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 System Design imbibes in students' 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 System Design

PEO1: Help students to achieve analytical, computational, and experimental skills for solving thermal-engineering-related problems.

PEO2: Have 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: Graduates will have inculcated to maintain high professionalism and ethical standards, effective technical presentation, and writing skills, and to 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 System Design)

Semester-I

<table>
<tr><th rowspan="3">Sr. No.</th><th rowspan="3">Subject</th><th rowspan="3">Code</th><th rowspan="3">Scheme L-T-P</th><th colspan="3">Exam Scheme</th><th rowspan="3">Credits (Min.)</th><th rowspan="3">Notional hours of Learning (Approx.)</th></tr>
<tr><th>Th.</th><th>T</th><th>P</th></tr>
<tr><th>Marks</th><th>Marks</th><th>Marks</th></tr>
<tr><td>1</td><td>Core Subject-1
Numerical Methods and Computations</td><td>METD101</td><td>3-1-0</td><td>100</td><td>25</td><td>0</td><td>4</td><td>70</td></tr>
<tr><td>2</td><td>Core Subject-2
Advanced Thermodynamics</td><td>METD103</td><td>3-1-0</td><td>100</td><td>25</td><td>0</td><td>4</td><td>70</td></tr>
<tr><td>3</td><td>Core Subject-3
Transport Phenomena - I</td><td>METD105</td><td>3-1-0</td><td>100</td><td>25</td><td>0</td><td>4</td><td>70</td></tr>
<tr><td>4</td><td>Core Elective – 1
1. Design of Refrigeration and Air-conditioning systems
2. Bio-Mass Conversion Systems
3. Electro-Chemical Energy storage systems
4. Environmental Pollution and Control
5. Gas Dynamics and Compressible Fluid Flow</td><td>METD111
METD113
METD115
METD117
METD119</td><td>3-0-0</td><td>100</td><td>0</td><td>0</td><td>3</td><td>55</td></tr>
<tr><td>5</td><td>Core Elective – 2
1. Electric Vehicles and Advanced IC Engines
2. Jet and Rocket Propulsion
3. Analysis and Design of Thermal Turbo Machines
4. Measurements and Data Analysis
5. Finite Element Method in Thermal Systems</td><td>METD121
METD123
METD125
METD127
METD129</td><td>3-0-0</td><td>100</td><td>0</td><td>0</td><td>3</td><td>55</td></tr>
<tr><td>6</td><td>Computational and Experimental Laboratory-I</td><td>METD107</td><td>0-0-6</td><td>0</td><td>0</td><td>150</td><td>3</td><td>110</td></tr>
<tr><td></td><td></td><td colspan="5" align="right">Total</td><td>21</td><td>430</td></tr>
<tr><td>7</td><td>Vocational Training/ Professional Experience/ Research Internship (Optional)(Only for PG Diploma in TSD/Exit)</td><td>METMV01
METMP01</td><td>0-0-10</td><td></td><td></td><td></td><td>5</td><td>200</td></tr>
</table>

Semester-II

<table>
<tr><th rowspan="3">Sr. No.</th><th rowspan="3">Subject</th><th rowspan="3">Code</th><th rowspan="3">Scheme L-T-P</th><th colspan="3">Exam Scheme</th><th rowspan="3">Credits (Min.)</th><th rowspan="3">Notional hours of Learning (Approx.)</th></tr>
<tr><th>Th.</th><th>T</th><th>P</th></tr>
<tr><th>Marks</th><th>Marks</th><th>Marks</th></tr>
<tr><td>1</td><td>Core Subject-4
Transport Phenomena – II</td><td>METD102</td><td>3-1-0</td><td>100</td><td>25</td><td>0</td><td>4</td><td>70</td></tr>
<tr><td>2</td><td>Core Subject-5
Energy Conversion Systems</td><td>METD104</td><td>3-1-0</td><td>100</td><td>25</td><td>0</td><td>4</td><td>70</td></tr>
<tr><td>3</td><td>Core Elective – 3
1. Design of Heat Exchangers
2. Theory and Design of Cryogenic Systems
3. Combustion for Propulsion Systems
4. Biofluidic and Bioheat Transfer
5. Nanofluid and its applications in Thermal Systems</td><td>METD132
METD134
METD136
METD138
METD140</td><td>3-0-0</td><td>100</td><td>0</td><td>0</td><td>3</td><td>55</td></tr>
<tr><td>4</td><td>Core Elective – 4
1. Machine Learning for Thermal Systems
2. Flow and Flame Diagnostics
3. Transport in Porous Media
4. Renewable Energy Systems
5. Design of Solar Thermal System</td><td>METD142
METD144
METD146
METD148
METD150</td><td>3-0-0</td><td>100</td><td>0</td><td>0</td><td>3</td><td>55</td></tr>
<tr><td>5</td><td>Institute Elective
1. Computational Fluid Dynamics
2. Fundamentals of Electric Vehicles
3. Energy Conservation, Management, and Audit
4. Optimization Techniques
5. Turbulence and Turbulent Flows</td><td>METD172
METD174
METD176
METD178
METD180</td><td>3-0-0</td><td>100</td><td>0</td><td>0</td><td>3</td><td>55</td></tr>
<tr><td>6</td><td>Mini Project</td><td>METD106</td><td>0-0-4</td><td></td><td></td><td>100</td><td>2</td><td>70</td></tr>
<tr><td>7</td><td>Computational and Experimental Laboratory-II</td><td>METD108</td><td>0-0-6</td><td>0</td><td>0</td><td>150</td><td>3</td><td>110</td></tr>
<tr><td></td><td></td><td colspan="5" align="right">Total</td><td>22</td><td>485</td></tr>
<tr><td>8</td><td>Vocational Training/ Professional Experience/ Research Internship (Optional) (Only for PG Diploma in TSD/Exit)</td><td>METMV02
METMP02</td><td>0-0-10</td><td></td><td></td><td></td><td>5</td><td>200</td></tr>
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Semester-III

