Department of Mechanical Engineering

Curriculum and Syllabi for M. Tech. in Thermal Engineering

With effect from 2019 entry batch

PO Statements:

1. Graduates will demonstrate sound domain knowledge on wider perspective to become successful professionals.
2. Graduates will demonstrate an ability to identify, formulate and solve thermal engineering problems.
3. Graduates will demonstrate an ability to conceptualise designs of thermal system or component and evaluate them to select optimal feasible solution considering safety, environment and other realistic constraints.
4. Graduates will demonstrate skill of good researcher to work on a problem, starting from scratch, to research into literatures, methodologies, techniques, tools, and conduct experiments and interpret data.
5. Graduates will demonstrate research skills to critically analyses complex thermal engineering problem for synthesizing new and existing information for their solutions.
6. Graduates will demonstrate skills to use modern engineering tools, software and equipment to analyze and solve complex engineering problems.
7. Graduates will exhibit the traits of professional integrity and ethics and demonstrate the responsibility to implement the research outcome for sustainable development of the society.
8. Graduates will be able to communicate effectively to comprehend and write effective reports following engineering standards.
9. Graduates will demonstrate skills of presenting their work unequivocally before scientific community, and give and take clear instructions.
10. Graduate will demonstrate traits of manager in handling engineering projects and related finance, and coordinate workforce towards achieving their goals.
11. Graduates will exhibit the traits of good academician and engage in independent and reflective lifelong learning.
12. Graduates will demonstrate an ability to work on laboratory and multidisciplinary tasks.

Course Structure

Semester I

S. N.	Code	Subject	L	T	P	Credits
1.	ME 5401	Advanced Thermodynamics	3	0	0	3
2.	ME 5402	Advanced Engineering Fluid Mechanics	3	0	0	3
3	ME 5403	Conduction and Radiation Heat Transfer	3	0	0	3
4.	ME 5404	Mathematical Methods in Thermal Engineering	3	0	0	3
5.	ME 5405	Thermal Engg. Lab	0	0	3	2
6.	ME 5xxx	Elective-I	3	0	0	3
7.	ME 5410	Seminar-I	0	0	2	1
Total contact hours/credits			**15**	**0**	**5**	**18**

Semester II

S. N.	Code	Subject	L	T	P	Credits
1.	ME 5406	Convective Heat Transfer Analysis	3	0	0	3
2.	ME 5407	Computational Lab/ Design of Experiments	0	0	3	2
3	ME 54xx	Elective-II	3	0	0	3
4.	ME 54xx	Elective-III	3	0	0	3
5.	ME 54xx	Elective-IV	3	0	0	3
6.	ME 54xx	Elective-V	3	0	0	3
7.	ME 5420	Seminar-II	0	0	2	1
Total contact hours/credits			**15**	**0**	**5**	**18**

Semester: III and IV

S. N.	Code	Subject	L	T	P	Credits	Semester
1	ME 6499	Project	-	-	-	14	III and IV
Total contact hours/Credits			-	-	-	14	---

Elective-I

S. N.	Code	Subject
1.	ME 5431	Entrepreneurship & Management
2.	ME 5131	Optimization Technique
3.	ME 5433	Gas Turbines and Jet Propulsions
4.	ME 5434	Advanced Internal Combustion Engineering
5.	ME 5435	Alternative Energy Sources

Elective-II

S. N.	Code	Subject
1.	ME 5436	Computational Fluid Flow and Heat Transfer
2.	ME 5437	Experimental Methods in Thermal Engineering
3.	ME 5438	Computational Methods in Thermal Engineering

Elective-III

S. N.	Code	Subjects
1.	ME 5439	Modern Trends in Refrigeration and Air Conditioning
2.	ME 5440	Advanced Power plant Engineering
3.	ME 5441	Compressible Flow
4.	ME 5442	Two-Phase flow and Boiling
5.	ME 5443	Energy Management

Elective-IV

S. N.	Code	Subject
1.	ME 5444	Principles of Combustion and Emissions
2.	ME 5445	Computer Aided Design of Thermal System
3.	ME 5446	Nuclear Engineering
4.	ME 5447	Solar Energy
5.	ME 5448	Turbulent Flows

Elective-V

S. N.	Code	Subject
1.	ME 5449	Microfluidics
2.	ME 5450	Hydel Power and Wind Energy
3.	ME 5451	Aerodynamics
4.	ME 5452	Batteries and Fuel Cells
5.	ME 5453	Cogeneration and Waste Heat Recovery System

Detailed Syllabi

ME 5401	Advanced Thermodynamics	L	T	P	C
	M.Tech. (Thermal), First Semester (Core)	3	0	0	3

Review of basic thermodynamics: Laws of thermodynamics, entropy, entropy balance for closed and open systems. Exergy: Concept of reversible work & irreversibility; Second law efficiency; Exergy change of a system: closed & open systems, exergy transfer by heat, work and mass, exergy destruction, exergy balance in closed & open systems; Exergy analysis of industrial systems – power systems and refrigeration systems.

Cycle analysis and optimization: Regenerative reheat Rankine cycle and Brayton cycle, combined cycle power plants, multi-stage refrigeration systems.

Thermodynamic optimization of irreversible systems: Finite time thermodynamics principles, optimization studies of various thermal systems, Minimization of entropy generation principle.

Properties of Gas Mixtures: Equation of state and properties of ideal gas mixtures; Change in entropy on mixing; Partial molal properties for non-ideal gas mixtures; Equations of state; Thermodynamics of Reactive System: Conditions of equilibrium of a multiphase - multicomponent system; Second law applied to a reactive system; Condition for reaction equilibrium.

Text & Reference Books:

- R. E. Sonntag, C. Borgnakke & G.J. Van Wylen, Fundamentals of Thermodynamics.
- K. Annamalai, I.K. Puri & M. A. Jog, Advanced Thermodynamics Engineering.
- Bejan, Entropy Generation Minimization.
- Bejan, Entropy Generation through Heat and Fluid Flow.
- M. J. Moran, H. N. Shapiro, D.B.Boettner & M. N. Bailey, Principles of Engineering Thermodynamics.

Course Outcomes:

1. Evaluate the thermodynamic properties of substances using various means
2. Energetically evaluate the performances of the thermal systems
3. Identify irreversibility of thermal systems both qualitatively and quantitatively.
4. Exergetically evaluate the performances of the thermal systems.
5. Perform energy and exergy audit of thermal systems.
6. Conceptualize, formulate and solve thermodynamically real life problems

ME 5402	**Advanced Engineering Fluid Mechanics**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Core)	**3**	**0**	**0**	**3**

Concept of continuum and definition of a fluid. Body and surface forces, stress tensor, principle of local stress equilibrium. Scalar and vector fields, Eulerian and Lagrangian description of flow. Motion of fluid element translation, rotation and deformation; vorticity and strain-rate tensors.

