REFRIGERATION SYSTEM** **(15 Hours)**
  Alternate Refrigerants – properties, applications, selection, mixed refrigerants, retrofit study, standard rating cycle for domestic refrigerator, refrigeration system components: compressors, condensers, expansion devices, evaporators, Multi stage compression with water intercooler, liquid sub-cooler, flash chamber, flash intercoolers and multiple expansion valves, multi evaporator systems, cascade refrigeration system, Design aspects of refrigeration system components, solid CO_2 – dry ice cycle.

- **VAPOUR ABSORPTION SYSTEMS** **(06 Hours)**
  Temperature concentration and enthalpy concentration diagrams, enthalpy balance for various components of aqua ammonia systems, Vapour absorption system-Electrolux refrigerator

- **NON - CONVENTIONAL REFRIGERATION SYSTEMS** **(06 Hours)**
  Steam jet refrigeration system, Performance analysis of steam jet refrigeration system, thermos electric refrigeration system, vortex tube Refrigeration, pulse tube refrigeration, adiabatic demagnetization, vapor adsorption refrigeration system

- **AIR CONDITIONING** **(15 Hours)**
  Review of air conditioning processes, summer and winter load calculations, cooling/heating load calculations, cooling coils, bypass factor, effective sensible heat factor, design consideration for cooling coils, high latent heat load, design of the evaporative cooling system, de-humidifiers and air washers, Comfort air conditioning, thermodynamics of human body, comfort charts, effective temperature, central air conditioning system, air handling unit, room air

distributions, fluid flow, and pressure losses, air filters, duct design Equal pressure drop method, velocity reduction method, static regain method, refrigeration, and air conditioning controls

Total Lectures (42 Hours)

3. BOOKS RECOMMENDED:

1. Stocker, W.F., and Jones, J.W., "Refrigeration and Air Conditioning," McGraw Hill, N. Y. 1986.
2. Dossat, R.J., "Principles of Refrigeration," 4th edition, Pearson Education India, 2002.
3. Threlkeld, J.L., "Thermal Environmental Engineering," Prentice-Hall, N. Y., 1970.
4. ASHRAE Fundamentals, Applications, Systems, and Equipment, 1999
5. Arora, C.P., "Refrigeration and Air Conditioning", 4th edition, Mc Graw Hill, 2021.

METD111	:	BIOMASS CONVERSION SYSTEMS	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Create awareness for biomass resources
CO2	Understand various biomass conversion routes
CO3	Model basic biomass conversion systems
CO4	Solve problems related to thermo-chemical routes of biomass conversion
CO5	Explain the concept of sustainability and resilience.
CO6	Estimate the life cycle of different biomass conversion systems

2. SYLLABUS:

- **INTRODUCTION** **(06 Hours)**
  Biopower, Bioheat, Biofuels, advanced liquid fuels, drop-in fuels - Biobased products.

- **BIOMASS FEEDSTOCKS** **(08 Hours)**
  Harvested Feedstocks, Feedstocks for first-generation biofuels, Feedstocks for second-generation Biofuels, Feedstocks for third-generation feedstocks, Agricultural waste - Forestry waste - Farm waste - Organic components of residential, commercial, institutional, and industrial waste.

- **BIOMASS CONVERSION TECHNOLOGIES** **(08 Hours)**
  Biorefinery Concept, understanding biorefinery concept, Biorefineries& end products, Hydrolysis, enzyme & acid hydrolysis, Fermentation, Anaerobic digestion, Trans-esterification, Combustion, Gasification, Pyrolysis, Other thermochemical conversion technologies, Scaling up emerging technologies.

- **SUSTAINABILITY & RESILIENCE** **(08 Hours)**
  Understanding sustainability, Environmental sustainability, Bioenergy & sustainability, Bioenergy & Environment, Criteria Pollutants, Carbon Footprint, Emissions of biomass to power generation applications, Emissions from biofuels, Indirect land-use change (ILUC) issues.

- **LIFE CYCLE ANALYSIS** **(12 Hours)**
  General understanding of LCA, Cradle-to-grave, field-to-wheels concepts, Goal and scope determination, defining LCA boundaries, Life Cycle Inventory, Advanced low-carbon fuels from waste, Advanced low-carbon fuels, and Case study.

Total Lectures **(42 ours)**

3. BOOKS RECOMMENDED:

1. Cheremisinoff, N.C., Cheremisinoff, P.N., Ellurbrush, F. "Biomass-Application, Technology & Production", Marcel Dekker, New York, 1980.
2. Klass, D.L., "Biomass for Renewable Energy, Fuels, and Chemicals", Academic Press, Elsevier, 1998.
3. Mousdale, D.M., "Bio-fuels: Biotechnology, Chemistry, and Sustainable Development", 1st edition, CRC Press, 2008.
4. Sorensen, B., "Renewable Energy", 5th edition, Academic Press, New York, 2017.
5. Boyle, G. "Renewable energy: Power for a Sustainable Future", 4th edition, Oxford University Press, 2018.

METD112	:	ELECTRO-CHEMICAL ENERGY STORAGE SYSTEM	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Illustrate the basic principle of electro-chemical cell
CO2	Examine circuit models in electrochemical cells
CO3	Apply the thermodynamic model of fuel cells and batteries to solving complex problems
CO4	Evaluate the chemical kinetics of electrochemical reactions
CO5	Apply the concept of transport phenomena in electrochemical cells.
CO6	Analyse the transport phenomena in electrochemical cells

2. SYLLABUS:

- **INTRODUCTION** **(08 Hours)**
  Basic Physics of Galvanic cell, Electro chemical energy conversion, Electro-Chemical Energy Storage

- **CIRCUIT MODELS** **(04 Hours)**
  Dynamics of Equivalent Circuits, Impedance spectroscopy, Impedance of Electrode

- **THERMODYNAMICS** **(08 Hours)**
  Statistical Thermodynamics, The Nernst Equation, Fuel Cells, and Lead-Acid Batteries, Li-ion batteries, Pseudo-capacitors, and Batteries, Reconstitution Electrodes

- **KINETICS** **(10 Hours)**
  Reactions in Concentrated Solutions, Theory of Chemical Kinetics and Charge Transfer Based on Non-equilibrium Thermodynamics, Butler-Volmer Equation, Electro-catalysis, Electro-Chemical Phase transformation, Homogeneous charge transfer, Charge Transfer at the metal electrode

- **TRANSPORT PHENOMENA** **(12 Hours)**
  Concentration Polarization, Transient Diffusion, Warburg Impedance, Boundary Layer Analysis of Electrochemical Cells, Forced convection in a fuel cell, Theory of Chemical Kinetics and Charge Transfer Based on Non-equilibrium Thermodynamics., Transport in Bulk Electrolytes, Homogeneous Reaction-diffusion, Transport in Bulk Electrolytes, Ion Concentration Polarization, Diffuse Charge in Electrolyte, Diffuse Double Layer Structure, Transport in porous media, Scaling analysis of energy storage, Porous electrode

Total Lectures (42 Hours)

3. BOOKS RECOMMENDED:

1. Newman, J., Thomas-Alyea, K.E., “Electrochemical Systems”, 3rd edition, Wiley-Interscience, 2004.
2. Ryan, O.H., Cha, S.W., “Fuel Cell Fundamentals”, 2nd edition, Wiley, 2009.
3. Huggins, R.A., “Advanced batteries: Materials Science Aspects”, Springer, 2008.
4. Bard, A.J., Faulkner, L.R., “Electrochemical Methods: Fundamentals and Applications”, 2nd edition, Wiley, 2000.
5. Job, R., “Electrochemical Energy Storage Physics and Chemistry of Batteries”, De Gruyter, 2020.

METD113	:	ENVIRONMENTAL POLLUTION AND CONTROL	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Evaluate the air pollution effect on human health and plant
CO2	Measure and characterize noise from the different sources such as construction, mining, etc.
CO3	Explain waste and advanced water treatment.
CO4	Summarize the handling of toxic and radioactive wastes incineration and verification.
CO5	Create concrete solutions to minimize the air, water, land, and noise pollution.
CO6	Understand the norms, rules, and regulations of air, water, land, and noise pollution

2. SYLLABUS

INTRODUCTION (02 Hours)

AIR POLLUTION AND CONTROL (12 Hours)
Air pollution; Air Pollution Effect on Plants; Air Pollution effect on Human health; Air quality monitoring; Air Pollution Meteorology; Gaussian Plume model; Urban Air Pollution; Air Pollution from Industries; Air Pollution Control; standards; norms; rules and regulations; Indoor Air Pollution.

NOISE POLLUTION AND CONTROL (12 Hours)
Sources of noise pollution – Properties and Measurements of Noise – Noise Propagation, Noise level meters – types, components, Noise Power level, Intensity level, Pressure level, Characteristics and Effects of noise – Characterization of Noise from Construction, Mining, Transportation and Industrial Activities, Airport Noise – General Control Measures – Effects of noise pollution – auditory effects, non-auditory effects

WATER POLLUTION AND CONTROL (12 Hours)
Water pollution – Sampling and analysis of waste treatment, Advanced wastewater treatments by physical, chemical, biological, and thermal methods, and Effluent quality standards. Solid waste management – Classification and their sources – Health hazards – Handling of toxic and radioactive wastes Incineration and verification

OTHER SOURCES OF POLLUTION AND THEIR CONTROL (04 Hours)
Pollution control in process industries, namely Cement, Paper. Petroleum and petrochemical, Fertilizers and distilleries, thermal power plants, and automobiles

(Total Lecture Hours:42)

3. BOOKS RECOMMENDED:

1. Manster, G.M., “Introduction to Environmental Engineering and Science”, 2nd edition, Pearson Publishers, 1991.
2. Rao, E.S., “Environmental Pollution Control Engineering”, Wiley Eastern Ltd., 1991.
3. Mahajan, S.P., “Pollution Control in Process Industries”, Tata McGraw-Hill, 1985.
4. Crawford, M., “Air Pollution Control Theory”, TMH, 1976.
5. Singal, S.P., “Noise Pollution and Control Strategy”, Alpha Publishers, 2005.

METD114	:	JET AND ROCKET PROPULSION	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs)

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

CO1	Understand the various types of jet systems and understand the difference between air-breathing and non-air breathing engines.
CO2	Analyze the thermodynamics cycles and performance parameters of air-breathing systems.
CO3	Demonstrate the rocket propulsion theory.
CO4	Illustrate the rocket nozzle types and their flow behavior at design and off-design conditions.
CO5	Explore the solid propellant rockets and details of their propellant.
CO6	Report the liquid propellant rockets and details of their propellant.