Third Semester							
MOOC Course-I*						3/4	70/80
MOOC Course-II*						3/4	70/80
Dissertation Preliminaries	METD295	-	-	-	350$	14	560
					Total	**20-22**	**700-720**

***** Students may choose any available MOOC courses from SWAYAM/NPTEL with the consent of their M.Tech. supervisor

Semester-IV

Fourth Semester							
Dissertation	METD296	-	-	-	600$	20	800

Total Credits: 21 + 22 + 20-22 + 20 = 83-85 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
MOOC Courses	-	-	6-8	-	6-8
Software/Laboratory	03	03	-	-	06
Mini Project	-	02	-	-	02
Dissertation	-	-	14	20	34
Total Credits	21	22	20-22	20	**83-85**

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 the Golden Section Search method

2. Syllabus:

INTRODUCTION	(03 Hours)
Introduction to Computer-Aided Engineering Analysis, Measuring Errors, Sources of Error, Binary Representation of Numbers, Floating-Point Representation, Propagation of Errors, 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	**(05 Hours)**
Primer on Integral Calculus, Trapezoidal Rule, Simpson's 1/3rd Rule, Romberg Integration, Gauss-Quadrature Rule, Discrete Data Integration, Improper Integration, Simpson's 3/8 Rule	
ORDINARY DIFFERENTIAL EQUATIONS	**(06 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	**(05 Hours)**
Golden Section Search Method, Newton's Method, Multidimensional Direct Search Method, Multidimensional Gradient Method, Simplex Method	

(Total Lecture Hours: 45)

3. Books Recommended:

1	Numerical methods for engineers, by S.C. Chapra, and R.P. Canale, Mcgraw-hill, Ed. 7, 2015
2	Numerical Methods in Engineering & Science, by B.S. Grewal, Khanna Publication, Ed. 11, 2013.
3	Numerical Mathematics and Computing, by Ward Cheney and David Kincaid, Cengage, Ed. 7, 2013
4	Applied Numerical Analysis, by Curtis Gerald and Patrick Wheatley, Pearson Education India, Ed. 7, 2007.
5	Analysis of Numerical Methods, by E. Isaacson & H. B. Keller, Dover Publications, 1994

METD103	:	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	Examine of stability in thermodynamic systems
CO5	Relate about statistical thermodynamics.
CO6	Implement concepts of 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	**(05 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	**(16 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 Lecture Hours: 45)

3. Books Recommended:

1	A. Bejan, “Advanced Engineering Thermodynamics,” 3rd edition, John Wiley and sons, 2006.
2	F.W.Sears and G. L. Salinger, “Thermodynamics, Kinetic Theory, and Statistical Thermodynamics,” Narosa Publishing House, New Delhi, 3rd edition, 1998
3	M.J.Moran and H.N.Shapiro, “Fundamentals Of Engineering Thermodynamics,” John Wiley and Sons
4	M. W. Zemansky and R. H. Dittman, “Heat and Thermodynamics” McGraw Hill International Editions, 7th edition, 2007
5	I. K. Puri and K. Annamalai, “Advanced Engineering Thermodynamics,” CRC Press, 2001
6	Kotas T .J., “The Exergy Methods of Thermal Plant Analysis,” 2nd Ed., Krieger Publ. Corp. U.S.A., 2000
7	Turner, W.C., (Ed.), “Energy Management Handbook,” John Wiley & Sons, N.Y., 2002.
8	Ibrahim Dincer, Marc A. Rosen, “Exergy – Energy, Environment and Sustainable Development,” Elsevier Publications, 2021

METD105	:	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	
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	**(07 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	
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	**(06 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	**(06 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 Lecture Hours: 45)

3. Books Recommended:

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

METD111	:	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	**(16 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 CO2 – 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	**(07 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	**(16 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 Lecture Hours: 45)

3. <u>Books Recommended:</u>

1	Stocker, W. F., and Jones, J. W., “Refrigeration and Air Conditioning,” McGraw Hill, N. Y. 1986
2	Dossat, R. J., “Principles of Refrigeration,” John Wiley and Sons, 1988
3	Threlkeld, J.L., “Thermal Environmental Engineering,” Prentice-Hall, N. Y., 1970
4	Baron, R. F., “Cryogenics Systems,” Oxford Press, USA, 1985.
5	ASHRAE Fundamentals, Applications, Systems, and Equipment, 1999

METD113	:	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	Discuss biomass resources
CO2	Explain 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	Apply the knowledge to deal with complex problems

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	**(09 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	**(10 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 Lecture Hours: 45)

3. Books Recommended:

1	Biomass-Application, technology & production, N.C. Cheremisinoff, P.N. Cheremisinoff & F. Ellurbrush, Marcel Dekker, New York, 1980
2	Biomass for Renewable Energy, Fuels, and Chemicals, Donald L. Klass, Reed, Academic Press, Elsevier, 1998
3	Bio-fuels: biotechnology, chemistry, and sustainable development by DM Mousdale, CRC Press, 2008
4	Renewable Energy by B Sorensen, Academic Press, New York, 2002
5	Renewable energy: Power for a sustainable future by G Boyle (Ed), Oxford, 1996

