NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

DEPARTMENT OF MECHANICAL ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

FOR M.TECH. PROGRAM IN

THERMAL ENGINEERING

Effective from 2014-15

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

To be a global knowledge hub in mechanical engineering education, research, entrepreneurship and industry outreach services.

MISSION

- Impart quality education and training to nurture globally competitive mechanical engineers.
- Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge.
- Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.

GRADUATE ATTRIBUTES

The Graduate Attributes are the knowledge skills and attitudes, which the students have at the time of graduation. These attributes are generic and are common to all engineering programs. These Graduate Attributes are identified by National Board of Accreditation.

1. **Scholarship of Knowledge**: Acquire in-depth knowledge of various manufacturing processes on a wider and global perspective, with an ability to discriminate, evaluate, analyze and synthesize existing and new knowledge, and integration of the same for enhancement of knowledge.
2. **Critical Thinking**: Analyze complex engineering problems critically, apply independent judgment for synthesizing information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context.
3. **Problem Solving**: Think laterally and originally, conceptualize and solve manufacturing engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, societal and environmental factors in the core areas of expertise.
4. **Research Skill**: Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyze and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.
5. **Usage of modern tools**: Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities with an understanding of the limitations.
6. **Collaborative and Multidisciplinary work**: Possess knowledge and understanding of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.
7. **Project Management and Finance**: Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economic and financial factors.
8. **Communication**: Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to

comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

9. **Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
10. **Ethical Practices and Social Responsibility**: Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.
11. **Independent and Reflective Learning**: Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

CURRICULAR COMPONENTS FOR ALL M. TECH. PROGRAMS IN MECHANICAL ENGINEERING

Category	**Sem – I**	**Sem – II**	**Sem – III**	**Sem – IV**	**Total No. of credits to be earned**
Core courses	16	12	--	--	**28**
Electives	06	09	--	--	**15**
Lab Courses	04	04	--	--	**08**
Comprehensive Viva-Voce	--	--	04	--	**04**
Seminar	--	02	--	--	**02**
Dissertation	--	--	08	18	**26**
Total	**26**	**27**	**12**	**18**	**83**

DEPARTMENT OF MECHANICAL ENGINEERING

M. TECH. IN THERMAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES:

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. They must be consistent with the mission of the Institution and Department. Department faculty members must continuously work with stakeholders (local employers, industry and RD advisors, and the alumni) to review the PEOs and update them periodically. The number of PEOs should be manageable and small in number, say 4±1, and should be achievable by the program.

PEO1.	Apply concepts of thermal engineering including thermodynamics, heat transfer and fluid mechanics to design and develop energy efficient equipment.
PEO2.	Model and design thermal systems using computational and optimization techniques.
PEO3.	Adopt methods of energy conservation for sustainable development.
PEO4.	Communicate effectively and support constructively towards team work.
PEO5.	Pursue lifelong learning for career and professional growth with ethical concern for society and environment.

Mapping of mission statements with program educational objectives:

Mission	PEO1	PEO2	PEO3	PEO4	PEO5
Impart quality education and training to nurture globall competitive mechanical engineers.	3	3	1	3	2
Provide vital state of the art research facilities to create, interpret, apply and disseminate knowledge.	3	2	3	3	3
Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.	2	2	2	3	3

Mapping of program educational objectives with graduate attributes

PEO	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8	GA9	GA10	GA11
PEO1	3	2	3	3	1	2	2	-	1	1	1
PEO2	2	2	3	2	3	2	1	-	1	1	1
PEO3	2	2	3	2	3	2	1	-	1	1	1
PEO4	1	1	-	1	-	1	2	3	3	2	2
PEO5	1	2	1	1	-	1	2	2	3	3	2

PROGRAM OUTCOMES:

Program Outcomes, as per NBA, are narrower statements that describe what the students are expected to know and be able to do upon the graduation. These relate to the knowledge, skills and behavior the students acquire through the program. The Program Outcomes (PO) are specific to the program and should be consistent with the Graduate Attributes and facilitate the attainment of PEOs.