2. SYLLABUS:

AIR BREATHING AND NON-AIR BREATHING ENGINES (8 Hours)
Introduction to various air-breathing engines such as turbojet, turboprop, turbofan engines, Ramjet, Scramjet, and non-air breathing engines. Conservation equations and derivation of the thrust equation for air-breathing and non-air breathing engines. General performance parameters. Efficiencies of air-breathing and non-air breathing engines.

CYCLE ANALYSIS (6 Hours)
Thermodynamic of the working cycle of turbojet, turboprop, turbofan, and ramjet engines. Engine Thrust, Propulsion Measures, Power-Generation Measures, System Matching and Analysis (Matching of Gas Turbine System Components – Gas Generator, Jet Engine, Power Generation Gas Turbine), Component Modeling, Solution of Matching Problems, Dynamic / Transient Response, Matching of Engine and Aircraft, use of matching and cycle analysis in second-stage design.

ROCKET TURBOMACHINERY FUNDAMENTALS: (4 Hours)
Elements of Rocket Turbopumps, Pump Design, Inducer Design, Impeller Design, thrust Balance, Pump Operating Envelop, Turbine Fundamentals, Shafts, Bearings, Seals, Rotordynamics, additive manufacturing.

ROCKET PRINCIPLE (3 Hours)
Rocket principle and rocket equation, A mass ratio of the rocket, desirable parameters to achieve high velocities, and propulsive efficiency. Performance parameters of a rocket, staging and clustering and classification of rockets.

NOZZLES (5 Hours)
Rocket nozzles; expansion of gases from the high-pressure chamber, efflux velocity, and shape of the nozzle. Convergent, divergent nozzle, choking and variation of parameters in the nozzle.

Expansion ration of nozzles and performance loss in nozzles. Under-expanded and over-expanded nozzles. Flow separation in nozzle, mass flow rates and characteristic velocities. The thrust developed by a rocket, thrust coefficient, vacuum and sea level impulse, efficiencies and thrust correction factor.

CHEMICAL PROPELLANTS **(4 Hours)**
Chemical propellants: Choice from considerations of molecular mass, specific heats, specific heat ratios, temperature, and pressure. Choice of chemical propellants: heats of formation, moles, and mixture ratio; choice of mixture ratio. Calculation of heat of combustion, temperature, molecular mass and rocket performance parameters. Solid propellants: double base, composite, modified double base, and nitramine propellants. Liquid propellants: Energy content and classification, earth storable and space storable propellants, hypergolic and other features, hybrid propellants. Influence of dissociation on propellant performance, frozen and equilibrium analysis

SOLID PROPELLANT ROCKETS **(5 Hours)**
Solid propellant rockets: burn rate of double base and composite propellants, parameters influencing burn rates. Choice of burn rates for stable operation. Propellant grain configurations: design of the solid propellant rocket. Ignition of solid propellant rockets, ignition problems, and solutions. Characteristic burn times and action times of solid propellant rockets, variation of burn rates with rocket size, erosive burning, and components of a solid-propellant rocket.

LIQUID PROPELLANT ROCKETS **(5 Hours)**
Introduction to liquid propellant rockets, propellant feed systems, cycles of operation, gas generator, topping/staged combustion cycle, expander, and other cycles, factors influencing the choice of cycle. Thrust chamber, injector types, and combustion chamber. Calculation of efficiency of liquid propellant rockets from non-uniform distribution of propellants and incomplete vaporization, and characteristic length of chamber. Cooling of thrust chamber and nozzle.

MONOPROPELLANT AND HYBRID ROCKETS **(2 Hours)**
The basic theory of monopropellant and hybrid rockets

3. BOOKS RECOMMENDED

1. Hill, P. G., Peterson, C. R., "Mechanics and Thermodynamics of Propulsion", 2nd edition, Pearson India, 2009.
2. Mattingly, J.D., "Elements of Propulsion: Gas Turbines and Rockets", AIAA Publication, 2006.
3. Sutton, G. P., Biblarz O., "Rocket Propulsion Elements", 8th edition, Wiley, 2010.
4. Mukunda H. S., "Understanding Aerospace Propulsion", Interline Publishing, 2004.
5. Ramamurthi, K., "Rocket Propulsion", 1st edition, Macmillan Publishers India, 2010.

METD120	**:**	**ELECTRIC VEHICLES AND ADVANCED I C ENGINES**	**L**	**T**	**P**	**Credits**
			3	**0**	**0**	**03**

1. COURSE OUTCOMES (COs)

CO1	Compare the general specifications of various commercially available vehicle
CO2	Apply material and design considerations for various engine components
CO3	Evaluate effects of various parameters including use of alternate fuels on normal and abnormal combustion, emission and performance in CI and SI Engines
CO4	Compare basic layout and structure of EV and I C Engines
CO5	Work out battery and motor sizing for various applications in two, three and four-wheeler segment
CO6	Analyse Bus Rapid Transit Systems

1. SYLLABUS:

Introduction to I C Engines: Historical Perspective, General Specifications of Engines used in various Two, Three, and Four Wheelers. Air Standard Thermodynamic Cycles for I C Engines and its comparison with Fuel Air and Actual Cycle, Thermodynamic properties of the working fluid,	**03**
Material and Design Consideration for Engine Components: Piston, Cylinder, Piston Rings, Connecting Rod, Cam Shafts, Crank Shafts, etc	**04**
Gas Exchange Process: Flow-through valves, Analysis of suction, and Exhaust Processes	**04**
Combustion in SI and CI Engines: Combustion Phenomenon in SI and CI Engines, Normal and Abnormal combustion in SI and CI Engines, modelling combustion process in SI engines, Advanced mode combustion like HCCI, PCCI, AFCI, RCCI, etc	**06**
Alternate Fuelled Engines: Producer Gas, Biogas, and Biodiesel Fuelled Engines	**03**
Engine Emission: Introduction to air pollution from SI and CI Engines, Photochemical smog, primary and secondary pollutants, Formation of NO and NO2 in SI and CI Engines, Mechanism of Particulate Matter formation, Composition of Particulates, soot structure, soot formation, Measurement of emission, instrumentation for HC, CO, NOx, and PM, EGR and Diesel Particulate Filter	**06**
Introduction to Electric Vehicles: Limitations of Internal Combustion Engines as Prime Mover, History of EV and EV Systems, Structure of Electric Vehicle covering essential Components, General Layout, Govt. policies on EV and its impact on the automotive sector	**02**

EV Power Train: Basic components like Battery, DC-AC Converters, Electric Motors, DC-DC Converters, Transmissions, and ECUs. Battery and Motor Selection, Calculations for Motor and battery sizing for EV for Two, Three, and Four-Wheeler Applications, Thermal Management of Battery, Initial acceleration, rated vehicle velocity, maximum velocity, and maximum gradeability of EV, the Basic architecture of EV Drive Train. **12**

Urban Transport: Urban Bus Specifications, Bus Rapid Transit Systems **02**

3. BOOKS RECOMMENDED:

1. Yamagata, H., "The Science and Technology of Materials in Automotive Engine", CRC Press Inc., 2005
2. Heywood, J.B., "Internal Combustion Engines Fundamentals", Mc Graw Hill, 2017
3. Ganesan, V., "Internal Combustion Engines", 4th edition. Tata Mc Graw Hill, 2017.
4. Ehsani, M., Gao, Y., Longo, S., Ebrahimi, K., "Modern Electric, Hybrid Electric and Fuel Cell Vehicles", 3rd edition, CRC Press, 2018.
5. Kent, J., "Handbook of Electric Vehicles", Clanrye International, 2015.

METD121	**:**	**GAS DYNAMICS AND COMPRESSIBLE FLUID FLOW**	**L**	**T**	**P**	**Credits**
			3	**0**	**0**	**03**

1. COURSE OUTCOMES (COs):

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

CO1	Predict the effect of compressibility and flow behavior in the field of gas dynamics
CO2	Solve 1-D design problems based on Isentropic, Fanno, and Rayleigh flow
CO3	Evaluate the different possible conditions for flow without choking in a 1-D duct with the variable area, friction, and heat transfer.
CO4	Identify the position and effect of shock within the 1-D duct and learn to use the polar shock diagram for 2-D flows.
CO5	Explain the method of characteristics for nozzles
CO6	Analysis of gas dynamics of wet steam

2. SYLLABUS:

- **ONE-DIMENSIONAL COMPRESSIBLE FLOW** **(10 Hours)**
  One dimensional flow concept, Isentropic flows, Stagnation/Total conditions, Characteristics speeds of gas dynamics, Dynamic pressure and pressure coefficients, Normal shock waves, Rankine-Hugonoit equations, Rayleigh flow, Fanno flow, Crocco's theorem, isentropic flow through the converging nozzle, the influence of friction on flow through the nozzle, supersonic nozzle, moving shocks, the combined effect of area changes, head addition, and friction in the nozzle.

- **TWO-DIMENSIONAL FLOWS** **(12 Hours)**
  Oblique shock wave and its governing equations, θ-B-M relations, The Hodograph and Shock Polar, Supersonic flow over wedges Mach line, Attached and Detached shock, Reflections, and interaction of oblique shock waves, Mach Reflection, Expansion waves, Prandtl-Meyer flow and its governing equations, Supersonic flow over convex and concave corners, Approximation of continuous expansion waves by discrete waves.

- **METHOD OF CHARACTERISTICS** **(10 Hours)**
  Concepts of Characteristic, Compatibility Relation, Theorems for Two-Dimensional Flow, characteristics and their association with Riemann Invariants, elements and their approximations by weak waves, Design of Supersonic Nozzle.

- **GAS DYNAMICS OF WET STEAM** **(10 Hours)**
  Clausius-Clapeyron equation, adiabatic exponent, conservation equations for wet steam, relaxation times, sound speed, an overview of relaxation zones, combined relaxation, flow in variable area nozzle, shocks in wet steam, condensation shock, and jump conditions.