Continuity equation, Constitutive Equations-Stokes law of viscosity. Derivation of Navier Stokes equations, Exact solutions of Navier-Stokes equations for incompressible flow: plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between two concentric rotating cylinders, stokes first and second problems, slow viscous flow: Stokes and Oseens approximation, theory of hydrodynamic lubrication.

Boundary layer: derivation, exact solutions, Blasius solution and numerical solutions. Approximate methods: Momentum integral method.

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

Description of turbulent flow, velocity correlations, Reynolds stresses. Equations for turbulence kinetic energy and kinetic energy of mean flow. Eddy viscosity models of turbulence: zero equation, one-equation and two-equation models. Prandtl's Mixing Length Theory. Empirical laws: law of the wall, velocity defect law, universal velocity.

Text & Reference Books:

- P. K. Kundu & Ira M. Cohen, Fluid Mechanics
- S. K. Som, G. Biswas & S. Chakraborty, Introduction to Fluid Mechanics and Fluid Machines
- G. K. Batchelor, Fluid Dynamics.
- Schlichting, Boundary Layer Theory
- F. M. White, Viscous Fluid Flow

Course Outcomes:

1. Students will be able to learn the fundamentals of fluid dynamics for practical applications.
2. Students will be able to gain knowledge on the development of boundary layer in fluid flow and to overcome boundary layer separations.
3. Students will be able to determine boundary layer thickness for flows over bodies.
4. Students will learn the fundamentals of turbulence and the governing equations.

ME 5403	**Conduction and Radiation Heat Transfer**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Core)	**3**	**0**	**0**	**3**

Introduction to Conduction- Recapitulation: Steady and Transient conduction; Fins, Lumped parameter and semi-infinite solid approximations, Heisler and Grober charts; 3-D conduction, isotropic, orthotropic and anisotropic solids.
Analytical Methods- Mathematical formulations, analytical solutions, variation of parameters, integral method, periodic boundary conditions, Duhamels theorem and Greens function.
Introduction to Radiation- Recapitulation: Radiative properties of opaque surfaces, Intensity, emissive power, radiosity, Planck's law, Wien's displacement law, Black and Gray surfaces, Emissivity, absorptivity, Spectral and directional variations, View factors.
Enclosure with Transparent Medium- Enclosure analysis for diffuse-gray surfaces and nondiffuse, nongray surfaces, net radiation method.
Enclosure with Participating Medium- Radiation in absorbing, emitting and scattering media. Absorption, scattering and extinction coefficients, Radiative transfer equation.

Combined Heat Transfer Modes- Combined mode heat transfer and method of their calculation.

Text & Reference Books:

- D. Poulikakos, Conduction Heat Transfer
- G. Meyers, Analytical Methods in Conduction Heat Transfer
- N. Ozisik, Heat Conduction
- R. Siegel and J. Howell, Thermal Radiation Heat Transfer
- M. F. Modest, Radiative Heat Transfer
- E. M. Sparrow and R. D. Cess, Radiation Heat Transfer
- F. P. Incropera and D. P. Dewitt, Fundamental of Heat and Mass Transfer
- N. Ozisik, Heat Transfer

Course Outcomes:

1. Students will be able to learn the fundamentals of conduction and radiative heat transfer for practical applications.
2. Students will be able to learn the analytical methods for solving conduction and radiative heat transfer problems.
3. Students will be able to calculate emissive power of bodies emitting radiation using the laws of radiative heat transfer.
4. Students will be able to apply conduction and radiative heat transfer laws in combination for a given application.

ME 5404	**Mathematical Methods in Thermal Engineering**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Core)	**3**	**0**	**0**	**3**

Linear Algebra: Vector space, Norms of vectors and matrices, Condition number of matrices, Singular value decomposition, Backward error analysis, Concept of linear dependence and independence, Characteristics of linear systems, Eigen values and eigenvectors.

Calculus: Functions of single variable, Limit, continuity and differentiability, Mean value theorems, Evaluation of definite and improper integrals, Differentiation under integral sign (Leibnitz rule), Partial derivatives, Total derivative, Maxima and minima,

Differential equations: Concept of order and degree of differential equations, First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Strum Louiville problems, Initial and boundary value problems, Concept of well-posed and ill-posed equations, Classification of PDEs and their characteristics,

Parabolic, elliptic and hyperbolic prototype equations

Numerical Methods: Floating point operations and errors, Interpolation, Root finding of linear and non-linear algebraic equations, Numerical differentiation, Numerical integration, Numerical solution of ODEs: initial and boundary value problems; Numerical instability.
Numerical solution of systems of linear algebraic equations: general concepts of elimination and iterative methods, Gaussian elimination, LU decomposition, tridiagonal matrix algorithm, Jacobi and

Gauss-Seidel iterations, necessary and sufficient conditions for convergence of iterative schemes, gradient search methods, steepest descent and conjugate gradient methods.

Text & Reference Books:

- G.Strang, Linear Algebra and its Applications.
- K. Hoffman and R. Kunze, Linear Algebra.
- H.Anton, Elementary Linear Algebra with Applications.
- Wilfred Kaplan, Advanced Calculus.
- George B. Thomas, Maurice D. Weir, Joel Hass, Frank R. Giordano, Thomas' Calculus.
- Dennis Zill, Warren Wright, "Advanced Engineering Mathematics.
- K. E. Atkinson, An Introduction to Numerical Analysis.
- Jain, Iyenger, Jain, Numerical Methods Numerical Methods for Scientific & Engineering Computation
- Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists.
- D. C. Montgomery and G.C. Runger, Applied Statistics and Probability for Engineers.
- Arnold, V., Ordinary Differential Equations.
- King, Billingham, Otto, Differential equations

Course Outcomes:

Students will be able to-

1. know the characteristics of linear system of equations and gain the knowledge of Eigen vectors and Eigen matrix.
2. recapitalize the basics of calculus and understand the method of estimating the maxima and minima of functions.
3. understand the concept of order and degree of differential equations and know the method of solving differential equations.
4. develop an intuitive understanding of solving initial and boundary value problems.
5. have an idea of solving linear and non-linear algebraic equations.
6. apply different mathematical and computational methods for solving thermal engineering problems.

ME 5405	**Thermal Engg. Lab**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester	**0**	**0**	**3**	**2**

Following experiments will be conducted by the Students:

- Performance and emission measurements in Diesel engines
- Performance test on a Hydro-turbine
- Performance evaluation of vapour compression refrigeration system
- Measurement and Analysis of combustion parameters in I.C. engines

ME 5410	**Seminar-I**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Core)	**0**	**0**	**2**	**1**

Individual students are required to choose a topic of their interest from thermal engineering related topics preferably from outside the M.Tech syllabus and give a seminar on that topic about 30 minutes. A committee consisting of at least two/three faculty members shall assess the presentation of the seminar and award marks to the students. Each student shall submit two copies of a write up of his / her seminar topic. One copy shall be returned to the student after duly certifying it by the Chairman of the assessing committee and the other will be kept in the departmental library. Internal continuous assessment marks are awarded based on the relevance of the topic, presentation skill, quality of the report and participation.