METD115	:	ELECTRO-CHEMICAL ENERGY STORAGE 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	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	**(05 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	**(12 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 Lecture Hours: 45)

3. **Books Recommended:**

1	Newman, John and Karen E. Thomas-Alyea. Electrochemical systems. 3rd ed. Wiley-Interscience, 2004
2	O' Hayre, Ryan, Suk-Won Cha. Fuel Cell Fundamentals. 2nd ed. Wiley, 2009
3	Huggins, Robert A. Advanced batteries: Materials Science Aspects. Springer, 2008
4	Bard, Allen J., and Larry R. Faulkner. Electrochemical Methods: Fundamentals and Applications. 2nd ed. Wiley, 2000

METD117	:	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	Show Handling of toxic and radioactive wastes Incineration and verification.
CO5	Create concrete solutions to minimize the air, water, land, and noise pollution.
CO6	Explain 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	**(13 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	**(06 Hours)**
Pollution control in process industries, namely Cement, Paper. Petroleum and petrochemical, Fertilizers and distilleries, thermal power plants, and automobiles	

(Total Lecture Hours: 45)

3. Books Recommended:

1	Manster, G.M., Introduction to Environmental Engineering and Science, 2nd ed., 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	Noise Pollution and Control Strategy, S.P. Singal -, Alpha Publishers, 2005

METD119	:	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	Evaluate Gas Dynamics of wet steam

2. Syllabus:

ONE-DIMENSIONAL COMPRESSIBLE FLOW	**(12 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	**(11 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 Lecture Hours: 45)

3. **Books Recommended:**

1	Rathakrishnan, Ethirajan. “Applied gas dynamics.” Wiley, (2019)
2	Somasundaram S.L., “Gas Dynamics & Jet Propulsion,” New Age International (P) Ltd., New Delhi, 1996
3	Zucker, Robert D., and Oscar Biblarz. Fundamentals of gas dynamics. John Wiley & Sons, 2019
4	Aerothermodynamics and flow in turbomachines Vavra, M.H., John Wiley 1960
5	The dynamics and thermodynamics of compressible fluids, Vol. I & II, Shapiro A.H., Ronald Press, 1965
6	A mathematical theory of compressible fluid flow – Richard Von Mosses – Academia Press. N.Y., 1958
7	B. Lakshminarayana. “Fluid dynamics and heat transfer of turbomachinery.” John Wiley & Sons; 1995
8	Korpela, S. A., “Principles of turbomachinery,” 2^{nd} Edition, Wiley and Sons, 2019
9	Ronald D. Flack, “Fundamentals of Jet Propulsion with Application,” Cambridge University Press, 2005
10	Ruey-Hung Chen, “Foundations of Gas Dynamics,” CAM Press, 2017

METD121	:	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

2. Syllabus:

INTRODUCTION TO I C ENGINES	**(03 Hours)**
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	
MATERIAL AND DESIGN CONSIDERATION FOR ENGINE COMPONENTS	**(04 Hours)**
Piston, Cylinder, Piston Rings, Connecting Rod, Cam Shafts, Crank Shafts, etc	
GAS EXCHANGE PROCESS	**(04 Hours)**
Flow-through valves, Analysis of suction, and Exhaust Processes	
COMBUSTION IN SI AND CI ENGINES	**(06 Hours)**
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	
ALTERNATE FUELLED ENGINES	**(03 Hours)**
Producer Gas, Biogas, and Biodiesel Fuelled Engines	
ENGINE EMISSION	**(06 Hours)**
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	
INTRODUCTION TO ELECTRIC VEHICLES	**(04 Hours)**

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	
EV POWER TRAIN	**(12 Hours)**
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.	
URBAN TRANSPORT	**(03 Hours)**
Urban Bus Specifications, Bus Rapid Transit Systems	

(Total Lecture Hours: 45)

3. Books Recommended:

1	The Science and Technology of Materials in Automotive Engine, Hiroshi Yamagata, CRC Press Inc
2	Internal Combustion Engines Fundamentals. John B Heywood. Mc Graw Hill (Indian Edition) 2017
3	Internal Combustion Engines by V Ganesan. 4th Edition. Tata Mc Graw Hill Edition
4	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles. Mehrdad Ehsani, Yimin Gao, et al
5	Handbook of Electric Vehicles, Joseph Kent. Clanrye International. (2015)

METM123	**:**	**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	Illustrate various types of jet systems and understand difference between air breathing and non-air breathing engines.
CO2	Analyze the thermodynamics cycles and performance parameters of air breathing systems
CO3	Demonstrate rocket propulsion theory and discuss classifications of rockets
CO4	Illustrate rocket nozzle types and their flow behavior at design and off-design conditions.
CO5	Analyse the performance parameters of rocket propulsion systems
CO6	Explain types of chemical rockets and details of its propellant