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Rathakrishnan, E., "Applied Gas Dynamics." Wiley, 2019.
2. Somasundaram S.L., "Gas Dynamics & Jet Propulsion", New Age International (P) Ltd., New Delhi, 1996
3. Zucker, R.D., Biblarz, O., "Fundamentals of Gas Dynamics". John Wiley & Sons, 2019.
4. Vavra, M.H. "Aerothermodynamics and Flow in Turbomachines", John Wiley 1974.
5. Shapiro A.H. "The Dynamics and Thermodynamics of Compressible Fluids", Vol. I & II, Ronald Press, 1965.

METD122	:	ANALYSIS AND DESIGN OF THERMAL TURBOMACHINES	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Explain the working principles of turbomachines and apply them to various types of turbomachines
CO2	Design axial compressors and turbines.
CO3	Determine the off-design behavior of axial turbines and compressors
CO4	Design radial compressor and turbine
CO5	Establish performance characteristics curves of thermal turbomachines.
CO6	Assess the performance outcomes of thermal turbomachines.

2. SYLLABUS:

- **INTRODUCTION TO THERMAL TURBOMACHINES** **(16 Hours)**
  Introduction - Turbomachines basics and classifications, Steam turbines - Types – Classification – constructional details of different types of steam turbines., Gas turbines – Types – Classification – Gas turbines engine and its components – constructional details of components – working principles of different components – Gas turbine power plant matching characteristics.

- **COMPRESSORS** **(13 Hours)**
  Centrifugal compressors – Components – Enthalpy-Entropy diagram -Energy transfer – Slip -Pressure coefficient -Isentropic efficiency – Effect of compressibility and pre-whirl -Diffuser – Nondimensional parameters – surging – choking – performance characteristics. Axial flow compressors – Components – Enthalpy-Entropy diagram – Velocity triangles -number and type of staging with characteristics – Air and blade angles – Degree of reaction – Losses – Radial equilibrium and actuator disc theory performance characteristics.

- **TURBINES** **(13 Hours)**
  Radial Turbines - Elements of radial turbine stages – Enthalpy-Entropy diagram – stage velocity triangles – stage losses – performance characteristics – outward flow radial stages. Axial Turbines -Impulse and Reaction- Velocity triangles -Turbine speed -Number of stages and stage work – Gas angles and blade angles. Losses in turbines – Reheat factor and condition curve -constant stage – efficiency – forms of actual condition curve – Turbine total wheel speed – Partial admission turbines – losses – Applications – performance estimation.

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

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

METD123	:	MEASUREMENTS AND DATA ANALYSIS IN THERMAL ENGINEERING	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Understand the knowledge of measurement systems and methods with emphasis on different transducers, intermediate modifying, and terminology devices.
CO2	Examine the engineering sensors for different types of thermal systems.
CO3	Analyze the measurement of force, torque, load, flow, pressure, temperature, and strain.
CO4	Evaluate the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation, and uncertainty estimation.
CO5	Illustrate various process control principles, transfer functions, block diagrams, and signal flow graphs.
CO6	Develop the concept of zero, first and second-order thermal systems.

2. SYLLABUS:

- **BASICS OF MEASUREMENT** **6 hours**
  Basic concepts of measurements, Different types of errors in measurements, Characteristics of measurement systems (calibration, sensitivity, and error analysis), Statistics in Measurements, Static and dynamic characteristics; System response- first and second-order systems and analysis, Uncertainty in measurements, Linear regression, Parity plot, Design of experiments: design of experiments based on sensitivity function and uncertainty analysis. Examples related to (a) determining the duration of the experiment and (b) choosing between steady-state and transient techniques.

- **HEAT TRANSFER AND GAS TEMPERATURE MEASUREMENT** **7 hours**
  Overview of thermometry, thermoelectric temperature measurement, Different principles of Temperature Measurement, thermometers, 31hermos positive elements, thermocouples in series & parallel, Resistance thermometry, Pyrometer, calibration of temperature measuring instruments, issues in measurements Heat flux measurement, Interferometry, Differential Interferometer, Thermal conductivity measurement: Guarded hot plate apparatus, heat flux meter.

- **MEASUREMENT OF FLOW PROPERTIES, FLOW VISUALIZATION** **6 hours**
  Different methods of incompressible and compressible obstruction flow measurements, Pitot static tube, Hot wire anemometer, Magneto and Ultrasonic

flow measurements, Doppler effect, Vortex Shedding Flow meter, Laser Doppler velocity meter.

- **PRESSURE, LOAD & STRAIN MEASUREMENT, TORQUE MEASUREMENT** **7 hours**
  Different pressure measurement instruments and their comparison, Transient response of pressure transducers, Measurement of vacuum, Electrical pressure transducers, force balance pressure gauges, Basics in the measurement of force, torque, and shaft power, Displacement measurements

- **PROCESS CONTROL** **8 hours**
  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.

- **DATA ANALYSIS AND DATA ACQUISITION SYSTEMS** **8 hours**
  Data analysis & interpretation: Statistical analysis of experimental data- normal error distributions (confidence interval and level of significance, Chauvenet's criterion, Chi-square test of goodness of fit, method of least squares (regression analysis, correlation coefficient), multivariable regression, Students' t-distribution, graphical analysis, and curve fitting, data acquisition systems: analog input-output communication, analog to digital converter, the static and dynamic characteristic of signals, Bits, Transmitting digital numbers, resolution, quantization error, signal connections, single and differential connections, signal conditioning.

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Doblin, E.O., Manik, D.N., "Measurement Systems", 6th edition, McGraw-Hill, New York, 2017.
2. Holman, J.P., "Experimental Methods for Engineers", 8th edition, McGraw-Hill Science Engineering, 2011.
3. Morris, A.S., "Principles of Measurement and Instrumentation", Prentice Hall of India, New Delhi, 1999.
4. Venkateshan, S.P., "Mechanical Measurements", 2nd edition, John Wiley & Sons and Ane Books Pvt. Ltd., 2015.
5. Nakra, B.C., Chaudhry, K.K., "Instrumentation, Measurement, and Analysis", Tata McGraw-Hill Education, 2003.

METD124	:	FINITE ELEMENT METHODS IN THERMAL ENGINEERING	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs)

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

CO1	Develop weighted residual methods
CO2	Classify the concepts of Nodes and elements
CO3	Apply finite element modelling techniques for 1-D problems.
CO4	Build finite element modelling techniques for 2-D problems.
CO5	Formulate and solve fluid and heat transfer problems using FEM
CO6	Extend the FEM to transient problems.

2. SYLLABUS

INTRODUCTION TO FINITE ELEMENT METHODS (03 hours)

General introduction to finite element method, Types of analysis methods, Boundary Information, Initial Value Problem, Boundary Value Problem, Numerical methods, Direct Finite Element Method, Minimum potential energy method, weighted residual method: Co-location method, Sub-domain method, Least-Square method, Galerkin method and Methods of moments.

ONE-DIMENSIONALANALYSIS (12 hours)

Solution of second-order linear model boundary value problem: Discretisation of the domain, 1-D Iso-parametric element, weak form development, Lagrange interpolation functions: linear and quadratic, elemental response, Connectivity of elements, Assembly of elemental responses. Incorporation of boundary conditions, solution for unknown: elimination and penalty approach. Application to 1-D Heat Transfer: with and without heat generation and constant and variable cross-section. 1-D Fluid flow analysis.

TWO DIMENSINAL ANALYSIS (09 hours)

Two-dimensional steady-state heat conduction equation, Triangular elements, development of elemental stiffness matrix and load vector, Assembly of elemental response. Solution of 2-D heat conduction problem with and without heat generation.

DYNAMIC ANALYSIS (09 hours)

1-D transient heat conduction in pin-fin: derivation of the fundamental equation in matrix form, assembly of elements, solution using the trapezoidal rule. Stability Analysis. Solution of Transient temperature distribution along the length of the pin fin.

COUPLED BOUNDARY VALUE PROBLEMS: Heat Transfer and Fluid Mechanics (12 hours)

Convection Heat Transfer, Governing Equations, Non-Dimensional Form of Governing Equations, Convection-diffusion problem, Finite element solution to the steady and transient convection-diffusion problem: Laminar heat transfer, Forced convection, Buoyancy-driven convective heat transfer, and mixed convection.

3. BOOKS RECOMMENDED

1. Logan D. L., “A First Course in the Finite Element Method”, Cengage Learning, 2012.
2. Reddy, J.N., Gartling, D.K., “Finite Element Method in Heat Transfer and Fluid Dynamics”, 3rd edition, CPC Press, 2010.
3. Seshu, P., “Finite Element Analysis”, PHI learning Pvt. Ltd., New Delhi, 2012.
4. Fagan, M., “Finite Element Analysis: Theory and Practice”, Pearson Education Limited, UK, 1992.
5. Lewis, R.W., Nithiarasu, P., Seetharamu, K., “Fundamentals of the Finite Element Method for Heat and Fluid Flow”, Wiley, July 2004

METD104	:	COMPUTATIONAL LABORATORY -I	L	T	P	Credits
			0	0	4	02

1. COURSE OUTCOMES (COs)

CO1	Demonstrate overview of data analysis and programming, and machine learning software
CO2	Develop numerical solutions for linear and non-linear algebraic equations using computer programs
CO3	Derive numerical solutions to initial value problems and boundary value problems
CO4	Solve ordinary differential equations (ODEs), and partial differential equations (PDEs) on a computer
CO5	Develop code to solve one-dimensional optimization problems using the Golden Section Search method
CO6	Get familiar with writing equations, plotting graphs, and performing data analysis in Microsoft excel

- **SOFTWARE**
  1. Introduction to open source and commercial software
- **CODING**
  2. Introduction to compiler, scripts, loops, logical statements
  3. Finding roots using the Bisection method
  4. Discovering roots using the Newton-Rapson method
  5. Solving ODE using the Rung-Kutta method of 2nd order: Heun's method, Mid-point method, and Ralston's method
  6. Solving ODE using the Rung-Kutta method of 3rd order, and 4th order
  7. Development of steady-state solver: (a) TDMA/ Line-by-line TDMA (b) Point-Jacobi (c) Gauss-Seidel Method (d) Gauss-Seidel over-relaxation Method
  8. Development of transient solver: (a) Euler or Explicit scheme (b) Pure implicit scheme (c) Crank-Nicolson scheme (d) ADI
  9. FDM code to solve PDE: elliptic equation
  10. FDM code to solve PDE: parabolic equation
  11. FDM code to solve PDE: hyperbolic equation

METD201	:	TRANSPORT PHENOMENA-II	L	T	P	Credits
			3	1	0	04

1. COURSE OUTCOMES (COs):

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

CO1	Recall fundamentals of convective heat transfer mode.
CO2	Develop mathematical models for forced and natural convection problems.
CO3	Extend modelling approach to two-phase flow problem.
CO4	Analyse radiative heat transfer between black and actual surfaces
CO5	Evaluate radiation heat transfer solution in participating medium
CO6	Combine the analogy between momentum, heat, and mass transfer.