Evaluation scheme-

Evaluation shall be based on the following pattern:
Report = 40 marks
Concept/knowledge in the topic = 30 marks
Presentation = 30 marks
Total marks = 100 marks

ME 5431	**Entrepreneurship & Management**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Elective-I)	**3**	**0**	**0**	**3**

Entrepreneur & Entrepreneurship. Entrepreneurial Competencies Entrepreneurship and Strategy. E. Entrepreneur, Leadership, Motivation & Productivity. Decision Making, Business Plan, S.S.I., System approach, Organization as system, MIS. Quality, TQM, ISO 9000 Standards.

Text & Reference Books:

- V. Desai, Dynamics of Entrepreneurship Development
- Marc J. Dollinger, Entrepreneurship: Strategies and Resources
- David H. Holt, Entrepreneurship: New Venture Creation
- S. Taneja, S.L.Gupta, Entrepreneurship Development New Venture Creation

Course Outcomes:

1. Able to plunge himself/herself Entrepreneurial market
2. Understanding the need and positioning himself catering the demand
3. Understand and able to invest according to business portfolio
4. Able to judge and forecasting the market need

ME 5131	**Optimization Technique**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Elective-I)	**3**	**0**	**0**	**3**

Introduction: Definition of optimization and its importance; Basic terminologies – design variables/vector, cost/objective function, constraints and variable bounds, etc; Different types of optimization problems – based on number of variables, based on nature of variables, based on constraints, based on approaches used, based on number of objectives, etc.
Single variable unconstrained optimization: Global optimum point; Local optimum point; Stationary point; Optimality criteria; Graphical method for optimum point; Direct methods for bracketing the optimum point – exhaustive search method and bounding phase method; Refining the bracketed optimum point through region elimination methods – interval halving method, Fibonacci search method and golden section search method; Gradient based methods – bisection method. Newton-Raphson method and secant method.

Multi-variable unconstrained optimization: Optimality criteria; Unidirectional search; Direct methods – simplex search method, Hooke-Jeeves pattern search method and Powell's conjugate direction method; Gradient based methods – Cauchy's steepest descent method, Newton's method, Marquardt's method, conjugate gradient method and variable metric method.
Multi-variable linear and constrained optimization: Definition and formulation of linear programming problem; unrestricted variables; slack variables; artificial variables; feasible design; infeasible design; basic solution; basic feasible solution; Simplex method for less than-equal type of constraints; Simplex method for equality and greater-than-equal types of constraints.
Multi-variable nonlinear and constrained optimization: Kuhn-Tucker conditions; Sensitivity analysis; Transformation methods – interior penalty function method, exterior penalty function and method of multipliers; Direct methods – variable elimination method, complex search method and random search method; Gradient based methods – cutting plane method, sequential linear programming and feasible direction method.
Integer and mixed optimization: Penalty function method and branch-and-bound method.

Text & Reference Books:

- K. Deb, Optimization for Engineering Design: Algorithms and Examples
- S. S. Rao, Engineering Optimization: Theory and Practice
- Ravindran, K. M. Ragsdell, G. V. Reklaitis, Engineering Optimization: Methods and Applications, Second Edition
- Jasbir S. Arora, Introduction to Optimum Design
- Ashok D. Belegundu and Tirupathi R. Chandrupatla, Optimization Concepts and Applications in Engineering

Course Outcomes:

1. Understand basic fundamentals of optimization techniques
2. Know the limitations of different solution methodologies.
3. Identify real-world objectives and constraints based on actual problem descriptions
4. Create mathematical optimization models.
5. Work through proper solution techniques.
6. Make recommendations based on solutions, analyses, and limitations of models.

ME 5433	**Gas Turbines and Jet Propulsion**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Elective-I)	**3**	**0**	**0**	**3**

Thermodynamic cycle analysis of gas turbines; open and closed cycles.

Axial flow turbines; blade diagrams and design of blading, performance characteristics. Centrifugal and axial flow compressors, blowers and fans.

Theory and design of impellers and blading. Matching of turbines and compressors.

Fuels and combustion, effect of combustion chamber design and exhaust on performance, Basic principles and methods of heat recovery.

Thermodynamic cycle analysis and efficiencies of propulsive devices, Thrust equation, classification and comparison of ram jets, turbojets, pulse jets and rockets, Performance of turbo-prop, turbo-jet and turbo-fan engines, Augmentation of thrust.

Text & Reference Books:

- HIH Saravanamutto, H. Cohen, GFC Rogers, Gas Turbine Theory
- V. Ganesan, Gas Turbine.
- J. D. Mattingly, Elements of Gas Turbine Propulsion

Course Outcomes:

1. Students will be able to analyse the thermodynamic cycles of gas turbine designs
2. Students will be able to draw performance characteristics of axial flow turbines, blowers and fans.
3. Students will be able to learn how performance of gas turbines varies with the fuels used, combustion chamber design.
4. Students will be able to analyse and calculate the efficiency of different propulsive systems.

ME 5434	**Advanced Internal Combustion Engineering**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), First Semester (Elective I)	**3**	**0**	**0**	**3**

Air standard and fuel–air cycle analysis of Otto, Diesel and limited pressure cycles, Effect of design and operating parameters on cycle efficiency, Modified fuel-air cycle considering heat losses and valve timing, Engine dynamics and torque analysis.
Fuels for I.C. Engines and their characteristics, combustion in S.I. Engines, spark knock and other abnormalities, combustion chambers, pollutant formation and control including catalytic converters, combustion in C.I. Engines, Diesel knock, Delay, fuel spray and mixing, Combustion chambers.
Advanced theory of carburetion, Cooling of engine and governing of engine, Ignition system: conventional and electronic, Supercharging, Variable compression ratio engine.
Exhaust emissions, its measurement and control, Fault diagnosis of S.I. Engines, Modelling of I.C. Engine Combustion.

Text & Reference Books:

- V. Ganeshan: I. C. Engines
- Heywood: Internal Combustion Engine Fundamental
- W. W. Pulkrabek: Engineering Fundamentals of I. C. Engines

Course Outcomes:

1. Students will be able to analyse various types of combustion chamber designs and understand their practical applications.
2. Students will be able to correlate the theory of gas power cycles in the operation of IC engines.
3. Students will be able to learn the mechanism of combustion processes in IC engines.
4. Students will be able to learn the modern developments in I.C. engines.

ME 5435	Alternative Energy Sources	L	T	P	C
	M.Tech. (Thermal), First Semester (Elective-I)	3	0	0	3

Energy scenario and renewable energy sources: global and Indian situation. Potential of nonconventional energy sources, economics.
Solar energy: radiation, flat-plate and concentrating collectors, fluid flow and heat transfer analysis, estimation of solar radiation, active systems, solar pond, passive space conditioning, power generation, photovoltaics.
Wind energy and principle of its convention. Types of wind machines.
Principles and applications of Wave energy, Tidal energy, Biomass energy, OTEC and Geothermal energy.
Hydrogen energy: Hydrogen as a renewable energy source, Hydrogen Fuel for Vehicles, Production and storage of Hydrogen.