2. Syllabus

INTRODUCTION	**(09 Hours)**
Introduction of gas turbine cycle and various components of gas turbine engine, Introduction of jet propulsion systems, Computation of stagnation properties, Basic components of air breathing engines, Inlet ducts for aircraft gas turbines, Brief idea about compressor, combustion chamber, turbine, and aircraft nozzles, Classification of propulsive device, types of rocket engines, application of rocket engines. Non-chemical rocket engines: Electric propulsion, Nuclear rocket engines, Solar Energy rockets.	
AIR BREATHING ENGINES	**(06 Hours)**
Performance parameters for air breathing engine (Thrust, Efficiency, Aircraft Range, Take-off Thrust, Specific Fuel Consumption), Basic gas generator & its variations, Turbojet, Turboprop, Turbofan, Pulse jet, Ram jet, Scramjet, Thrust Augmentation	
PARAMETRIC CYCLE ANALYSIS OF AIR BREATHING GAS TURBINE ENGINES	**(09 Hours)**
Parametric Cycle Analysis of Ideal Turbo Jet Engine, Real Turbojet Cycle, Analysis of Turbofan Engine, Analysis of Turbofan Engine, Analysis of Turboprop Engine, Ramjet & Scramjet Engine.	
ROCKET PERFORMANCE PARAMETERS	**(06 Hours)**
Laws of thermodynamics, combustion parameters, rudiments of gas dynamics, Ideal rocket performance, thrust equation, Total impulse and Specific Impulse, Specific impulse efficiency, volume specific impulse, impulse-to-weight ratio, energy balance, efficiencies and coefficients of rocket engines.	
NOZZLES FOR ROCKET ENGINES	**(03 Hours)**

Rocket nozzles; expansion of gases from high pressure chamber. Convergent divergent nozzle, choking and variation of parameters in nozzle. Expansion ratio of nozzles and performance loss in nozzles. Under-expanded and over-expanded nozzles. Losses and performance analysis of rocket engines.	
ROCKET PROPELLANTS AND ENGINES	**(12 Hours)**
Classification of Chemical propellants, Solid propellants, Liquid propellants, Gel Propellants and Hybrid Propellants. Solid-propellant rocket engines—Burning mechanism, Propellant Burning and regression rates, Propellant grain configuration, Ignition system. Liquid-propellant rocket engines—Classification of engines, Combustion of Liquid Propellants, Combustion chamber geometry, Ignition systems, cooling systems, Hybrid-propellant rocket engines— combustion chamber, grain configuration, Ignition of hybrid propellants	

(Total Lecture Hours: 45)

3. Books Recommended:

1	Hill, P. G. and Peterson, C. R., “Mechanics and thermodynamics of propulsion” Wesley Publishing Company, USA, 1992
2	Mattingly, J. D., “Elements of gas turbine propulsion”, Tata McGraw-Hill Edition, NY, USA, 2005
3	Jack D. Mattingly, “Elements of Propulsion: Gas Turbines and Rockets,” AIAA Publication, USA, 2016
4	Sutton, G. P. and Biblarz O., “Rocket propulsion elements” Wiley Publications, USA, 2016
5	Mukunda H. S., “Understanding aerospace propulsion,” Interline Publishing, Bengaluru, India, 2017

METD125	**:**	**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 & analyze the performance outcomes of thermal turbomachines.

2. Syllabus:

INTRODUCTION OF 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	**(14 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	**(15 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 Lecture Hours: 45)

3. Books Recommended:

1	Theory and Design of Steam and Gas Turbines, Lee J.F., McGraw-Hill Book Company Inc., London, 1999
2	Steam turbines – Theory and Design, Shlyakhin. P., University Press of the Pacific, 2005
3	Gas Turbine Theory" H.I.H. Saravanamuttoo, Prof G.F.C. Rogers, H. Cohen, & P V Straznicky, 7th edition, Person publishers, 2017
4	Turbo Machine, Yahya S.M., 4th Edition, Tata McGraw Hill, 2011
5	Axial Flow Compressors, Fluid Mechanics and Thermodynamics, Horlock J. H. Butterworths Scientific Publications, 1958
6	Axial Flow Turbines: Fluid Mechanics and Thermodynamics, J. H. Horlock, Butterworths, 1966

METD127	:	MEASUREMENTS AND DATA ANALYSIS	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	(08 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	**(08 Hours)**
Overview of thermometry, thermoelectric temperature measurement, Different principles of Temperature Measurement, thermometers, 29hermos 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	**(06 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	**(07 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	**(08 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	**(08 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 Lecture Hours: 45)

3. <u>Books Recommended:</u>

1	E.O. Doblin, Measurement Systems, McGraw-Hill, New York, 1986
2	J.P. Holman, Experimental Methods for Engineers, McGraw-Hill Science Engineering; 8th Edition, 2011
3	T.G. Beckwith and N.L. Buck, Mechanical Measurements, Addison-Wesley, MA (USA), 1969
4	D.C. Montgomery, Design and Analysis of Experiments, John Wiley, New York, 2001
5	A.S. Morris, *Principles of Measurement and Instrumentation*, Prentice Hall of India, New Delhi, 1999
6	S. P. Venkateshan, Mechanical Measurements, John Wiley & Sons and Ane Books Pvt. Ltd., 2nd Edition, 2015
7	Nakra, B. C., and K. K. Chaudhry. Instrumentation, measurement, and analysis. Tata McGraw-Hill Education, 2003

METD129	:	FINITE ELEMENT METHOD 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	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 METHOD	(05 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	**(10 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	**(06 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.