At the end of the program the student will be able to:

PO1	Understand advanced concepts of thermal engineering systems.
PO2	Apply principles of thermal engineering to improve the performance of energy conversio devices.
PO3	Perform tests on thermal energy conversion devices as per standards and interpret results.
PO4	Apply finite element, CFD and optimization techniques to model, analyze and simulate thermal systems.
PO5	Analyze thermal systems and their components for optimal performance.
PO6	Identify sources of harmful engine emissions to develop pollution abatement techniques
PO7	Design and analyze the performance of gas turbines and propulsion devices.
PO8	Apply concepts of thermal engineering to execute research projects.
PO9	Apply principles of measurements for performance evaluation of thermal systems.
PO10	Identify viable renewable energy sources and develop appropriate ways to harness them.
PO11	Translate competencies to support team effort.
PO12	Engage in lifelong learning for career and professional growth with ethical concern for society and environment.

Mapping of program outcomes with program educational objectives

PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
PEO1	3	3	3	2	3	2	-	3	3	1	2	2
PEO2	3	2	1	3	3	-	1	3	-	1	1	2
PEO3	3	3	3	3	2	3	1	2	2	3	-	3
PEO4	2	2	3	-	-	-	-	2	2	-	3	2
PEO5	2	1	2	-	-	1	-	1	-	2	3	3

SCHEME OF INSTRUCTION

M. TECH. (THERMAL ENGINEERING) COURSE STRUCTURE

I Year, Semester – I

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	ME 5101	Incompressible and Compressible Flows	4	0	0	4	PCC
2.	ME 5102	Computational Methods in Thermal Engineering	4	0	0	4	PCC
3.	ME 5103	Advanced Heat and Mass Transfer	4	0	0	4	PCC
4.	ME 5104	Finite Element Methods for Thermal Engineering	4	0	0	4	PCC
5.		Elective-1	3	0	0	3	DEC
6.		Elective – 2	3	0	0	3	DEC
7.	ME5105	Thermal Engineering Laboratory	0	0	3	2	PCC
8.	ME5106	CFD Laboratory – I	0	0	3	2	PCC
		Total	**22**	**0**	**6**	**26**	

I Year, Semester – II

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME5151	Internal Combustion Engines	4	0	0	4	PCC
2	ME5152	Gas Turbines and Jet Propulsion	4	0	0	4	PCC
3	ME5153	Renewable Sources of Energy	4	0	0	4	PCC
4		Elective – 3	3	0	0	3	DEC
5		Elective – 4	3	0	0	3	DEC
6		Elective – 5	3	0	0	3	DEC
7	ME5154	Energy Systems Laboratory	0	0	3	2	PCC
8	ME5155	CFD Laboratory – II	0	0	3	2	PCC
9	ME5191	Seminar	0	0	3	2	PCC
		Total	**21**	**0**	**9**	**27**	

II Year, Semester – I

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6142	Comprehensive Viva – Voce	4	PCC
2	ME6149	Dissertation - Part A	8	PCC
		Total	**12**	

II Year Semester – II

S. No.	Course Code	Course Title	Credits	Cat. Code
1	ME6199	Dissertation - Part B	18	PCC
		Total	**18**	

List of Elective Courses

Semester – I

Course code	Course Title
ME5111	Combustion
ME5112	Power plant engineering
ME5113	Energy systems and management
ME5114	Advanced refrigeration and air-conditioning
ME5418	Optimization methods in engineering
ME5419	Micro and smart systems
ME5421	Mechanical vibrations

Semester – II

Course code	Course Title
ME5161	Cryogenics
ME5162	Alternate Fuels
ME5163	Design of Heat Transfer Equipment
ME5164	Advanced Computational Fluid Dynamics
ME5165	Convective Heat Transfer
ME5166	Jet and Rocket Propulsion
ME5167	Conjugate Heat Transfer
ME5168	Measurements in Thermal Engineering
ME5467	CAD for Thermal Engineering

DETAILED SYLLABUS

ME5101	INCOMPRESSIBLE AND COMPRESSIBLE FLOWS	PCC	3-1-0	4 Credits

PREREQUISITES: None

COURSE OUTCOMES: At the end of the course the student will be able to:

CO1	Ascertain basic concepts in the fluid mechanics
CO2	Analyze practical problems of fluid flow
CO3	Design compressible flow components used in Turbo machines and air- conditioning.
CO4	Understand the performance of fluid flow devices in laminar and Turbulent flows
CO5	Apply the concepts in the analysis of fluid flow problems

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction: Introduction to Fluid Mechanics-Properties of Fluids

Fluid Statics: Fluid Statics, Fundamental Equations-Applications of Fundamental Equations, Relative Motion of Liquids

Kinematics of Fluids: Kinematics of Fluids- Review of basics-Velocity potential, Stream function and Vorticity.