Text & Reference Books:

- J.W. Twidell and A. Weir, Renewable Energy Sources,
- V. V. N. Kishore, Renewable Energy Engineering and Technology
- P. Gevorkian, Sustainable Energy Systems Engineering
- Godfrey Boyle, Renewable Energy, Power for a Sustainable Future.
- B. H. Khan, Non-Conventional Energy Sources
- P. R. Pryde, Nonconventional Energy Resources
- V. Desai, Nonconventional Energy
- S.P. Sukhatme, Solar Energy
- F. Kreith and J. F. Kreider, Principles of Solar Engineering

Course Outcomes:

1. Students will be able to learn the fundamentals and the potential of different alternative energy sources.
2. Students will be able to learn the principle of operation of different alternative energy systems, such as solar, wind, tidal, hydrogen based systems.
3. Students will be able to estimate the performance of energy systems based on different energy sources solar, wind, tidal, hydrogen etc.

ME 5406	Convective Heat Transfer Analysis	L	T	P	C
	M.Tech. (Thermal), Second Semester (Core)	3	0	0	3

Introduction to convection, Derivation of governing equations of momentum, energy and species transport, Order of magnitude analysis, Reynolds analogy.

Convective heat transfers in external flows: Derivation of hydrodynamic and thermal boundary layer equations, Similarity solution techniques, Momentum and energy integral methods and their applications in flow over flat plates with low and high Prandtl number approximations.

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

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

Concept of boiling heat transfer and regimes in pool boiling, Condensation: Nusselt film condensation theory, dropwise condensation and condensation inside tubes,

Text & Reference Books:

1. Louis C. Burmeister-Convective Heat Transfer
2. Bejan-Convective Heat Transfer
3. T. Cebeci & P. Bradshaw, Physical and Computational Aspects of Convective Heat Transfer
4. S. Kakac, Y. Yener & A. Pramuanjaroenkij- Convective Heat Transfer
5. Kays & Crawford-Heat Transfer

Course Outcomes-

Students will be able to-

1. discover the physical mechanism of convection, and its classification. (Understand)
2. derive the differential equations that govern both natural and forced convection on the basis of mass, momentum, energy and species transport. (Apply)
3. develop an intuitive understanding of friction drag, pressure drag, heat and mass transfer coefficients for both laminar and turbulent internal, and external flows. (Evaluate)
4. examine different flow regions in internal and external flow and determine the correlations among dimensionless parameters. (Analyze)
5. demonstrate the physical mechanism of convection under various modes and their relative importance. (Apply)
6. solve the real-world engineering problems related to heat and mass transfer field. (Create).

ME 5407	Computational Lab / Design of Experiments	L	T	P	C
	M.Tech. (Thermal), Second Semester (Core)	0	0	3	2

Computational Lab:

Students opted for Elective Computational Fluid Flow and Heat Transfer/ Computational Methods in Thermal Engineering have to study the following:

- Programs for solving simultaneous linear equations and differential equations
- Exercises on heat conduction, fluid flow, fins, etc. using commercial CFD solvers
- Modelling of flow around streamlined and Bluff bodies using commercial CFD solvers
- Simulation on natural and mixed convection problems, laminar/turbulent flows, forced convection problems using commercial CFD solvers.
- Exercises on hydrodynamic and thermal boundary layer problems using commercial CFD solvers.

Design of Experiments:

Students opted for Elective Experimental Methods in Thermal Engineering have to design different experiments as prescribed by the Course Coordinators.

Course Outcomes-

Students will be able to-

1. understand different numerical techniques related to computational aspects of fluid dynamics and heat transfer. (Understand)
2. perform an error analysis for various numerical methods (Evaluate)
3. describe the need of modeling and simulation and its overall methodology of execution. (Understand)
4. apply their knowledge to solve a system of linear and nonlinear algebraic equations using standard direct and iterative technique. (Apply)
5. examine, analyse and formulate a thermal and fluid flow problem using various numerical techniques. (Analyse)

ME 5420	Seminar-II	L	T	P	C
	M.Tech. (Thermal), Second Semester (Core)	0	0	2	1

Individual students are required to choose a topic of their interest from engineering domain preferably from outside the M.Tech syllabus. Evaluation will be executed based on Clarity on the topic, Literature review, Content, Presentation, Response to Questions.

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

1. Identify and compare technical and practical issues related to Engineering domain.

2. Prepare report with proper citation.
3. Analyse technical issues and develop competence in presenting it.

ME 5436	Computational Fluid Flow and Heat Transfer	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-II)	3	0	0	3

A brief overview of the basic conservation equations for fluid flow and heat transfer, classification of partial differential equations and pertinent physical behaviour, parabolic, elliptic and hyperbolic equations, role of characteristics, Computational economy, Numerical stability, Selection of numerical methods, validation of numerical results: Numerical error and accuracy – Round off error, accuracy of numerical results – Iterative convergence – Condition for convergence, Rate of convergence, under-relaxation and over relaxation, Termination of iteration: Tridiagonal Matrix algorithm.
Finite Difference method: Discretization – Converting Derivatives to discrete Algebraic Expressions, Taylor's series approach, polynomial fitting approach, Discretization error.
Heat conduction – Steady one-dimensional conduction in Cartesian and cylindrical co-ordinates, Two dimensional steady state conduction problems in Cartesian and cylindrical co-ordinates – point by point and line by line method of solution.
One dimensional, two dimensional and three dimensional transient heat conduction problems in Cartesian and cylindrical co-ordinates- Explicit, Implicit, Crank Nicholson and ADI methods- stability of each system.
The finite volume method: Discretization of diffusion problems: one dimensional steady diffusion problems, specification of interface diffusivity, source-term linearization. Discretization of transient one-dimensional diffusion problems. Discretization for multi-dimensional diffusion problems. Solution of discretized equations using point and line iterations, strongly implicit methods and pre-conditioned conjugate gradient methods.
Convection diffusion problems: Central difference, upwind, exponential, hybrid and power law schemes, concept of false diffusion, QUICK scheme. Numerical solution of the Navier-Stokes system for incompressible flows: stream-function vorticity method, requirement of a staggered grid. SIMPLE, SIMPLEC and SIMPLER algorithms.