2. SYLLABUS:

ENERGY TRANSPORT BY CONVECTION **(25 Hours)**

- **Forced Convection Heat Transfer** **(12 Hours)**

The physical mechanism of convection, thermal boundary layer, heat transfer in turbulent flow, solution of convection equations for a flat plate, nondimensional convection equations and similarities, functional forms of friction and convection coefficients, analogies between momentum and heat transfer, drag and heat transfer in external flow, parallel flow over flat plates, flow across cylinders and spheres, flow across tube banks, average velocity and temperature, the entrance region, general thermal analysis, laminar and turbulent flow in tubes (circular and non-circular), transitional flow in tubes

- **Natural Convection Heat Transfer** **(05 hours)**

The physical mechanism of natural convection, equation of motion and the Grashof number, natural convection over surfaces, natural convection over finned surfaces and PCBs, natural convection inside enclosures, combined natural and forced convection

- **Momentum and Energy Transport in Two-Phase Flow** **(08 hours)**

Introduction, flow regimes, and maps, Homogeneous model, separated flow model, drift flux model, two-phase Pressure drop modeling, Boiling heat transfer, pool boiling, flow boiling, Condensation heat transfer, film condensation, dropwise condensation, application of Reynold's analogy to non-boiling two-phase flow

ENERGY TRANSPORT BY RADIATION **(12 Hours)**

- **Thermal Radiation** **(06 Hours)**

Black body radiation, radiation intensity, radiative properties, solar heat gains through windows, need for view factors, Concept of view factors, Mathematical definition, View factor Algebra, Hotel's crossed string method, View factors for 2D surfaces using algebra, View factors from 2D surfaces using charts. Enclosure analysis, Radiosity Irradiation method for Gray diffuse enclosures, 2 and 3 surface enclosures, Radiation shields, Concept of re-radiating surface

- **Gas Radiation** **(06 Hours)**

Introduction to gas radiation – The equation of transfer – Simple derivation solutions to the equation of transfer, Concept of mean beam length – Calculation of mean beam length for simple geometries from charts and formula, Engineering treatment of gas radiation in enclosures – modified enclosure theory – problems to illustrate the modified enclosure theory, heat transfer from the human body

DIFFUSION TRANSPORT BY MASS **(05 Hours)**

Analogy between heat and mass, steady and transient mass diffusion, mass convection

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Ghiaasiaan, S.M., "Convective Heat and Mass Transfer", CRC Press, 2018.
2. Kakaç, S., Yener, Y., Pramuanjaroenkij, A., "Convective Heat Transfer", CRC Press, 2014.
3. Muralidhar, K., Banerjee, K., "Conduction and Radiation", Narosa Publishers, 2010.
4. Balaji, C., "Essentials of Radiation Heat Transfer", John Wiley & Sons, 2014.
5. Siegel, R., Howell, J.R. "Thermal Radiation Heat Transfer, Taylor & Francis, 2002.

METD202	**:**	**ENERGY CONVERSION SYSTEMS**	**L**	**T**	**P**	**Credits**
			3	**1**	**0**	**04**

1. COURSE OUTCOMES (COs):

At the end of the course the students will be able to:

CO1	Describe the mechanism of various types of steam boilers, steam turbine
CO2	Carry out design and analysis of boiler accessories, condenser, feed water heater, cooling tower
CO3	Assess combustion mechanism, combustion equipments, heat balance sheet of boiler plant
CO4	Describe the mechanism of non-conventional power generation and direct energy conversion
CO5	Analyze the Gas turbine power plant to improve overall performance
CO6	Evaluate power plant economy and evaluate steam power plant to improve performance

2. SYLLABUS:

STEAM POWER PLANT **(12 hours)**

Rankine cycle, mean temperature of heat addition, reheat cycle, regenerative cycle, reheat- regenerative cycle, feed water heaters, Supercritical pressure cycle,

Boiler specifications, Radiant type natural circulation boiler, High pressure forced circulation boilers, heat absorption in boilers, Circulations in down comers and riser, steam drum and its internals, supercritical boiler, Fluidized bed combustion boilers – Bubbling and circulatory, Economizers, Air preheaters, Superheaters, Desuperheaters, Reheaters, fabric filters and bag house collector, electrostatic precipitators, feed water heaters, deaerator, ash handling system, cogeneration power plant, back pressure turbine, pass out turbine

Classification of steam turbine, compounding of steam Turbines, Arrangements of steam turbines, Direct contact and Surface condensers, cooling towers, Performance parameters.

COMBUSTION EQUIPMENTS AND FIRING METHODS **(06 hours)**

Fuel bed combustion, Mechanical Stokers, Pulverized Coal Firing System, pulverisers, coal crushers, burners, Cyclone Furnace, Fluidized Bed Combustion, different regimes, advantages and disadvantages of Fluidized bed combustion, proximate analysis, ultimate analysis, combustion reactions and heat balance sheet, natural draught and mechanical draught

RENEWABLE POWER GENERATION AND DIRECT ENERGY CONVERSION **(12 hours)**

Solar power plant: Solar energy- General terms and introduction, solar energy collectors, Solar pond, Low temperature, medium and high temperature power generation,
Wind power plant: Introduction, Wind turbine operation, velocity and power from wind, types of wind mills
Waste to energy plant
Direct energy conversion system: Fuel cells: working principle and types of fuel cell, Photovoltaic power system

GAS TURBINE POWER PLANT **(06 hours)**

General aspects of gas turbine, Analysis of gas turbine, performance of gas turbine plant, components, fuels and materials, combined - Gas and steam turbines

POWER PLANT ECONOMICS **(06 hours)**

Introduction, Load-Duration curves, Load factor, Capacity factor, Reserve factor, demand factor, Diversity factor, plant use factor, base load plant, peak load plant, power plant economics – electricity cost, fixed costs and depreciation, Present-Worth Concept, Incremental Heat Rate, Effect of Load Factor on Cost per kWh

Total Hours **(42 hours)**

3. BOOKS RECOMMENDED:

1. Nag, P.K., “Power Plant Engineering”, McGraw Hill Education, New Delhi, 2014.
2. Ei-Wakil, M.M., “Power Plant Technology”, McGraw Hill Education, New Delhi, 2010.
3. Hegde, R.K., “Power Plant Engineering”, Pearson India Education, New Delhi, 2015.
4. Arrora and Domkundwar, “Power Plant Engineering”, Dhanpat Rai & Sons, New Delhi, 2008.
5. Sharma, P.C., “Power Plant Engineering”, S.K. Kataria & Sons, New Delhi, 2010.

METD230	**:**	**DESIGN OF HEAT EXCHANGERS**	**L**	**T**	**P**	**Credits**
			3	**0**	**0**	**03**

1. COURSE OUTCOMES (COs):

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

CO1	Identify different types of heat exchangers and understand the primary design methodologies
CO2	Design and analyse the double pipe, and shell and tube heat exchanger
CO3	Analyse the thermal performance of tube finned and plate finned heat exchanger
CO4	Evaluate the thermal performance of Gasketed and Spiral plate heat exchanger
CO5	Calculate the pressure drop in the tubular and extended surface heat exchanger
CO6	Estimate the furnace outlet temperature using furnace model

Introduction **(04 hours)**

Introduction, application of heat exchanger, classification of heat exchanger, design and simulation of heat exchanger, Review of heat transfer principles & convection correlation, Basic design methodologies, Net Transferable Units method and Logarithmic Mean Temperature, Examples.

Design of Tubular Heat Exchanger **(10 hours)**

Heat transfer coefficient, double pipe heat exchanger design, Shell & tube type heat exchangers, nomenclature, J-factors, conventional design methods, bell, Delaware method

Design of Extended Surface Heat Exchanger **(15 hours)**

Enhancement of heat transfer compact heat exchanger, Compact heat exchangers, J-factors, Design method Extended surface heat exchanger, Rating problem of tube finned heat exchanger, Rating problem of plate finned heat exchanger, Pressure drop calculations and tutorials, Sizing problem.

Design of Plate Heat exchangers **(05 hours)**

Introduction, Types of the plate heat exchanger, thermal design of Gasketed plate heat exchanger, thermal design of spiral plate heat exchanger

Heat Exchanger Pressure Drop Analysis **(05 hours)**

Importance of pressure drop, Major contributions to the heat exchanger pressure drop, Tubular heat exchanger pressure drop, Extended surface heat exchanger pressure drop, Plate heat exchanger pressure drop

Furnace design **(03 hours)**

Design development of Stirred Reactor Furnace model, Estimate the furnace outlet temperature

3. BOOKS RECOMMENDED

1. Shah, R.K. and Sekulic D.P., “Fundamentals of Heat Exchanger Design”, John Wiley & Sons, Inc, 2003
2. Kays, V.A. and London, A.L., “Compact Heat Exchangers,” McGraw Hill, 2002.
3. Holger Martin, “Heat Exchangers” Hemisphere Publ. Corp., Washington, 2001.
4. Kuppan, T., “Heat Exchanger Design Handbook”, Macel Dekker, Inc., N.Y., 2000
5. Seikan Ishigaki, “Steam Power Engineering, Thermal, and Hydraulic Design Principles,” Cambridge Univ. Press, 2001.

METD231	**:**	**THEORY AND DESIGN OF CRYOGENIC SYSTEMS**	**L**	**T**	**P**	**Credits**
			3	**0**	**0**	**03**

1. COURSE OUTCOMES (COs):

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

CO1	Select suitable cryogen and material for developing cryogenic systems for different applications.
CO2	Carry out design and analysis of gas liquefaction systems and cryogenic refrigeration systems, including cryocoolers.
CO3	Select proper cryogenic insulating material and designing of cryogenic insulation.
CO4	Analyse gas purification and separation system using cryogenics.
CO5	Select and design storage, handling, and transfer systems for cryogens.
CO6	Design vacuum system for the cryogenic application.