(Total Lecture Hours: 45)

3. <u>Books Recommended:</u>

1	Logan D. L., A first course in the finite element method, Cengage Learning, 2012.
2	J. N. Reddy and D. K. Gartling, Finite Element Method in Heat Transfer and Fluid Dynamics, CPC press Third Edition, 2010
3	P. Seshu, 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	Roland W. Lewis, PerumalNithiarasu and Kankanhalli N. Seetharamu, Fundamentals of the Finite Element Method for Heat and Fluid Flow, Wiley, July 2004

METD107	:	COMPUTATIONAL AND EXPERIMENTAL LABORATORY -I	L	T	P	Credits
			0	0	6	03

1. Course Outcomes (COs)

CO1	Develop numerical solutions, linear, non-linear algebraic equations, initial value problems and boundary value problems using computer programs
CO2	Derive numerical solutions to initial value problems and boundary value problems
CO3	Develop code to solve ordinary differential equations (ODEs), and partial differential equations (PDEs), and optimization problems.
CO4	Understand and demonstrate the operation of identified system/ instrument/ equipment
CO5	Perform given practical task independently on system/instrument/equipment
CO6	Analyse and evaluate the observations and deduce conclusions therein

COMPUTATIONAL LAB

SOFTWARE

1. Introduction to open source and commercial software

CODING

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

EXPERIMENTAL Lab

(Any 10 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

METD102	:	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	
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	**(06 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	**(07 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	
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	**(08 Hours)**
Analogy between heat and mass, steady and transient mass diffusion, mass convection	

(Total Lecture Hours: 45)

3. Books Recommended:

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

METD104	:	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	**(07 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	**(08 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 Lecture Hours: 45)

3. Books Recommended:

1	Power plant engineering, P.K Nag, McGraw Hill Education, New Delhi, 2014
2	Power plant Technology by ‘M.M.Ei-Wakil’, McGraw Hill Education, New Delhi, 2010
3	Power plant engineering by R.K. Hegde, Pearson India Education, New Delhi, 2015
4	Power plant engineering by ‘Arrora&Domkundwar’, DhanpatRai& Sons, New Delhi, 2008
5	Power plant engineering by ‘P C Sharma’, S.K. Kataria& Sons, New Delhi, 2010

METD132	:	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	Design and perform the thermal performance of tube finned and plate finned heat exchanger
CO4	Estimate thermal performance of Gasketed and Spiral plate heat exchanger
CO5	Estimate the pressure drop in the tubular and extended surface heat exchanger
CO6	Estimate furnace outlet temperature using furnace model

2. Syllabus:

Introduction	**(05 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	**(05 Hours)**

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

(Total Lecture Hours: 45)

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	Saunders, E.A.D., "Heat Exchangers Selection Design and Construction," Longman Scientific and Technical, N.Y., 2001
4	Holger Martin, "Heat Exchangers" Hemisphere Publ. Corp., Washington, 2001
5	Kuppan, T., "Heat Exchanger Design Handbook", Macel Dekker, Inc., N.Y. , 2000
6	Seikan Ishigaki, "Steam Power Engineering, Thermal, and Hydraulic Design Principles," Cambridge Univ. Press, 2001

METD134	:	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	**(05 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	**(04 Hours)**
Principles of gas separation, Ideal system	

(Total Lecture Hours: 45)

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., USA, 2002

METM136	**:**	**COMBUSTION FOR PROPULSION 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	Analyse the combustion system using principles of thermodynamics.
CO2	Model combustion kinetics and chemical explosion mechanisms
CO3	Explain basic concepts about various types of flames; modelling and application to energy systems.
CO4	Analyse combustion characteristics and how these can be measured.
CO5	Illustrate different type of pollutants generated by combustion, their effects on health and on the environment and various methods to control it.
CO6	Describe different combustion mechanisms and how these can be efficiently used in engineering applications.

2. Syllabus:

Introduction	**(04 Hours)**
Introduction to combustion, Applications of combustion, Types of fuel and oxidizers, Characterization of fuel, Various combustion mode, Scope of combustion, Fundamental laws of transport phenomena, Conservations Equations	
Thermodynamics of Combustion	**(08 Hours)**
Mixture composition, energy and entropy properties of gaseous mixtures, Thermodynamic properties of reacting mixtures, Laws of thermodynamics, Stoichiometry, Thermochemistry, adiabatic temperature, 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 explosion, Explosion limits and oxidation of hydrogen, Carbon monoxide and hydrocarbons	
Premixed Flames	**(06 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 Flames	**(06 Hours)**
Laminar Diffusion flames, turbulent diffusion flames, Schvab-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, mechanisms of	

pollutant formation during combustion, pollutants reduction in conventional combustors, pollutants reduction by control of 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	
Combustion Process in Propulsion Systems	**(06 Hours)**
Principal ideas of combustion in gas turbine, solid propellant rockets: Erosive burning, and liquid propellant rockets	

(Total Lecture Hours: 45)

3. Books Recommended:

1	Kuo K.K., "Principles of Combustion", John Wiley, USA, 2005
2	Turns S.R., "An Introduction to Combustion", New York: McGraw-Hill, NY, USA, 2017
3	Law C.K., "Combustion Physics", Cambridge University Press, Cambridge, United Kingdom, 2010
4	Mishra D.P., "Fundamentals of Combustion", Prentice Hall of India, New Delhi, INDIA, 2010
5	Mukunda H. S., "Understanding Combustion", Universities Press, Hyderabad, Telangan, 2009

METD138	:	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	Describe 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	Explain 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 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	**(12 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	**(11 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 Lecture Hours: 45)

3. **Books Recommended:**

1	Transport phenomena in biological systems by G.A. Truskey, F. Yuan, and D.F. Katz, Pearson
2	Applied biofluid mechanics by L. Waite and J. Fine, McGraw-Hill Education
3	Optical-thermal response of laser-irradiated tissue (Vol. 2) by A.J. Welch, J. Martin, and C.V. Gemert, Springer, New York
4	Heat conduction, 3rd Edition by L.M. Jiji, Springer Science & Business Media
5	Nano and bio heat transfer and fluid flow by M. Ghassemi, and A. Shahidian, Academic Press
6	Porous media: Applications in biological systems and biotechnology by K, Vafai, Springer, Cham.