Theory of Stress and Rate of Strain: General theory of Stress and Rate of Strain Fundamental Equations – Integral form-Fundamental Equations – Integral form-Reynolds Transport Theorem-Applications of the Integral Form of Equations-Numerical.

Fundamental Equations in Differential Form: Fundamental: Equations in Differential Form-One-dimensional Inviscid Incompressible Flow-Euler's Equation and Bernoulli's Equation-Applications of the Bernoulli's Equations-Numerical.

Two and Three – dimensional Inviscid Incompressible Flow: Two and Three – dimensional Inviscid Incompressible Flow-Laminar Flow- Flow between Parallel Flat plates-Steady Flow in Pipes-Applications of Laminar Flow-Numericals.

The Laminar Boundary layer: The Laminar Boundary layer – Prandtl's Boundary Layer Equations-The Boundary layer along a Flat Plate-Solution to the Boundary Layer Equations-Momentum Integral Equation-Separation of Boundary Layer and Control-Numericals

Turbulent Flow: Introduction to Turbulent Flow – Modified N-S Equations-Semi - empirical Theories-Turbulent Boundary Layer-Numericals

Dimensional Analysis: Flow over a bluff body – Lift and Drag-Dimensional Analysis and Similitude.

Introduction to Compressible Flow: Introduction to Compressible Flow – review of Fundamentals-Stagnation Properties – Relations and Tables-Numericals

Wave Motion: Wave Motion-Propagation of Motion in Compressible Fluids-Mach number and Mach Cone-Numericals

Isentropic Flow: Isentropic Flow Relations-Flow through Nozzles and Diffusers-Isentropic Flow Relations and Tables-Numericals

Flow across Normal Shock and Oblique Shock: Basic Equations Normal Shock – Prandtl-Meyer Equation, Oblique shock-Property variation – Relations and Tables-Numericals.

Flow through a constant area duct with Friction: Flow through a constant area duct with Friction-Fanno Line,Fanno Flow -Variation of Properties – Relations and Tables-Numericals. Flow through a constant area duct with Heat Transfer-Flow through a constant area duct with Heat Transfer-Rayleigh Line, Rayleigh Flow – Variation of Properties – Relations and Tables-Numericals.

READING:

1. S.W. Yuan ., *Foundations of Fluid Mechanics*, Prentice Hall of India, 2000
2. S.M. Yahya , *Fundamentals of Compressible Flow, with Aircraft and Rocket Propulsion*, 4th edition, New Age techno, 2010
3. Schlichting, H., *Boundary Layer Theory,* 8th edition, Springer, 2004.
4. White F.M., *Viscous Fluid Flow*, 3rd edition, Tata McGraw Hill Book Company, 2011.

ME5102	COMPUTATIONAL METHODS IN THERMAL ENGINEERING	PCC	4-0-0	4 Credits

PRE-REQUISITES: None

COURSE OUTCOMES: At the end of the course the student will be able to:

CO1	Understand the stepwise procedure to completely solve a fluid dynamics problem using computational methods.
CO2	Derive the governing equations and understand the behavior of the equations.
CO3	Analyze the consistency, stability and convergence of various discretisation schemes for parabolic, elliptic and hyperbolic partial differential equations.
CO4	Analyze variations of SIMPLE schemes for incompressible flows and Variations of Flux Splitting algorithms for compressible flows.
CO5	Analyze various methods of grid generation techniques and application of finite difference and finite volume methods to various thermal problems.

CO-PO MAPPING:

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	P10	P11	P12
CO1	3	2	-	3	2	-	1	2	-	-	-	-
CO2	3	2	-	3	2	-	1	2	-	-	-	-
CO3	3	2	-	3	2	-	1	2	-	-	-	-
CO4	3	2	-	3	2	-	1	2	-	-	-	-
CO5	3	2	-	3	2	-	1	2	-	-	-	-

DETAILED SYLLABUS:

Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical Methods

Governing equations of fluid dynamics: Models of the flow, The substantial derivative, Physical meaning of the divergence of velocity, The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Mathematical behavior of partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behavior of Hyperbolic, Parabolic and Elliptic equations.

Basic aspects of discretization: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points.
Grids with appropriate transformation: General transformation of the equations, Metrics and Jacobians, The transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.