2. SYLLABUS:

- **INTRODUCTION AND APPLICATIONS** **(02 Hours)**
- **CRYOGENICS FLUIDS** **(02 Hours)**
  Properties of Air, Oxygen, Nitrogen, Hydrogen, Helium and its isotopes

- **PROPERTIES AND SELECTION OF MATERIALS** **(03 Hours)**
  Study of material properties & their selection for the cryogenic application.

- **GAS LIQUEFACTION and REFRIGERATION SYSTEMS** **(10 Hours)**
  Basics of Refrigeration, Ideal system, Linde Hampson system, Precooled Linde Hampson system, Linde dual pressure system, Claude system, Heylandt system, Kapitza system, Collins cycle

- **CRYOGENIC INSULATION** **(07 Hours)**
  Vacuum insulation, Multilayer insulation (MLI), Methods of measuring the effective thermal conductivity of MLI, Liquid & vapor shield, Evacuated porous insulation, Gas-filled powders, and fibrous materials, Solid foams, Vacuum technology

- **CRYOCOOLERS** **(06 Hours)**
  Ideal Stirling cycle, Design parameters (Schmidt's Analysis), GM cryocooler, Pulse Tube cryocooler, Phasor Analysis

- **CRYOGENIC INSTRUMENTATION** **(04 Hours)**
  Peculiarities of cryogenic strain measurement, Pressure, Flow, Density, Temperature, and liquid level measurement for cryogenic application

- **STORAGE & HANDLING SYSTEMS** **(03 Hours)**

Dewar vessel design, Piping, Support systems, Vessel safety devices and storage systems, Industrial storage systems

- **TRANSFER SYSTEMS** **(03 Hours)**
  Transfer from storage, Uninsulated transfer lines, Insulated lines, and Transfer system components.

- **GAS SEPARATION** **(02 Hours)**
  Principles of gas separation, Ideal system

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Haselden, C., "Cryogenic Fundamentals", Academic Press, 2001.
2. Barron R., "Cryogenic Systems", Plenum Press, 2001.
3. Walker G., "Cryocoolers", Springer, 2014.
4. Mikulin, Y., "Theory and Design of Cryogenic systems", MIR Publication, 2002.
5. Barron, R. F., "Cryogenics Systems", Oxford Press, 2002

METD232	:	COMBUSTION	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs)

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

CO1	Describe different combustion mechanisms and how these can be efficiently used in engineering applications.
CO2	Illustrate elementary chemical and physical processes of combustion phenomena
CO3	Describe combustion characteristics and how these can be measured.
CO4	Illustrate different types of pollutants generated by combustion and their effects on health and the environment.
CO5	Explain basic concepts about combustion processes for efficient designing of burners for different types of fuels and combustion chambers.
CO6	Apply the knowledge of combustion to deal with real life problems.

2. SYLLABUS:

- **INTRODUCTION** **(02 Hours)**
  Introduction to combustion, Applications of combustion, Types of fuel and oxidizers, Characterization of fuel, Various combustion modes, Scope of combustion.

- **THERMODYNAMICS OF COMBUSTION** **(08 Hours)**
  Mixture composition, energy and entropy properties of gaseous mixtures, Thermodynamics properties of reacting mixtures, Laws of thermodynamics, Stoichiometry, Thermochemistry, adiabatic temperature, and chemical equilibrium. Conditions of chemical equilibrium, equilibrium constant, challenges in chemical equilibrium.

- **COMBUSTION KINETICS** **(08 Hours)**
  Basic Reaction Kinetics, Elementary reactions, Chain reactions, Multistep reactions, simplification of reaction mechanism, Global kinetics reaction rate formula, approximations for construction of global reaction rate, global rates of hydrocarbon fuels

- **CHEMICAL MECHANISMS** **(03 Hours)**
  Explosive and oxidative characteristics of fuels, Criteria for the explosion, Explosion limits, and oxidation of hydrogen, Carbon monoxide, and hydrocarbons

- **PHYSICS OF COMBUSTION** **(03 Hours)**
  Fundamental laws of transport phenomena, Conservations Equations

- **PREMIXED FLAME** **(07 Hours)**
  Laminar premixed flame, laminar flame structure, Stability limits of laminar flames, Laminar flame speed, Flame speed measurements, Flame stabilizations, Ignition and quenching, turbulent flames, turbulent flame speed, external aided ignition (spherical propagation, plane propagation), auto ignition, flammability limits

- **DIFFUSION FLAME** **(07 Hours)**
  Laminar Diffusion flames, turbulent diffusion flames, Schwab-Zel'dovich formulation, Burke-Schumann problem, Gaseous Jet diffusion flame, Droplet Combustion, Liquid fuel combustion, Atomization, Spray and Solid fuel combustion.

- **COMBUSTION AND ENVIRONMENT** **(04 Hours)**
  Atmosphere, Chemical Emission from combustion, Quantification of emission, Emission control methods. Mechanisms of pollutant formation during combustion, pollutants reduction in conventional combustors, pollutants reduction by flame temperature, dry low-oxides of nitrogen combustors, lean premix per vaporize combustion, rich-burn quick-quench lean-burn combustor, catalytic combustion, correlations and modelling of oxides of nitrogen and carbon monoxide emission.

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Kuo, K.K., “Principles of Combustion”, John Wiley and Sons, 2005.
2. Turns, S.R., “An introduction to combustion”, New York: McGraw-Hill, 2017.
3. Law, C.K., “Combustion physics”, Cambridge University Press, 2010.
4. Mishra, D.P., “Fundamentals of Combustion”, Prentice Hall of India, 2010.
5. Mukunda, H.S., “Understanding combustion”, Universities Press, 2009.

METD233	:	BIOFLUID AND BIOHEAT TRANSFER	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs): At the end of the course, the students will be able to

CO1	demonstrate of cardiovascular systems and significant fluid flow problems in large arteries
CO2	apply the knowledge of fluid mechanics to analyze the flow behavior in biological systems
CO3	apply bio-heat transfer models to analyze human body thermoregulation
CO4	understand the basics of tissue optics and model light transport in the tissue layer
CO5	apply knowledge of porous media in bioheat transfer applications
CO6	develop a numerical model to study light transport in biological tissue.

2. SYLLABUS

- **BIOFLUIDICS** **(10 Hours)**

Fluid mechanics review, Solid Mechanics Review, Rheology of blood, Blood morphology, Blood flow in a channel, Viscometers, and Rheometers, Viscoelasticity, Introduction to Biomicrofluidics, pressure-driven flows, surface tension driven flows, modulating surface tension, Flow Bifurcation, Pulsating flow

- **HUMAN BODY THERMOREGULATION** **(12 Hours)**

Introduction to human body thermoregulation; Metabolism; Convection over the body surface, sweating, respiration; Heat transfer to blood vessels; Body heat balance; Hypothalamus; Maintaining body temperatures; Cold thermoreceptors and heat receptors; Body temperature measurement (mean skin temperature, mean torso temperature, and core temperature); Temperature-induced dynamic change of blood flow (Vasodilation and Vasoconstriction); Body heat storage; thermal comfort; Cold-spell and heat wave conditions, fever, Thermo-regulation models, Bio-heat transfer models, Blood perfusion as a heat-removal/addition mechanism

- **TISSUE OPTICS** **(10 Hours)**

Fundamental interactions of light with tissue, Overview of tissue optics, Monte Carlo modeling of light transport in Tissue (Steady State and Time of Flight), Measurement of Ex vivo and In Vivo Tissue optical properties, Thermal Damage and Rate Processes in Biological Tissues, Hypothermia, and hyperthermia

- **SPECIAL TOPICS** **(10 Hours)**

Application of bioheat transfer - Detection of breast cancer, Tumor thermal treatment
Cryobiology, Determination of degree of skin burn, Porous and Bioporous Media, Darcy equation for momentum conservation, Convective heat and mass transfer in porous media, Application to targeted drug delivery, Topics of current interest

Total Lectures **42 Hours**

3. BOOKS RECOMMENDED:

1. G.A. Truskey, F. Yuan, D.F. Katz, "Transport phenomena in biological systems", Pearson. 2009
2. L. Waite and J. Fine, "Applied biofluid mechanics", McGraw-Hill Education, 2007
3. A.J. Welch, J. Martin, and C.V. Gemert, "Optical-thermal response of laser-irradiated tissue", Springer, New York, 2011.
4. L.M. Jiji, "Heat conduction", Springer Science & Business Media, 2009.
5. K. Vafai, "Porous media: Applications in biological systems and biotechnology" Springer, Cham, 2010.

METD234	:	TURBULENCE AND TURBULENT FLOWS	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs)

At the end of the course, the students will be able to

CO1	Evaluate turbulent flows.
CO2	Use self-preservation solutions for free shear flows (jets, wakes, etc.)
CO3	Choose a turbulence model for computational flow analysis (CFD)
CO4	Evaluate and interpret experimental measurements
CO5	statistically represent turbulent flows.
CO6	Apply the knowledge of turbulence and turbulent flows to real life problems.

2. SYLLABUS:

INTRODUCTION (02 Hours)

Nature of turbulence, Method of analysis, generation and diffusion of turbulence, Length scales in turbulent flows.

TURBULENT TRANSPORT OF MOMENTUM AND HEAT (10 Hours)

The Reynolds equations, elements of the kinetic theory of gases, Estimates of Reynolds stress, Turbulent heat transfer, and Turbulent shear flow near the rigid wall. Transport in stationary, homogeneous turbulence, Transport in shear flows, Dispersion of contaminants, Turbulent transport in evolving flows**.** Dynamics of Turbulence—Kinetic energy of mean flow, Kinetic energy of the turbulence, Vorticity dynamics, The dynamics of temperature fluctuations

SHEAR FLOWS (12 Hours)

Boundary Free Shear Flows—Almost parallel two-dimensional flows, turbulent wakes, The wake of a self-propelled body, turbulent jets and mixing layers, the comparative structure of wakes, jets and mixing layers, and Thermal plumes. Wall Bounded Shear Flows—The problem of multiple scales, turbulent flows in pipes and channels, Planetary boundary layers, The effects of a pressure gradient on the flow in surface layers, The downstream development of turbulent boundary layers

THE STATISTICAL DESCRIPTION OF TURBULENCE (06 Hours)

The probability density, Fourier transforms and characteristic functions, joint statistics and statistical independence, Correlation functions, spectra, and the central limit theorem.

SPECTRAL DYNAMICS **(06 Hours)**

Velocity and Length scales in laminar and turbulent boundary layers, molecular versus turbulent dissipation, Kolmogorov Microscales of Dissipation, One and three-dimensional spectra, The energy cascade, The spectrum of turbulence, The effects of production and dissipation, Time spectra, Spectra of passive scalar contaminants.