METD140	:	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	Explain 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	(07 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	**(06 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: 45)

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 NanoscaleHeat 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

METD142	:	MACHINE LEARNING FOR 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	Understand different types of machine learning and map problems to different classes of machine learning algorithms
CO2	Describe and apply machine-learning algorithms including decision trees, naïve Bayes, and logistic regression.
CO3	Design and implement advanced neural network architectures, including Multilayer Perceptrons (MLPs), Convolutional Neural Networks (CNNs), and Recurrent Neural Networks (RNNs) (including LSTM and GRU variants), to solve complex real-world problems.
CO4	Utilize Bayesian Regression, Binary Trees, Random Forests, Support Vector Machines (SVM), Naïve Bayes, k-Means, k-Nearest Neighbors (kNN), Gaussian Mixture Models (GMM), and Expectation Maximization (EM) to analyze and optimize mechanical systems
CO5	Evaluate the performance of algorithms and compare different machine learning techniques.
CO6	Apply structured probabilistic models, Monte Carlo methods, autoencoders, and generative adversarial networks (GANs) to analyze and optimize mechanical systems

2. Syllabus:

MATHEMATICAL BASICS	**(04 Hours)**
Introduction to Machine Learning, Linear Algebra, Probability	
COMPUTATIONAL BASICS	**(04 Hours)**
Numerical computation and optimization, Introduction to Machine Learning packages	
LINEAR AND LOGISTIC REGRESSION	**(05 Hours)**
Bias/Variance Tradeoff, Regularization, Variants of Gradient Descent, MLE, MAP, Applications	
NEURAL NETWORKS	**(14 Hours)**
Multilayer Perceptron, Backpropagation, Applications, **Convolutional Neural Networks:** CNN Operations, CNN architectures, Training, Transfer Learning, Applications, **Recurrent Neural Networks:** RNN, LSTM, GRU, Applications	
CLASSICAL TECHNIQUES	**(09 Hours)**
Bayesian Regression, Binary Trees, Random Forests, SVM, Naïve Bayes, Applications, k-Means, kNN, GMM, Expectation Maximization, Applications	
ADVANCED TECHNIQUES	**(09 Hours)**

Structured Probabilistic Models, Monte Carlo Methods, Autoencoders, Generative Adversarial Networks
Total Lectures 45 Hours

(Total Lecture Hours: 45)

3. Books Recommended:

1	Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning (Adaptive Computation and Machine Learning series), The MIT Press, 2016
2	Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2016
3	Geoff Dougherty, Pattern Recognition and Classification: An Introduction, Springer, 2013
4	Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, Dmytro Dzhulgakov, Machine Learning with PyTorch and Scikit-Learn: Develop machine learning and deep learning models with Python. Packt Publishing Ltd., 2022
5	Manaranjan Pradhan, U Dinesh Kumar, Machine Learning using Python, Wiley, 2020
6	Andreas C. Müller, Sarah Guido, Introduction to Machine Learning with Python: A Guide for Data Scientists, 2016

METD144	:	FLOW AND FLAME DIAGNOSTICS	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 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,	
EQUIPMENT'S FOR DIAGNOSTICS	**(10 Hours)**
Lasers, Camera, Synchronization, Seeding, Light-sheet optics, Image Processing	
TECHNIQUES	**(14 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	**(13 Hours)**
Soot— LII, Droplet & Spray Measurements — ILIDS-(Droplet Sizing), PDPA (Velocity & Size), Density Gradient—Schlieren, Rhodhamine PLIF, Shadowgraphy.	

(Total Lecture Hours: 45)

3. Books Recommended:

1	H. C. van de Hulst, Light Scattering by Small Particles, Dover, New York, USA,1981
2	T. D. McCay and J. A. Roux, eds., Combustion Diagnostics by Nonintrusive Methods, Progress in Astronautics and Aeronautics Series, Vol. 92, AIAA, Washington, DC, USA, 1984
3	A. C. Eckbreth, Laser Diagnostics for Combustion Temperature and Species, 2nd edition, Gordon & Breach, 1996
4	M. Raffel, C. E. Willert, J. Kompenhaus, Particle Image Velocimetry: A Practical Guide, Springer-Verlag, 1998
5	K. Kohse-Hoinghaus and J. B. Jeffries, eds., Applied Combustion Diagnostics, Taylor and Francis, 2002
6	R. J. Goldstein, Fluid Mechanics Measurements, Taylor and Francis, 1996
7	LacknerMaximillan, Avinash Kumar Agarwal, Franz Winter, “Handbook of Combustion, Vol. 2”, Wiley Publication, 2010

METD146	:	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	classify the basics of porous media properties
CO2	convert the microscopic pore-scale equations into the macroscopic domain-scale equations
CO3	describe various experimental techniques available to measure different properties of porous media
CO4	perform a numerical simulation to close the volume-averaged equation
CO5	Explain 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	**(04 Hours)**
Basics of tensor manipulations and tensor algebra, Definition of various averages, averaging theorems and their derivations	**(05 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	**(05 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 Lecture Hours: 45)