Text & Reference Books:

1. John D Anderson Jr , Computational Fluid Dynamics, McGraw Hill
2. Hoffman Klaus Vol-1 & 2 Computational Fluid Dynamics
3. D.A.Anderson, J.C.Tannehill, R.H.Fletcher, Computational Fluid Flow, Heat Transfer
4. S.V. Patankar Hemisphere, Numerical Fluid Flow & Heat transfer
5. H.K Versteeg, W Malalasekera, An Introduction to Computational Fluid Dynamics

Course Outcomes-

Students will be able to-

1. understand various differential equations for flow phenomena and numerical methods for their solution. (Understand)
2. use and develop flow simulation software for the most important classes of flows in thermal engineering. (Apply)
3. critically analyse different mathematical models and computational methods for flow simulations. (Evaluate)
4. apply flow computations using current best practice for model and method selection, and assessment of the quality of results obtained. (Analyse)

ME 5437	Experimental Methods in Thermal Engineering	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-II)	3	0	0	3

Probability and Statistics: Fundamental definition, Conditional probability and Bayes theorem, Mean, median, mode and standard deviation, Random variables, Poisson, Normal and Binomial distributions, Regression analysis, Elements of sampling theory.

Introduction to measurement: Importance of measurement and experimentation, calibration, uncertainty analysis, error propagation, Gaussian or Normal distribution, confidence level, regression analysis, correlation coefficient, Chi-Square test, zeroth-, first- and second-order systems.

Pressure Measurement: Manometers, bourdon tube pressure gage, diaphragm gage, bellow gage, McLeod gage, Pirani gage and ionization gage.

Flow measurement: Positive displacement flow meters, venture, orifice, impact tube, flow

nozzle, sonic nozzle, rotameter, pitot static tube, hot-wire anemometer, laser Doppler anemometer, flow visualization techniques – shadowgraph, Schlieren and interferometer.

Temperature measurement: Hg-in-glass thermometer, RTD, thermistor, thermocouple, thermopile, liquid-crystal thermography, optical pyrometer.

Thermal conductivity measurement: Guarded hot plate apparatus, heat flux meter.

Data acquisition and processing: Signal conditioning, data transmission, storage, A to D and D to A conversion.

Text & Reference Books:

1. J. P. Holman, Experimental Methods for Engineers.
2. T.G. Beckwith, J.H. Lienhard V, R. D. Marngoni, Mechanical Measurements.
3. E.O. Doebelin, Measurement systems, Application and Design.

Course Outcomes

Students will be able to
1. learn the fundamentals of fluid dynamics for practical application
2. evaluate the uncertainty analysis, error analysis for various experimental results.
3. gain knowledge for undergoing various pressure and flow measurement techniques.

ME 5438	Computational Methods in Thermal Engineering	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-II)	3	0	0	3

Root finding: Complex algebraic and transcendental equations. Solution of linear equations by LU decomposition and Newton Raphson method, Root finding used in integration, evaluation of areas, surface of revolution, length of curve and volumes, Evaluation of centroid of regular geometric bodies, Double integration to compute areas, triple integration to compute volumes and quadruple integration to compute view factors, Interpolation and its use in thermal engineering.

Solution of ordinary differential equations, Runge-Kutta method and Euler method, Solution of non-linear equations of any order and any degree, Solution of initial value problems and boundary value problems, Solution of boundary value problem through initial value problems, shooting method, optimization of objective functions to determine the solution of boundary value problems. Application of shooting method or the optimization method to solve thermal engineering problems like: boundary layer flow on a flat plate, thermal boundary layer on a vertical and flat plate, flow near a rotating disk, Falkner-Skan wedge flow, travel of projectile in air with drag, temperature distribution in a circular fin, triangular fin and general solution to steady 1D heat conduction in any shape.

Introduction to finite difference (FD) method, Forward, CD and upwind schemes, Solution of ODE by FD method. Introduction to stability, numerical errors and accuracy, Application of finite difference method to thermal engineering problems, Solution of hydrodynamic and thermal boundary layer equations by FD method, Solution of Falkner-Skan problem by FD method, Extensive Application to transient heat transfer by FD method. FD method used for 2D and 3D problems.

Text & Reference Books:

1. Jain, Iyenger, Jain, Numerical Methods Numerical Methods for Scientific & Engineering Computation
2. Dennis Zill, Warren Wright, Advanced Engineering Mathematics.
3. K. E. Atkinson, An Introduction to Numerical Analysis.
4. John D Anderson Jr, Computational Fluid Dynamics, McGraw Hill
5. Hoffman Klaus Vol-1 & 2 Computational Fluid Dynamics

Course Outcomes-

Students will be able to-

1. use and develop flow simulation softwares for different classes of flows in thermal engineering.
2. critically analyze different computational methods for fluid flow and heat transfer analysis.

ME 5439	**Modern Trends in Refrigeration and Air-Conditioning**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), Second Semester (Elective-III)	**3**	**0**	**0**	**3**

Introduction to modern refrigeration and air-conditioning practices, Industrial and Commercial applications.
Refrigeration Systems: Gas-Cycle systems, Vapour-Compression systems, Vapour-Absorption systems, Multistage multi evaporator and Cascade systems, Electrolux system and solar energy applications. Steam jet refrigeration, vortex tube and thermoelectric refrigeration

System and Component design of refrigeration systems.
Refrigerants: Properties of refrigerants: primary, secondary and mixtures
Psychometry, simple psychometrics processes, use of psychometrics chart, Comfort and industrial air conditioning, Air filtration, Principles of ventilation, Physiological factors. Comfort index.
Load Analysis and Calculations: Design conditions, Load classifications, Cooling & Heating load analysis.
Air conditioning systems: Spray systems, chilled water and DE Coils, absorption and adsorption systems, Humidifiers, Air conveying: fans, ducts and air diffusion equipment.
Design and constructional details of Unitary & Central systems.
Instruments, Control of refrigeration and Air-Conditioning.

Text & Reference Books:

1. Arora C. P, Refrigeration and Air conditioning
2. R.C. Arora, Refrigeration and Air-conditioning.
3. Ananthanarayanan, Basic Refrigeration and Air Conditioning
4. W. B. Gosney, Principles of Refrigeration.
5. Stoecker, Refrigeration and Air Conditioning
6. Manohar Prasad, Refrigeration and Air Conditioning

Course Outcomes-
Students will be able to-
1. identify different refrigeration systems for different applications. (Understand)
2. identify the important properties of refrigerant and to select refrigerant for a refrigeration system. (Apply/Analyze)
3. evaluate the performance of most commonly used refrigeration systems.
(Analyze/Evaluate)
4. explain the working principles of various other refrigeration systems with their practical applications. (Apply)
5. apply thermodynamic principles to perform psychrometric calculations in evaluating the performance of simple air conditioning systems. (Understand/Apply)
6. identify parameters for human comfort and interpret the comfort indices.
(Apply/Analyze)
7. design air transmission system by applying the principles of fluid flow and heat transfer. (Apply/Evaluate/Create)
8. explain the importance of proper air distribution, draw air-flow patterns for different air diffusers and list the criteria for selecting supply and return air outlets. (Analyze)

ME 5440	**Advanced Power Plant Engineering**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), Second Semester (Elective-III)	**3**	**0**	**0**	**3**

Introduction: Choice of power generation; Load & Load duration curves; Load factor; Diversity factor; Load deviation curve; Load management; Number and size of generating unit; Cost of electrical energy; Tariff-Power factor improvement.