TURBULENCE SIMULATIONS AND MODELLING **(06 Hours)**

Zero-order models (Algebraic Models), One-Equation Models, Two-Equation Models, Large Eddy Simulation, Direct Numerical Simulation, appropriate turbulence modelling for turbomachinery flows using a two-equation turbulence model.

3. BOOKS RECOMMENDED

1. Tennekes, H. and Lumley, J.L. “A First Course on Turbulence”, MIT Press, Cambridge, 1972.
2. Pope S.B. "Turbulence" Cambridge University Press, Cambridge, U.K., 2000.
3. Davidson P.A, “Turbulence” Oxford University Press, Oxford, U.K., 2004.
4. Biswas, G. and Eswaran, V. "Turbulent Flows" Narosa Publishing House New Delhi, India, 2002.
5. Wilcox, D.C. "Turbulence Modeling for CFD", DCW Industries, La Canada, CA, 2006.

METD240	:	RENEWABLE ENERGY SYSTEMS	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Design solar systems for a given energy utility by applying principles of solar energy Conversion
CO2	Estimate the wind potential and perform power forecast analysis
CO3	Design bio-energy-based systems for a given utility by applying principles of bio-mass to-energy conversion.
CO4	Characterize different types of waste and compare various conversion technologies suitable for industrial applications in line with Government approved RDF and MSW policies
CO5	Compare Hydrogen production methods and use of hydrogen resources with other energy resources in the present context
CO6	Apply the knowledge to real life renewable energy-based systems.

2. SYLLABUS:

- **SOLAR RADIATION** **(12 Hours)**
  Extra-terrestrial and terrestrial, Solar radiation measuring instruments, Estimation of Solar Radiation, Various earth-sun angles.
  Solar Energy Conversion Systems: Solar Thermal Systems: Basics, Flat plate collectors-liquid, and air type. Theory of flat plate collectors, selective coating, advanced collectors, Concentrators: optical design of concentrators, solar water heater, solar dryers, solar stills, Solar ponds, solar cooling and refrigeration, Solar thermal power generation. Solar Photovoltaic Systems: Principle of photovoltaic conversion of solar energy, Solar cells, home lighting systems, Solar lanterns, Solar PV pumps, Govt. policies.
  Introduction to Solar Photovoltaic Thermal Systems (PV/T): Air-based, Water-based, Refrigerant-based Systems. Solar energy storage options: Electrical and Thermal Energy storage options for Solar Energy

- **BIOMASS & BIOENERGY** **(12 Hours)**
  Biogas System: Anaerobic digestion, biogas production, Types of digesters, installation, operation and maintenance of biogas plants, Biogas plant manure utilization, and manure values, factors affecting biogas production, Biogas utilization and storage, Compressed Biogas (CBG) production from agro-waste; biogas for motive power generation, design calculations for biogas plants, Govt. policies. Liquid Biofuels: Biodiesel – The mechanism of transesterification, biodiesel fuel characteristics, technical aspects of biodiesel/Ethanol and other liquid fuels utilization in the engine. Biomass gasification: Different types of the gasifier, power generation and applications

- **WIND ENERGY CONVERSION SYSTEMS** **(08 Hours)**
  History of wind energy, Current status, and future prospects, Wind energy in India. Power available in the wind, Components of Wind Energy Conversion Systems,

Horizontal and Vertical axis wind turbine, Wind turbine power and torque characteristics, Tip speed ratio, Wind speed prediction and forecasting, Betz limit, Govt. Policies

- **WASTE TO ENERGY CONVERSION** **(06 Hours)**
  Introducing Municipal Solid Waste Management; Waste Generation and characterization, Waste Processing Techniques; Source Reduction, Biological Conversion Products: Compost and Biogas, Incineration pyrolysis and Energy Recovery, waste plastic, RDF/Sewage utilization, Govt. Policies on MSW and RDF, Introduction to Microbial Fuel Cell

- **HYDROGEN ENERGY AND FUEL CELLS** **(04 Hours)**
  Benefits of Hydrogen Energy, Hydrogen Production Technologies, Hydrogen Energy Storage, Use of Hydrogen Energy, Electrolysis, Bio-hydrogen Production, Biogas reformation to Syngas, Basic principle of working of fuel cell

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. Duffie, J.A., Beckman, W.A., "Solar Engineering and Thermal Processes", John Wiley and Sons., 2013.
2. Mukunda, H.S, "Understanding Clean Energy and Fuels from Biomass", Wiley India Pvt. Ltd, 2011
3. Mital, K.M., "Biogas Systems, Principle and Applications", New Age International Ltd, 1996
4. Rai, G.D., "Non-Conventional Energy Sources", Khanna Publication, 1988
5. Basu, P., "Biomass Gasification and Pyrolysis: Practical Design and Theory", 1st edition, Academic Press, 2010.

METD241	:	FLOW AND FLAME DIAGNOSTICS	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs)

CO1	Explain the need for diagnostics experiments in fluid flow and reacting flow
CO2	Explain the concepts and methods of various diagnostics techniques in fluid flow and reacting flow
CO3	Explore different analysis techniques commonly used in diagnostics experimental work
CO4	Explore modern diagnostic techniques in fluid flow and reacting flows
CO5	Interpret diagnostics data in fluid mechanics and combustion
CO6	Apply the knowledge of flow and flame diagnostics to real life systems.

2. SYLLABUS

INTRODUCTION TO OPTICAL FLOW DIAGNOSTICS (08 Hours)

Importance of diagnostics, Intrusive Vs. Non-Intrusive Measurements, Point Vs. Planar Measurements, Spatial Vs. Temporal Resolution, Time Vs. Ensemble Averaging,

EQUIPMENTS FOR DIAGNOSTICS (10 Hours)

Lasers, Camera, Synchronization, Seeding, Light-sheet optics, Image Processing

TECHNIQUES (12 Hours)

Velocity — 2D-2C PIV, 2D-3C PIV (Stereo), 3D-3C PIV (Tomographic), LDVHeat Release Rate —Chemiluminescence Imaging (CH, OH, C2, CO2), PLIF (CH, OH, HCHO, H), Temperature —2Line PLIF, IR Camera, Thermographic Phosphors, Mixture Fraction, Acetone PLIF, Rayleigh Scattering.

MISCELLANEOUS (12 Hours)

Soot— LII, Droplet & Spray Measurements — ILIDS-(Droplet Sizing), PDPA (Velocity & Size), Density Gradient—Schlieren, Rhodhamine PLIF, Shadowgraphy.

3. BOOKS RECOMMENDED

1. van de Hulst, H.C., "Light Scattering by Small Particles", Dover, New York, 2012.
2. McCay, T.D., Roux, J.A., "Combustion Diagnostics by Nonintrusive Methods," Progress in Astronautics and Aeronautics Series, Vol. 92, AIAA, 1984.
3. Eckbreth, C., "Laser Diagnostics for Combustion Temperature and Species", Gordon & Breach, 1996.
4. Kohse-Höinghaus, K., Barlow, R.S., Aldén, M., Wolfrum, J., "Combustion at the focus: laser diagnostics and control", Comb Inst, 2005.
5. Raffel, M., Willert, C.E., Kompenhaus, J., "Particle Image Velocimetry: A Practical Guide," Springer-Verlag, 1998.

METD242	:	TRANSPORT IN POROUS MEDIA	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	explain the basics of porous media properties
CO2	convert the microscopic pore-scale equations into the macroscopic domain-scale equations
CO3	demonstrate various experimental techniques available to measure different properties of porous media
CO4	perform a numerical simulation to close the volume-averaged equation
CO5	understand the basics of local thermal equilibrium and local non-thermal equilibrium approach
CO6	derive volume-averaged equations for multiphase flow

2. SYLLABUS:

- Basics of porous media flow, Basic quantities including porosity, filtration velocities, single and two-phase flows, measurement of essential parameters including porosity, permeability, relative permeability, capillary pressure **(06 Hours)**

- Principal components of a permeability tensor, measurements of this tensor using 1-D and radial flow methods **(03 Hours)**

- Basics of tensor manipulations and tensor algebra, Definition of various averages, averaging theorems and their derivations **(04 Hours)**

- Volume averaging applied to single-phase flows, Derivation of Darcy's law using the averaging problems, Development of closure formulation, an overview of the Hazen-Dupuit-Darcy (HDD) model, extensions of HDD model **(08 Hours)**

- Volume averaging applied to two-phase flows: Derivation of the two permeability tensors along with the two viscous-drag tensors, Development of appropriate closure formulation, Development of a workable closure formulation using transformations **(09 Hours)**

- Experimental techniques: Flow visualization, quantitative methods, inverse parameter estimation **(04 Hours)**

- Special Topics: Hat conduction in a porous medium, Forced convection through a porous medium, Radiation heat transfer in a porous medium, numerical techniques **(08 Hours)**

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. D. Zhang, “Stochastic Methods for Flow in Porous Media: Coping with Uncertainties”, Academic Press, California, 2002.
2. D. R. Ingham and I. Pop, “Transport Phenomena in Porous Media, Volumes I-III”, Elsevier, New York (2005).
3. M. Kaviany, “Principles of Heat Transfer in Porous Media”, Springer New York, 1995.
4. J. Bear and Y. Bachman, “Introduction to Modeling of Transport Phenomena in Porous Media”, Kluwer Academic Publishers, 1990.
5. S. Whitaker, “The Method of Volume Averaging”, Springer, New York, 1999.

METD243	:	NANOFLUIDS AND ITS APPLIATIONS IN THERMAL SYSTEMS	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

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

CO1	Select the suitable approach for the synthesis of nanofluid
CO2	Understand the factors affecting the stability and measure the stability of nanofluid
CO3	Measure or predict the thermal properties of nanofluids
CO4	Determine the enhancement in convection heat transfer in nanofluid
CO5	Apply the nanofluid in the various thermal systems at the lab and industrial scale
CO6	Identify the Challenges and Limitations of Nanofluids to Engineering Applications

2. SYLLABUS

- **Introduction and Synthesis of Nanofluids** **(06 Hours)**

Introduction to heat transfer, micron-sized solid particles, fundamentals and advantages of nanofluids, classification, synthesis of nanofluids, General issues of concern, micro emulsion-based methods for nanofluids, Solvothermal synthesis, synthesis using supports, magnetic nanofluids, Inert gas condensation.