3. Books Recommended:

1	Principles of Heat Transfer in Porous Media, by M. Kaviany, Springer New York, 1995
2	Transport Phenomena in Porous Media, Volumes I-III, edited by D. R. Ingham and I. Pop, Elsevier, New York,2005

3	Dynamics of Fluids in Porous Media, J. Bear, Dover, 1988
4	Introduction to Modeling of Transport Phenomena in Porous Media, J. Bear and Y. Bachman, Kluwer Academic Publishers, London, 1990
5	Enhanced Oil Recovery, L.W. Lake, Gulf Publishing Co. Texas, 1989
6	The Mathematics of Reservoir Simulation, R.E. Ewing, SIAM Philadelphia, 1983
7	Stochastic Methods for Flow in Porous Media: Coping with Uncertainties, Zhang, D., Academic Press, California, 2002
8	The Method of Volume Averaging, S. Whitaker, Springer, New York, 1999

METD148	:	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	**(13 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	**(09 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	**(05 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 Lecture Hours: 45)

3. <u>Books Recommended:</u>

1	J. A. Duffie and W.A. Beckman, Solar Engineering and Thermal Processes, John Wiley and Sons., 2013
2	G. N. Tiwari, Solar Energy, Narosa Publishing House Pvt. Ltd., 2012
3	H. S. Mukunda, Understanding Clean Energy, and fuels from biomass. Wiley India Pvt. Ltd, 2011
4	K. M. Mital, Biogas Systems, Principle and Applications. New Age International Ltd, 1996
5	G. D. Rai, Non-Conventional Energy Sources, Khanna Publication, 1988
6	Prabir Basu, Biomass Gasification and Pyrolysis: Practical Design and Theory
7	Gasification: Christopher Higman: Gulf Professional Publishing, 2nd Edition

METD150	:	DESIGN OF SOLAR THERMAL 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	Calculate inclination angle of solar collectors
CO2	Design solar water and air heater
CO3	Design solar concentrator for specific application
CO4	Design solar powered desiccant air conditioning system
CO5	Design solar powered atmospheric water harvesting system
CO6	Design solar thermal desalination system

2. Syllabus:

FUNDAMENTALS OF SOLAR ENERGY	(04 hours)
Energy demand and potential of solar energy, Reckoning of time, Solar angles, Solar radiation and resource	
SOLAR COLLECTOR	**(16 hours)**
Flat Plate Collector: Basic elements, Performance analysis, Absorptivity, Heat transfer coefficients and correlations, Collector efficiency and heat removal factors, Effect of various parameters, Case study: application of flat plate collector for air heating and water heating Evacuated tube Collector: Principle of working, advantages of evacuated tube collector over flat plate collector, Types of evacuated tubes, Thermal analysis, Case study: application of flat plate collector for air heating and water heating Parabolic trough collector: Principle of working, optical and thermal analysis of parabolic trough collector, End effect and blocking in a parabolic trough collector, Case study: application of parabolic trough collector for process heat Parabolic dish collector and Scheffler reflector: Principle of working, construction, tracking mechanism, application of parabolic dish collector and Scheffler reflector.	
SOLAR REFRIGERATION AND AIR CONDITIONING	**(10 hours)**
Scope of solar cooling, Photovoltaic refrigeration, Adsorption/ absorption refrigeration using solar heat, solid and liquid desiccant, construction of desiccant bed, desiccant wheel	

and desiccant coated heat exchanger. Heat and mass balance of desiccant wheel, Construction and principle of working of solar powered desiccant air conditioning system, selection of solar collector, Energy, exergy and economic analysis. Concept of heat storage.	
ATMOSPHERIC WATER HARVESTING USING SOLAR HEAT	**(08 hours)**
Need of atmospheric water harvesting system, selection of desiccant material and solar collector, Construction and principle of working of solar powered atmospheric water harvesting system, effect of design and operating parameters on daily yield, Energy, exergy and economic analysis.	
SOLAR THERMAL DESALINATION	**(07 hours)**
Need of desalination system, types of desalination techniques, solar thermal desalination, solar still, improvements in solar still, limitations of solar still, Humidification-dehumidification desalination using solar heat, selection of solar collector, heat and mass balance of humidifier, packing materials of humidifier. effect of design and operating parameters on daily yield, Energy, exergy and economic analysis.	

(Total Lecture Hours: 45)

3. Books Recommended:

1	Kalogirou S. A., Solar Energy Engineering: Processes and Systems, Academic Press, 3rd Edition, 2023
2	Garg H.P., Prakash J., Solar Energy: Fundamentals and Applications, Tata McGraw-Hill, 1st Revised Edition, 2016
3	Goswami D. Y., Principles of Solar Engineering, CRC Press, 4th Edition, 2022
4	Duffie J. A., Beckman W.A., Solar Engineering of Thermal Processes, John Wiley and Sons, 4th edition, 2013
5	Sukhatme S., Nayak J: Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 3rd edition, 2008

METD172	:	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	Explain advanced numerical techniques such as LBM and Meshless techniques.
CO6	Gain experience in applying 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	**(10 Hours)**
Unstructured Grid Formulation, An overview of Finite Element Method, boundary element method, Lattice Boltzmann Method, Meshless Technique	

(Total Lecture Hours: 45)