Thermal Power Stations: Types of thermal power plants; elements of thermal power plant: Boiler, superheater, economiser, condenser, combustion chamber: Fluidized bed combustion, gas loops and turbines etc., Site selection of Steam power plant, Principles of Electric Power station. General lay out. Instrumentation and control

Gas Turbine Power plant: Types, Open and close cycle gas turbines; Components of the plant, Plant lay out, Combined cycle power plant

Advanced Power Cycles: Cogeneration systems-topping and bottoming cycles-Thermodynamic performance of steam turbine cogeneration systems-gas turbine cogeneration systems

Hydropower Plant: Mass curve and storage capacity; Classification; Components; Turbines-Characteristics and their selection; Governor; Plant layout and design; Auxiliaries; Underground, automatic, remote controlled, and pumped storage plants.

Nuclear Power Plant: Basic principles, Elements of Nuclear power plant, Nuclear reactor and fuels, Hazards due to Nuclear power plants, Nuclear Instrumentation.

Diesel-electric Power Plant: Working principle, Elements of the plant, Starting and stopping; Efficiency and Heat balance.

Text & Reference Books:

1. P.K.Nag, Power plant Engineering
2. El Wakil, Power plant Engineering
3. A.J. Wood, B. F. Wollenberg, Power Generation, Operation and Control.
4. Arora and Domkundwar, A Course in Power Plant Engineering

Course Outcomes:

Students will be able to-

1. develop skills to identify and select a proper plant layout and design under given conditions. (Apply)
2. carry out performance analysis of different power plants and investigate performance results. (Analyse)
3. demonstrate the working principles of different power plants and their maintenance. (Understand)
4. develop an intuitive understanding of load factor, diversity factor etc and estimate the cost of power generation. (Evaluate)

ME 5441	**Compressible Flow**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), Second Semester (Elective-III)	**3**	**0**	**0**	**3**

Fundamental Aspects of Compressible Flow: Introduction, Isentropic flow in a stream tube, speed of sound, Mach waves;

One dimensional Isentropic Flow: Governing equations, stagnation conditions, critical conditions, maximum discharge velocity, isentropic relations;

Normal Shock Waves: Shock waves, stationary normal shock waves, normal shock wave relations in terms of Mach number;

Oblique Shock Waves: Oblique shock wave relations, reflection of oblique shock waves, interaction of oblique shock waves, conical shock waves;

Variable Area Flow: Equations for variable area flow, operating characteristics of nozzles, convergent-divergent supersonic diffusers;

Adaiabatic Flow in a Duct with Friction: Flow in a constant area duct, friction factor variations, the Fanno line; Flow with Heat addition or removal: One-dimensional flow in a constant area duct neglecting viscosity, variable area flow with heat addition, one dimensional constant area flow with both heat exchanger and friction.

Text & Reference Books:

1. H. Shapiro, The Dynamics and Thermodynamics of Compressible Fluid Flow.
2. S. M. Yahya, Fundamentals of Compressible Flow.
3. Osthuizen and Carscallen, Compressible Fluid Flow.

Course Outcomes:

Students will be able to-
1. Understand the various aspects of compressible flow and its various governing equations.
2. Understand the formation of normal and oblique shock waves.
3. Analyze various Adiabatic Flow in a Duct with constant and variable cross sectional area.

ME 5442	**Two-Phase Flow and Boiling**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), Second Semester (Elective-III)	**3**	**0**	**0**	**3**

Introduction, different terminologies, flow regimes for single and two component vertical and horizontal flow, flow regime mappings.

Conservation equations based on homogeneous flow, drift flux model, separated flow model (multi-fluid model), flooding, fluidization, two phase transportation.

Introduction to Lockhart-Martinelli and other important correlations for pressure drop, correlations for void fraction.

Detailed discussion on bubbly, slug and annular flow.Description and classification of boiling, pool boiling curve.

Rohsenow correlation for nucleate boiling, Zubers theory for critical heat flux, Bromley theory for film boiling, Cheus correlation for flow boiling.

Text & Reference Books:

1. John G. Collier and John R. Thome, Convective Boiling and Condensation
2. Arnold Reusken &Sven Gross, Numerical Methods for Two-phase Incompressible Flows.
3. Cl Kleinstreuer, Two-Phase Flow: Theory and Applications.
4. Van P. Carey, Liquid-Vapor Phase Change Phenomena.
5. S. Mostafa Ghiaasiaan, Two-Phase Flow, Boiling, and Condensation
6. M. Ishii & T. Hibiki, Thermo-fluid Dynamics of Two Phase Flow.

Course Outcomes:

Students will be able to-
1. learn different correlations for pressure drop and void fractions.
2. study various flow regimes of boiling

ME 5443	Energy Management	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-III)	3	0	0	3

Energy Scenario – world and India, Energy Resources Availability in India, Energy consumption pattern, Energy conservation potential in various Industries and commercial establishments, Energy intensive industries – an overview. Energy conservation and energy efficiency – needs and advantages, Energy auditing – types, methodologies, barriers. Role of energy manager – Energy audit questionnaire.

Instruments for energy auditing: Instrument characteristics – sensitivity, readability, accuracy, precision, hysteresis, Error and calibration, Measurement of flow, velocity, pressure, temperature, speed, Lux, power and humidity, Analysis of stack, water quality, power and fuel quality.

Thermal Utilities: Operation and energy conservation- Boilers, Furnaces, Waste Heat Recovery Systems

Thermal energy transmission / protection systems: Steam traps – refractories – optimum insulation thickness – insulation – piping design

Financial management: Investment – need, appraisal and criteria, financial analysis techniques – break even analysis –simple payback period, return on investment, net present value, internal rate of return, cash flows.

Text & Reference Books:

1. Hamies, Energy Auditing and Conservation; Methods Measurements, Management and Case Study.
2. Smith, CB Energy Management Principles
3. Write, Larry C, Industrial Energy Management and Utilization
4. P. O'Callaghan, Energy Management

Course Outcomes:

Students will be able to-
1. get an overview of the energy scenario of India and the world.
2. learn various thermal energy utilities and thermal energy transmission systems for designing thermal systems.
3. gather knowledge about the financial management of the thermal energy systems.

ME 5444	Principles of Combustion and Emissions	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-IV)	3	0	0	3

Introductory concepts, Thermodynamics of reacting systems: conservation of mass and energy in a chemical reaction, adiabatic flame temperature, second law aspects of chemical reactions, Essentials of chemical Kinetics: molarity and order of chemical reaction, general equation for rate of reaction, equation of Arrhenius, activation energy.

Pre-mixed systems: Theories of premixed laminar and turbulent flames; concepts of ignition, flame stabilization, extinction and quenching, Methods of solving laminar flame problems; Effects of different variables on flame speed; Methods of measuring flame velocity; Flame quenching.