- **Stability of Nanofluids** **(08 Hours)**

Key Concepts of stability, factors affecting stability, Electrokinetic phenomena and electrical double layer, Zeta Potential. Interaction of particles: aggregation, flocculation, and coagulation. Sedimentation velocity, Brownian motion, DLVO theory, synthesis approach of nanofluids, stability measurement, and methods to improve stability.

- **Thermal Properties of Nanofluids** **(08 Hours)**

Density, specific heat capacity, thermal conductivity: measurement techniques, the effect of particle material, base liquid, temperature, concentration, size, and shape of nanoparticles. Mechanisms of thermal conductivity enhancement, classical models for suspensions of particles in a liquid, Brownian motion of nanoparticles, nanolayer, clustering of nanoparticles, combined effects of Ballistic Phonon Transport and clustering, combined effects of Brownian motion and clustering. Viscosity: classical and theoretical models for suspensions of particles in a liquid, effects of nanofluid parameters, the combined effect of enhanced thermal conductivity and increased viscosity on heat transfer.

- **Heat Transfer Enhancement in Nanofluids** **(08 Hours)**

Forced convective heat transfer in nanofluids: horizontal and vertical loops. Free convective heat transfer in nanofluids, nanofluid feasibility criteria for laminar and turbulent flow conditions. Flow stability in thermosyphon loops, surface modified channels, nanofluid flow and heat transfer enhancement using an electric and magnetic field, pool boiling of nanofluids, critical heat flux in pool boiling of nanofluids.

- **Applications of Nanofluids in thermal systems** **(08 Hours)**

Heat Pipes: nanofluids for heat transfer intensification in mini loop thermosyphons with a transparent envelope. Nanocoating in Heat Pipes. Nanofluids for solar energy retrieval: solar thermal collectors, optical properties of nanofluids, extinction coefficient, solar stills. Nano-encapsulated phase change material. Electronic chip cooling. Nano refrigerants and nano lubricants in air conditioning systems. Thermal battery management systems in electric vehicles.

- **Challenges and Limitations of Nanofluids to Engineering Applications (04 Hours)**

Nanofluid stability, high cost of nanofluids, degradation of fluid transfer components. Health, safety, and environmental issues related to the manufacturing and usage of nanofluids and Nanoparticles. Performance comparison criteria for nanofluids. Hybrid Nanofluids.

(Total Lecture Hours: 42)

3. BOOKS RECOMMENDED:

1. S.K. Das, S.U.S. Choi, W. Yu, T. Pradeep, Nanofluids – Science and Technology, John Wiley & Sons, 2008.
2. M. Rebay, S. Kakaç, R.M. Cotta, Microscale and Nanoscale Heat Transfer –Analysis, Design and Application, CRC Press, 2016.
3. V. Bianco, O.Manca, S. Nardini, K. Vafai, Heat Transfer Enhancement with Nanofluids, CRC Press, 2015.
4. M. Hatami, D. Jing, Nanofluids – Mathematical, Numerical, and Experimental Analysis, Academic Press, 2020.
5. H. Ali, Advances in Nanofluid Heat Transfer, Elsevier, 2022.

METD244	**:**	**INDUSTRIAL REFRIGERATION**	**L**	**T**	**P**	**Credits**
			3	**0**	**0**	**03**

1. COURSE OUTCOMES (COs):

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

CO1	Select the appropriate refrigerants and mixture for the industrial refrigeration system.
CO2	Select and design the expansion process for low-temperature production.
CO3	Select and design various non-conventional refrigeration systems for low-temperature applications.
CO4	Understand and apply the food preservation method and food storage methods for various applications
CO5	Select and design water coolers and ice-making systems.
CO6	Understand and apply the various refrigeration control equipment for different applications.

2. SYLLABUS:

- **REFRIGERANT:** **(08 Hours)**
  Various types of refrigerants and refrigerant mixtures, azeotrope and zeotrope refrigerants, properties, and enthalpy-composition charts for mixtures of ideal and real mixtures.
- **LOW-TEMPERATURE PRODUCTION**: **(08 Hours)**
  Joule Thomson effect and adiabatic expansion, cascade system and multiple pressures vapor compression system.
- **REFRIGERATION CONTROL**: **(08 Hours)**
  essential elements, detecting elements, actuating elements, electric motor and controls, control of refrigeration equipment.
- **NON-CONVENTIONAL REFRIGERATION SYSTEM**: **(08 Hours)**
  thermo-electric refrigeration system, magnetic refrigeration system, magnetic moment and entropy of paramagnetic material, thermal valve, Vortex flow refrigeration system.
  Tran-critical CO2 cycle.
- **FOOD REFRIGERATION**: **(05 Hours)**
  microbiology of food, method of chilling, freezing, and deep freezing of meat, fish, dairy product, vegetable, and poultry. Food storage and method of food storage.
- Design of water cooler, ice plants, and cold storage plants, **(05 Hours)**

Total 42 hours

3. BOOKS RECOMMENDED

1. Arora, S.C., Romkundwar, S.A., “Course in Refrigeration and Air conditioning”, Dhanpat Rai & Sons, 1997.
2. Stocker, W. F., and Jones, J. W., “Refrigeration and Air Conditioning”, McGraw Hill, 1986.
3. Dossat, R. J., “Principles of Refrigeration”, John Wiley and Sons, 1988.
4. Baron, R. F., “Cryogenics Systems”, Oxford Press, USA, 1985.
5. Arora, C.P., “Refrigeration and Air Conditioning”, McGraw-Hill, 3rd edition, 2013

METD210	:	COMPUTATIONAL FLUID DYNAMICS	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

At the end of the course the students will be able to:

CO1	Develop an understanding of major theories, approaches and methodologies used in CFD
CO2	Build skills in the actual implementation of CFD methods (e.g., boundary conditions, different numerical schemes etc.)
CO3	Acquire a working knowledge of computational complexity, accuracy, stability, and errors in solution procedures
CO4	Develop numerical models for fluid flow and heat transfer problems
CO5	Understand advanced numerical techniques such as LBM and Meshless techniques.
CO6	Apply the CFD analysis to real-life engineering designs.

2. SYLLABUS:

- **Introduction to Computational Fluid Dynamics and Principle of Conservation** **(05 Hours)**
  Introduction of Computational Fluid Dynamics: What, When, and Why?, CFD Applications, Numerical vs. Analytical vs. Experimental, Conservation of mass, Newton's second law of motion, Expanded forms of Navier-Stokes equations, Conservation of energy principle, Special forms of the Navier-Stokes equations, Classification of second-order partial differential equations, Initial and boundary conditions, Governing equations in generalized coordinates.

- **Fundamentals of Discretization** **(08 Hours)**
  Discretization principles: Pre-processing, Solution, Post-processing, Finite Element Method, Finite difference method, Well posed boundary value problem, Possible types of boundary conditions, Conservativeness, Boundedness, Transportiveness, Higher-order schemes to FDM, Finite volume method (FVM), Illustrative examples: 1-D steady-state heat conduction without and with constant source term

- **Finite Volume Method** **(06 Hours)**
  Some Conceptual Basics and Illustrations through 1-D Steady-State Diffusion Problems: Physical consistency, Overall balance, FV Discretization of a 1-D steady-state diffusion type problem, Composite material with position-dependent thermal conductivity, Four essential rules for FV Discretization of 1-D steady-state diffusion type problem, Source term linearization, Implementation of boundary conditions

- **Discretization of Unsteady State Problems** **(04 Hours)**
  1-D unsteady-state diffusion problems: implicit, fully explicit and Crank-Nicholson scheme, FVM for 2-D unsteady-state diffusion problems

- **Discretization of Convection-Diffusion Equations** **(06 Hours)**
  A Finite Volume Approach: Finite volume discretization of convection-diffusion problem: Central difference scheme, Upwind scheme, Exponential scheme and Hybrid scheme, Power-law scheme, Generalized convection-diffusion formulation, Finite volume discretization of two-dimensional convection-diffusion problem, The concept of false diffusion, QUICK scheme

- **Discretization of Navier Stokes Equations** **(06 Hours)**
  Discretization of the Momentum Equation: Stream Function-Vorticity approach and Primitive variable approach, Staggered grid and Collocated grid, SIMPLE Algorithm, SIMPLER Algorithm

- **Special Topics** **(07 Hours)**
  Unstructured Grid Formulation, An overview of Finite Element Method, boundary element method, Lattice Boltzmann Method, Meshless Technique

Total Lectures 42 Hours

3. BOOKS RECOMMENDED:

1. S.V. Patankar, "Numerical Heat Transfer and Fluid Flow", McGraw-Hill, 2017.
2. T. J. Chung, "Computational Fluid Dynamics", Cambridge University Press, 2010.
3. H. K. Versteeg, W. Malalasekera, "An Introduction to Computational Fluid Dynamics", Longman Scientific & Technical, 2007
4. J.H. Ferziger, M. Peric, "Computational Methods for Fluid Dynamics", Springer., 2002.
5. J. C. Tannehill, D. A.Anderson, R. H. Pletcher, "Computational Fluid Mechanics and Heat Transfer", Taylor &Francis, 2020

METD211	:	OPTIMIZATION TECHNIQUES	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

At the end of the course the students will be able to:

CO1	Understand the concept of optimization, related terms and formulate mathematical models for practical problems based on the information provided.
CO2	Use linear programming to solve real life linear programming problems
CO3	Solve transportation and transhipment problems, travelling salesman problem and integer programming
CO4	Determine solutions that will be deployed in real world situations after conducting sensitivity and post optimality analysis
CO5	Apply classical methods to solve nonlinear programming problems
CO6	Use evolutionary algorithms to solve complex engineering problems where classical methods are not suitable.

2. SYLLABUS:

- **Introduction** **[04 hours]**

  Introduction to Optimization, Linear Programming – Formulation, Graphical method, simplex method and special cases.

- **Sensitivity and post optimality analysis** **[08 hours]**

  Sensitivity Analysis and post optimality analysis of linear programming problems – changes in resources and objective function, changes affect feasibility and optimality, duality, dual simplex algorithm, generalize simplex algorithm.

- **Special types of linear programming problems** **[06 hours]**

  Transportation problems, Transshipment problems, Travelling salesman problems, Integer programming.