3. Books Recommended:

1	S.V.Patankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill
2	T. J. Chung, Computational Fluid Dynamics, Cambridge University Press
3	H.K.Versteeg& W. Malalasekera, An Introduction to Computational Fluid Dynamics, Longman Scientific & Technical
4	J. H. Ferziger and M.Peric, Computational Methods for Fluid Dynamics,Springer
5	John C. Tannehill, Dale A.Anderson and Richard H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Taylor &Francis
6	John D.Anderson Jr, Computational Fluid Dynamics, McGraw Hill Book Company
7	J.Blazek, Computational Fluid Dynamics: Principles and Applications, Elsevier

METD174	:	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	**(05 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	**(10 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 Lecture Hours: 45)

3. Books Recommended:

1	Ehsani, M.,Gao,Y.,Longo, S. and Ebrahimi,K.M ,Modern electric, hybrid electric, and fuel cell vehicles, by., CRC Press, 2018
2	Husain, I.,Electric and hybrid vehicles: design fundamentals, CRCpress,2010
3	Mi,C.and 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, CengageLearning,2012
5	Denton T, Electric and Hybrid Vehicles, Routledge,2020

METD176	:	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:

GLOBALANDNATIONAL ENERGYSCENARIO	**(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	
ENERGYEFFICIENCYINBOILER, STEAM, AND FURNACE SYSTEM UTILITIES	**(10 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: 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	
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	**(06 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 Lecture Hours: 45)

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, Fairmont Press, 2018
5	A.Thumann, Handbook of Energy Audits, Fairmont Press, 2012
6	Energy Conservation Guide book by Dale R Patrick; Taylor and Francis; 3rd Edition

METD178	:	OPTIMIZATION TECHNIQUES	L	T	P	Credits
			3	0	0	03

1. Course Outcomes (COs):

CO1	Formulate mathematical models for practical problems based on the information provided
CO2	Conduct sensitivity and post optimality analysis of a solution to ensure appropriate solutions that will be deployed in real-world situations
CO3	Apply evolutionary algorithms to solve single objective problems where analytical methods are not suitable.
CO4	Apply evolutionary algorithms to solve complex engineering problems for multiple objectives where analytical methods are not suitable.
CO5	Apply appropriate optimization techniques to solve single and multiobjective engineering problems
CO6	Develop codes of optimization models using MATLAB software for various engineering problems.

2. Syllabus:

Introduction to Optimization, Linear Programming – Formulation, Graphical method, simplex method, and special cases	**(04 Hours)**
Sensitivity Analysis and post optimality analysis – changes in resources and objective function, changes affect feasibility and optimality, duality, dual simplex algorithm, generalize simplex algorithm	**(08 Hours)**
Traveling salesman problem, Integer programming and dynamic programming	**(06 Hours)**
Introduction to MATLAB, 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	**(06 Hours)**
Nonlinear Programming problems: Graphical method, convex function, convex region, necessary and sufficient conditions, Lagrangian method, Karush-Kuhn-Tucker (KKT) conditions, solving nonlinear problems using MATLAB.	**(07 Hours)**
Introduction to the 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	**(14 Hours)**

(Total Lecture Hours: 45)

3. Books Recommended:

1	Sharma, J.K. Operations research: theory and applications. Trinity Press, an imprint of Laxmi Publications Pvt. Limited
2	Hillier, F.S. and Lieberman, G.J. Introduction to operations research: Concepts and *Cases*, Tata McGraw-Hill Education
3	Taha, H.A. Operations research: an introduction. Pearson Education India
4	Rao, S.S. Engineering optimization: theory and practice. John Wiley & Sons
5	Deb, K., 2012. Optimization for engineering design: Algorithms and examples. PHI Learning Pvt. Ltd
6	Vasuki, A. Nature-Inspired Optimization Algorithms. CRC Press
7	Goldberg, D.E. Genetic algorithms: in search, optimization and machine learning. Pearson Education India

METD180	:	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	represent turbulent flows statistically
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	**(07 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	**(08 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.	

(Total Lecture Hours: 45)

3. Books Recommended:

1	Tennekes,H. and Lumley, J.L." A first course on turbulence"MIT Press, CambridgeMass., 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, 3rdedition 2006
6	Hanjalic, K. and Launder, B. "Modelling of turbulence in engineering and environment – Second-moment route to closure" Cambridge University Press, Cambridge, U.K., 2013
7	Durbin, P .A., and Paterson. Reif, B.A. "Statistical theory and modeling for turbulent Flows"2nd edition, John Wiley, Chichester, U.K, 2011
8	David S-K Ting, "Basics of Engineering Turbulence", Academic Press (Elsevier), 2016
9	Hans-Josef Rath, CarstenHolze, Hans-Joachim Heinemann, Rolf Henke HeinzeHonlinger, "New Results in Numerical and Experimental Fluid Mechanics V", Springer Publications, 2006

METD108	:	COMPUTATIONAL AND EXPERIMENTAL LABORATORY-II	L	T	P	Credits
			0	0	6	03

1. Course Outcomes (COs):

CO1	Develop computer code to solve steady-state, transient heat conduction problems using FVM
CO2	Derive numerical solutions to various convection-diffusion problems using multiple schemes such as central difference scheme, upwind scheme, and hybrid differencing scheme
CO3	Solve lid-driven cavity problem
CO4	Understand and demonstrate the operation of identified system/ instrument/ equipment
CO5	Demonstrate practical skills to work on identified problem
CO6	Develop skills for team effort and coordination through practical group performance

COMPUTATIONAL LAB

COMMERICAL SOLVER

1. Introduction to mesh generation software
2. Introduction to commercial 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

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

EXPERIMENTAL Lab

(Any 10 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