Non-Pre-mixed systems; Burke-Schumann's theory of laminar diffusion flames; Droplet burning; Laminar diffusion flames.

Theories of gaseous diffusion flames; droplet and spray combustion: theories of atomization, spray combustion models, spray combustion characteristics and design of burners; mechanism and kinetics of coal combustion; fluidized bed combustion;

Emissions from combustion: constituents and types of emission, mechanisms of hydrocarbon and particulate emissions, theories of soot and NOx formation, Control of emissions.

Text & Reference Books:

1. Turns: An Introduction to Combustion: Concepts and Applications
2. K. K. Kuo, Principles of Combustion

Course Outcomes:

Students will be able to-
1. study various concepts of basic combustion and emissions.

2. gather knowledge about premixed and non-premixed systems.
3. understand the theories of atomization and spray combustions.

ME 5445	Computer Aided Design of Thermal System	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-IV)	3	0	0	3

Introduction to Engineering Design, thermal Systems, Basic Considerations in Design, Computer-Aided Design of Thermal Systems, Material Selection, Properties and Characteristics for Thermal Systems.

Modelling of Thermal systems, Mathematical Modelling, Physical Modelling and Dimensional Analysis.

Numerical Modelling and Simulation, Solution Procedures, System Simulation.

Optimization in Design, Methods of optimization, Lagrange multipliers, search methods, dynamic programming, geometric programming, linear programming,

Economic considerations: Case studies.

Text & Reference Books:

1. W. F. Stoecker, Design of Thermal System
2. Y. Jaluria, Design &Optimization of Thermal Systems.
3. R. F. Boehm, Design Analysis of Thermal Systems
4. K. Deb, Optimization for Engineering Design.

Course Outcomes:

Students will be able to
1. learn the various computational methods for solving thermal engineering problems.
2. learn various methods of optimization techniques for various classes of problems.

ME 5446	Nuclear Engineering	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-IV)	3	0	0	3

Nuclear Reactions: Mechanism of nuclear fission - nuclides - radioactivity – decay chains - neutron reactions - the fission process - reactors - types of fast breeding reactor - design and construction of nuclear reactors – heat transfer techniques in nuclear reactors - reactor shielding.

Reactor material: Nuclear Fuel Cycles - characteristics of nuclear fuels - Uranium - production and purification of Uranium - conversion to UF4 and UF6 - other fuels like Zirconium, Thorium – Berylium

Reprocessing-Nuclear fuel cycles - spent fuel characteristics - role of solvent extraction in reprocessing

Separation of Reactor Products-Processes to be considered - 'Fuel Element' dissolution - precipitation process – ion exchange - Isotopes - principles of Isotope separation.

Waste Disposal and Radiation Protection: Types of nuclear wastes - safety control and pollution control and abatement - radiation hazards prevention

Text & Reference Books:

1. S. Glasstone and A. Sesonske, Nuclear Reactor Engineering,
2. J. Kenneth Shultis, Richard E, Faw, Richard E. Faw, Fundamentals of Nuclear Science and Engineering.
3. Tatjana Tevremovic, Nuclear Principles in Engineering,
4. Kenneth D. Kok, Nuclear Engineering.
5. Cacuci, Dan Gabriel, Nuclear Engineering Fundamentals.
6. J. R. Lamarsh, Introduction to Nuclear Reactor Theory
7. R. H. S. Winterton, Thermal Design of Nuclear Reactors.

Course Outcomes:

Students will be able to-
1. learn various mechanisms of nuclear reactions and nuclear materials.
2. gain knowledge about nuclear fuel cycles
3. learn various techniques of nuclear waste disposal and pollution control

ME 5447	**Solar Energy**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), Second Semester (Elective-IV)	**3**	**0**	**0**	**3**

Solar Energy Technology, Current alternate energy sources-thermodynamic view point and conversion methods, Components of solar energy systems, collector performance, Radiation and meteorological data processing, long term conversion factors.

System configurations and system performance prediction, Simulations, design methods. System design and optimisation, Solar thermal systems applications to power generation, heating and cooling. Solar passive devices: solar stills, ponds, greenhouse, dryers, Trombe wall, overhangs and winged walls, Economics of solar energy system.

Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer-sunshine recorder

Solar Non-Concentrating Collectors- Design considerations – Classification- air, liquid heating collectors –Derivation of efficiency and testing of flat plate collectors –Analysis of concentric tube collector - Solar green house.

Text & Reference Books:

1. S.P. Sukhatme, J. K. Nayak, Solar Energy: Principles of Thermal Collection and Storage.
2. H P Garg, J Prakash, Solar Energy: Fundamentals and Applications
3. F. Kreith and J. F. Kreider, Principles of Solar Engineering
4. J.A. Duffie and W.A. Beckman, Solar Engineering of Thermal Processes

Course Outcomes:

Students will be able to-
1. explain the basics of solar energy, its measuring instruments and solar energy conversion processes.
2. to explain the design and construction of solar collectors for solar energy harvesting.
3. to explain the design and construction of solar passive components for solar energy harvesting.
4. to build the abilty to analyse the performances of solar thermal systems

ME 5448	**Turbulent Flows**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), Second Semester (Elective-IV)	**3**	**0**	**0**	**3**

Turbulent Flows, Introduction to stability of laminar flows, Linearized stability analysis using Orr Sommerfeld equations for inviscid and viscous flows, Stability with flexible compliant boundaries, for free convection flows and under centrifugal forces, Transition to turbulence.

General properties of turbulence: instability and non-linearity, statistical nature, vortex stretching, turbulence scales and cascade, mixing and enhanced diffusivity, energy spectrum.

Introduction to mathematical analysis of turbulent flows, the closure problem, Reynolds averaged Navier Stokes equations, Equations for Reynolds stresses, turbulence kinetic energy and energy of mean flow convection, production and dissipation of turbulence, re-distribution, turbulent diffusion.

Turbulence modelling, Eddy viscosity/mixing-length models, application to free shear flows and wall-bounded flows. Two-equation models of turbulence: standard k and ε model. Turbulent free shear flows. Turbulent wallbounded flows, Law of the wall, velocity defect law, law of the wake.

Text & Reference Books:

1. Stephen B. Pope, Turbulent Flows
2. Hendrik Tennekes and John L. Lumley, A First Course in Turbulence
3. Wilcox, Turbulence Modelling for CFD

Course Outcomes:

Students will be able to-
1. introduce the concept of turbulent flows and its various properties.
2. study various turbulent modelling techniques.

ME 5449	**Microfluidics**	**L**	**T**	**P**	**C**
	M.Tech. (Thermal), Second Semester (Elective-V)	**3**	**0**	**0**	**3**

Introduction: Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions, continuum hypothesis and deviations from the same, scaling laws for micro-domains.