- **Introduction to MATLAB and solving linear and nonlinear problems using MATLAB** **[06 hours]**

  Introduction to MALAB, creating and manipulating vectors and matrix, user defined function, special built-in function to create special vectors and matrices, symbolic math, built-in function to solve linear programming problems.

- **Nonlinear programming problems** **[04 Hours]**

  Nonlinear Programming problems: Graphical method, convex function and convex region, necessary and sufficient conditions, Lagrangian method, Karush-Kuhn-Tucker (KKT) conditions, solving nonlinear problems using MATLAB.

- **Evolutionary Algorithms** **[14 hours]**

  Introduction to evolutionary algorithm, introduction to multi-objective optimization, genetic algorithms, differential evolution algorithm, Particle swarm optimization, tabu search, simulated Annealing technique, solving real life engineering problems using MATLAB.

[Total Teaching Hours – 42]

3. BOOKS RECOMMENDED

1. Hillier, F.S., Lieberman, G.J., "Introduction to Operations Research: Concepts and Cases", 8th edition, Tata McGraw-Hill Education, 2005.
2. Taha, H.A., "Operations Research: an Introduction", 10th edition, Pearson Education India. 2016.
3. Rao, S.S., "Engineering Optimization: Theory and Practice", 3rd edition, John Wiley & Sons, 2013.
4. Vasuki, A., "Nature-Inspired Optimization Algorithms", CRC Press, 2020.
5. Goldberg, D.E., "Genetic Algorithms: in search, Optimization and Machine Learning", Pearson Education India, 1989.

METD212	**:**	**ENERGY CONSERVATION, MANAGEMENT AND AUDIT**	**L**	**T**	**P**	**Credits**
			3	**0**	**0**	**03**

1. COURSE OUTCOMES (COs):

At the end of the course the students will be able to:

CO1	Apply various energy conservation techniques to estimate energy-saving potential
CO2	Compare various appliances/utilities based on their stars and labeling, benchmarking values, and PAT Scheme in industries
CO3	Calculate the usage of energy for a given industrial utility and suggest a suitable way to minimize energy bill
CO4	Relate the significance of energy usage in buildings and understand the ways to reduce the energy bill
CO5	Compute various performance parameters of HVAC systems and suggest suitable ways for improving energy efficiency
CO6	Build suitable energy conservation module for domestic and industrial systems.

2. SYLLABUS:

GLOBAL AND NATIONAL ENERGY SCENARIO (08 Hours)

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

ENERGY EFFICIENCY IN BOILER, STEAM, AND FURNACE SYSTEM UTILITIES (08 Hours)

Energy conservation opportunities in boiler systems, retrofitting of FBC in conventional boilers, Steam line distribution standard practices including sizing and layouts, selection, operation, maintenance of steam traps, and energy-saving opportunities in steam systems.

Energy Efficiency in Furnaces 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

COGENERATION **(05 Hours)**

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

ENERGY CONSERVATION IN FANS, BLOWERS COMPRESSORS, AND PUMP SYSTEMS **(10 Hours)**

Energy-saving opportunities, performance evaluation and efficient system operation. Air Systems: Efficient operation of the compressed air system, Leakage tests. Pumps and Pumping Systems: Pump curves, factors affecting pump performance, Energy loss in throttling, Effects of impeller diameter change, Flow control strategy, Variable speed drives, and Energy conservation opportunities.

Energy Conservation in HVAC and Cooling Towers **(05 Hours)**

Total Lectures 42 hours

3. BOOKS RECOMMENDED:

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

METD213	:	FUNDAMENTALS OF ELECTRIC VEHICLES	L	T	P	Credits
			3	0	0	03

1. COURSE OUTCOMES (COs):

At the end of the course the students will be able to:

CO1	Explain the basics of electric vehicles, their architecture, technologies, and fundamentals.
CO2	Calculate various forces acting on the moving vehicle, power, and torque required to drive the vehicle, drive cycles and energy consumed.
CO3	Understand battery parameters such as SoC, SoH, factors affecting battery cell lifecycle and parameters to select EV battery
CO4	Design battery pack and BMS based on mechanical, thermal, and electric aspects
CO5	Explain various methods of battery thermal management
CO6	Explain torque production, d-equivalent, chargers and charging standards

2. SYLLABUS:

- **Introduction** **(04 Hours)**
Overview of electric vehicles in India, Basics of Batteries, Charging and swapping infrastructure, source of Lithium for batteries, EV subsystems

- **Vehicle Dynamics** **(04 Hours)**
Forces acting when a vehicle moves, Aerodynamics drag, rolling resistance and uphill resistance, power, and torque to accelerate

- **Vehicle Subsystems: EV power-train** **(12 Hours)**
Concept of the drive cycle, Drive cycles and energy used per km, EV subsystem: Design of EV drive train, Introduction to battery parameters, why lithium-Ion battery? Batteries in the future, Li-Ion battery cell, State of charge and state of health estimation and self-discharge, battery pack development, computation of effective cost of the battery, charging batteries, Fundamentals of battery pack design, mechanical design, thermal design, electrical design, BMS design of the electric vehicle

- **Battery Thermal Management** **(08 Hours)**
Passive cooling, Active cooling

- **Vehicle Accessories** **(08 Hours)**
EV motors and controllers, power and efficiency, torque production, speed and back EMF, the-q equivalent circuit, field-oriented control, three-phase AC, thermal design, engineering considerations, future frontiers

- **Battery Charging and Swapping** **(06 Hours)**

EV chargers: slow or fast, Battery swapping, standardization and onboard chargers, public chargers, bulk chargers/swap stations, Analytics

Total Lectures **42 Hours**

3. <u>BOOKS RECOMMENDED:</u>

1. Ehsani, M., Gao,Y., Longo, S., Ebrahimi, K.M., "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", CRC Press, 2018.
2. Husain, I., "Electric and Hybrid Vehicles: Design Fundamentals", CRC press, 2010.
3. Mi, C., Masrur, M.A., "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives", John Wiley & Sons, 2017.
4. Erjavec, J., "Hybrid, Electric, and Fuel-Cell Vehicles", Cengage Learning, 2012
5. Denton, T., "Electric and Hybrid Vehicles", 2nd edition, Routledge¸ 2020

METD203	:	COMPUTATIONAL LABORATORY-II	L	T	P	Credits
			0	0	4	02

1. COURSE OUTCOMES (COs):

At the end of the course the students will be able to:

CO1	Understand the features available in meshing software and CFD solver
CO2	Solve fluid flow and heat transfer problems using a CFD solver.
CO3	Develop computer code to solve both steady and transient heat conduction problems using FVM
CO4	Derive numerical solutions to various convection-diffusion problems using multiple schemes such as central difference scheme, upwind scheme, and hybrid differencing scheme
CO5	Solve lid-driven cavity problem
CO6	Develop a solution for fluid flow problems using a mesoscopic approach (LBM)

- **ANSYS-FLUENT**
  1. Introduction to mesh generation software (ICEM/Workbench)
  2. Introduction to ANSYS-FLUENT solver
  3. Heat transfer simulation through a solid medium (Steady-state/Transient + various boundary conditions + with and without source term)
  4. Fluid flow simulation through the channel (Laminar/ Turbulent)
  5. Non-isothermal flow simulation through channel/enclosure/over bodies (Laminar + Turbulent)
  6. Flow and heat transfer simulation through a porous medium
  7. Multiphase modelling & simulation
  8. Flow & Heat transfer simulation for various engineering applications

- **CODING**
  9. Introduction to compiler, scripts, loops, logical statements
  10. FVM code for heat conduction with and without source term
  11. FVM code for the pin-fin problem
  12. FVM code for convection-diffusion problem based on central difference scheme
  13. FVM code for convection-diffusion problem based on the upwind scheme
  14. FVM code to analyse false-diffusion of upwind scheme
  15. FVM code for convection-diffusion problem based on the hybrid differencing scheme
  16. FVM code for the explicit method based transient heat conduction problem
  17. FVM code for the implicit scheme based transient heat conduction problem
  18. LBM code for channel flow

METD204	**:**	**EXPERIMENTAL LABORATORY-II**	**L**	**T**	**P**	**Credits**
			0	**0**	**4**	**02**

1. COURSE OUTCOMES (COs):

At the end of the course the students will be able to:

CO1	Understand and demonstrate the operation of identified system/ instrument/ equipment
CO2	Perform given practical task independently on system/instrument/equipment
CO3	Analyse and evaluate the observations and deduce conclusions therein
CO4	Represent results graphically and deduce conclusions therein
CO5	Demonstrate practical skills to work on identified problem
CO6	Develop skills for team effort and coordination through practical group performance

Thermal Engineering Lab-I & II

(Any 20 experiments)

1. Calibration of thermocouple
2. Thermal conductivity of insulating powder
3. Heat transfer through composite wall
4. Heat transfer from pin fin apparatus
5. Emissivity measurement
6. Radiation exp-2 (Thermal imaging camera)
7. Performance test on vapor compression refrigeration system
8. Performance test on vapor absorption system.
9. Performance test on Ice plant
10. Performance test on air conditioning plant
11. Performance test on Cascade Refrigeration system
12. Performance test of 4-stroke Petrol Engine.
13. Performance test of 4-stroke Diesel Engine.
14. Heat Balance Preparation for 4-stroke Diesel Engine.
15. Heat Balance Preparation for four-stroke Petrol Engine
16. Determination of friction power of multi-cylinder petrol engine using Morse Test Method.
17. Determination of friction power of single/multi-cylinder petrol engine using Willan's Line Method.
18. Demonstration of wind tunnel
19. Demonstration of thermal turbomachines
20. Performance on a nozzle test rig
21. Junker's gas calorimeter
22. Bomb's calorimeter
23. Redwood viscometer

24. Gas chromatography
25. Heat pipe experiments
26. Pulsating heat pipe experiments
27. Thermosyphon experiments
28. Microchannel heat sink experiment
29. PCM based experiment-1
30. PCM with extended surface experiment-2
31. Combustion flame and analysis experiments
32. Vortex tube refrigeration
33. Liquid nitrogen plant demonstration
34. Pulse tube refrigeration system
35. Two-phase flow experiments
36. Fluid dynamics experiment-1
37. Fluid dynamics experiment-2
38. Automobile demonstration and experiment
39. Free convection experiment
40. Forced convection experiment
41. Heat exchanger experiment-1
42. Heat exchanger experiment-2
43. Measurement experiment-1
44. Measurement experiment-2
45. Calibration of various instruments