Microscale gas flows: Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscale Couette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility, introductory concepts on gas flows in transitional and free molecular regimes, some representative applications of micro-scale gas flows in accelerometers, micro-propulsion and micro-nozzles.

Microscale liquid flows: Pressure driven liquid microflow, apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro-flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis, analysis of hydro-dynamically and thermally fully developed electro-osmotic flows, ac electro-osmosis.

an introduction to fluid dynamics over nano scales (nanofluidics), concepts of nano-fluids and their augmented transport characteristics.

Text & Reference Books:

1. Terrence Conlisk, Essentials of Micro-and Nanofluidics.
2. Dongqing Li,(Editor), Encyclopedia of Microfluidics and Nanofluidics.
3. S. Chakraborty (Editor), Microfluidics and Microscale Transport Processes.
4. S. Mitra and S. Chakraborty (Editors), Handbook of Microfluidics and Nanofluidics.

Course Outcomes:

Students will be able to-

1. Cover the basic principles of fluid mechanics on the microscale.
2. Solve the simple problems of gas and liquid flows in microchannel.
3. Present a wealth of real-world engineering examples to give students a feel for how fluid mechanics on the microscale is applied in engineering practice.
4. Develop an intuitive understanding of fluid mechanics on the microscale by emphasizing the physics and physical arguments.
5. Understand the fundamentals of electro-kinetics and solve electro-kinetically driven liquid flows in microchannel.
6. Illustrate the basics of Nano-fluidics and Nano-fluids

ME 5450	Hydel Power and Wind Energy	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-V)	3	0	0	3

Hydel Power: Stream flow data and water power estimates, use of hydrographs; hydraulic turbine, characteristics and part load performance, design of wheels, draft tubes and penstocks, cavitation; governing of hydro turbines, mechanical and electro-mechanical governors, electronic load controller; selection of hydro turbines based on specific speed and their optimal selection, model testing of hydro turbines, performance testing of turbines at site; silt erosion and their combined effect on operation of hydro turbines; Erection, commissioning, operation and maintenance of turbines.

Wind Power and Engineering: Estimates of wind energy potential, wind maps; aerodynamic and mechanical aspects of wind machine design; wind tunnel simulations, conversion and storage methods; industrial applications. Instrumentation for wind velocity measurements.

Text & Reference Books:

1. Nigam, P.S., Handbook of Hydroelectric Engineering
2. Hossein Samadi-Boroujeni, Hydropower - Practice and Application
3. P. Jain, Wind Energy Engineering.
4. P. Gipe, Wind Energy Basics.
5. T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi, Wind Energy Handbook.

Course Outcomes:

Students will be able to-
1. learn the hydro-electric power plant, its various components and functions.
2. learn wind tunnel simulation for various aerodynamic structures.

ME 5451	Aerodynamics	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-V)	3	0	0	3

Governing equations for inviscid incompressible flow, Fluid circulation and rotation, Vorticity, Velocity potential, Stream function, Complex potential, Elementary flow patterns and their superposition.

Flow past a cylinder, Magnus effect, Kutta condition, Vortex theory of lift, Conformal transformation, The Jowkowski transformation, Lift on arbitrary cylinder, Aerodynamic center, Pitching moment.

Aerofoils, Low speed flows over aerofoils-the vortex sheet, Thin aerofoil theory, Lifting line theory, inviscid compressible flow, Thin airfoils in subsonic and supersonic flow, Characteristics of thin aero foils, Motion in three dimensions.

Finite wings, Downwash and induced drag, Prandtl-Lachester theory, Biot- Savarat law, General series solution, Glauret method, Multhop's method, Horseshoe effects, Ground effects, Lineraised compressible flows in two dimensions, Aerofoil in compressible flows.

Introduction to Compressible boundary layer, similarity solutions.

Text & Reference Books:

1. J. D. Anderson Jr., Fundamentals of Aerodynamics.
2. M. Kuethe and C. Chow, Foundations of Aerodynamics.
3. J. Katz and A. Plotkin, Low Speed Aerodynamics.
4. E. L. Houghton and A. E. Brock, Aerodynamics for Engineering Students.

Course Outcomes:
Students will be able to-
1. formulate governing equations for inviscid incompressible and compressible flow.
2. understand the concept of aerofoils and its characteristics.

ME 5452	Batteries and Fuel Cells	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-V)	3	0	0	3

Energy Resources, Energy Crisis, Need for Energy storage: Fuel cell and Battery.

Battery –Introduction, Types of Batteries and their operational principle.

Fuel Cells- principle - working - thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell.

Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – relative merits and demerits.

Application of fuel cell and economics: Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space.

Economic and environmental analysis on usage of Hydrogen and Fuel cell. Future trends in fuel cells.

Text & Reference Books:

1. B. Hart and G.J.Womack, Fuel Cells: Theory and Application
2. Viswanathan and M Aulice Scibioh, Fuel Cells – Principles and Applications,
3. L. Rebecca and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide,
4. Bent Sorensen (Sorensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications,

Course Outcomes:
Students will be able to:
1. understand the concepts of fuel cells and its working principles.
2. learn the application of various types of fuel cells for domestic and large scale applications.
3. learn the Economic and environmental analysis on usage of Hydrogen and Fuel cell

ME 5453	Cogeneration and Waste Heat Recovery Systems	L	T	P	C
	M.Tech. (Thermal), Second Semester (Elective-V)	**3**	**0**	**0**	**3**

Introduction – principles of thermodynamics – cycles – topping – bottoming – combined cycle –Rankine cycles – performance indices of cogeneration systems – waste heat recovery –sources and types.

Cogeneration technologies: Configuration and thermodynamic performance – steam turbine cogeneration systems – gas turbine cogeneration systems – reciprocating IC engines cogeneration systems – combined cycles cogeneration systems – advanced cogeneration systems: fuel cell.

Issues and applications of cogeneration technologies: Cogeneration plants electrical interconnection issues – utility and cogeneration plant interconnection issues – applications of cogeneration in utility sector – industrial sector – building sector – rural sector – impacts of cogeneration plants – fuel, electricity and environment.

Waste heat recovery systems: Selection criteria for waste heat recovery technologies – recuperates – Regenerators – economizers – plate heat exchangers– Waste heat boilers – classification, location, service conditions, design Considerations – fluidized bed heat exchangers – heat pipe exchangers.

Economic analysis: Investment cost – economic concepts – measures of economic performance – procedure for economic analysis – examples – procedure for optimized system selection and design – load curves –sensitivity analysis.

Text & Reference Books:

1. Charles H. Butler, Cogeneration
2. EDUCOGEN – The European Educational tool for cogeneration
3. J.H. Horlock JH, Cogeneration - Heat and Power, Thermodynamics and Economics,
4. Seagate Subrata, Lee SS EDS, Waste Heat Utilization and Management

Course Outcomes:

Students will be able to-

1. study various cogeneration technologies.
2. study various waste heat recovery techniques.