Parabolic partial differential equations: Finite difference formulations, Explicit methods – FTCS, Richardson and DuFort-Frankel methods, Implicit methods – Laasonen, Crank-Nicolson and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization.

Stability analysis: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, artificial dissipation and dispersion.

Elliptic equations: Finite difference formulation, solution algorithms: Jacobi-iteration method, a Gauss-Siedel iteration method, point- and line-successive over-relaxation methods, and alternative direction implicit methods.

Hyperbolic equations: Explicit and implicit finite difference formulations, splitting methods, multi-step methods, applications to linear and nonlinear problems, linear damping, flux corrected transport, monotone and total variation diminishing schemes, tvd formulations, entropy condition, first-order and second-order tvd schemes.

Scalar representation of navier-stokes equations: Equations of fluid motion, numerical algorithms: FTCS explicit, FTBCS explicit, Dufort-Frankel explicit, Maccormack explicit and implicit, BTCS and BTBCs implicit algorithms, applications.

Grid generation: Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation.

Finite volume method for unstructured grids: Advantages, Cell Centered and Nodal point Approaches, Solution of Generic Equation with tetra hedral Elements, 2-D Heat conduction with Triangular Elements

Numerical solution of quasi one-dimensional nozzle flow: Subsonic-Supersonic isentropic flow, Governing equations for Quasi 1-D flow, Non-dimensionalizing the equations, MacCormack technique of discretization, Stability condition, Boundary conditions, Solution for shock flows.

READING:

1. Anderson, J.D.(Jr), *Computational Fluid Dynamics*, McGraw-Hill Book Company, 1995.
2. Hoffman, K.A., and Chiang, S.T., *Computational Fluid Dynamics*, Vol. I, II and III, Engineering Education System, Kansas, USA, 2000.
3. Chung, T.J., *Computational Fluid Dynamics*, Cambridge University Press, 2003.
4. Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., *Computational Fluid Mechanics and Heat Transfer*, McGraw Hill Book Company, 2002.
5. Versteeg, H.K. and Malalasekara, W*., An Introduction to Computational Fluid Dynamics*, Pearson Education, 2010.

ME5103	ADVANCED HEAT AND MASS TRANSFER	PCC	4-0-0	4 Credits

PREREQUISITES: None

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

CO1	Understand both the physics and the mathematical treatment of the advanced topics pertaining to the modes of heat transfer.
CO2	Apply principles of heat transfer to develop mathematical models for uniform and non-uniform fins.
CO3	Employ mathematical functions and heat conduction charts in tackling two-dimensional and three-dimensional heat conduction problems.
CO4	Analyze free and forced convection problems involving complex geometries with prope boundary conditions.
CO5	Apply the concepts of radiation heat transfer for enclosure analysis.
CO6	Understand physical and mathematical aspects of mass transfer.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	-	2	1	-	-	1	-	-	-	1
CO2	3	2	-	2	1	-	-	2	-	-	-	1
CO3	3	1	-	2	2	-	-	1	-	-	-	1
CO4	3	1	-	2	2	-	-	2	-	-	-	1
CO5	3	1	-	1	1	-	-	2	-	-	-	1
CO6	3	1	-	1	1	-	-	1	-	-	-	1

DETAILED SYLLABUS:

Introduction: Introduction to Heat Transfer – Different Modes, Governing Laws, Quasi-Linearization of the Stefan-Boltzmann Law, Applications to Heat Transfer, Simple Problems for recapitulation of the above.

General Heat Conduction Equation : General Heat Conduction Equation in (i) Cartesian, (ii) Polar and (iii) Spherical Co-ordinate Systems – Derivation of all the equations from first principles, Solution to heat conduction equation – Initial and Boundary Conditions, Different kinds of boundary conditions with examples.

Steady-state one-dimensional heat conduction problems in Cartesian System : Steady-state one-dimensional heat conduction problems (i) with and without heat generation and (ii) with and without varying thermal conductivity - in Cartesian system with various possible boundary conditions, Numerical Problems.

Steady-state radial heat conduction problems in Polar System: Steady-state radial heat conduction problems (i) with and without heat generation and (ii) with and without varying thermal conductivity - in cylindrical system with various possible boundary conditions, Numerical Problems.

Steady-state radial heat conduction problems in Spherical System: Steady-state radial heat conduction problems (i) with and without heat generation and (ii) with and without varying thermal conductivity - in Spherical system with various possible boundary conditions, Numerical Problems.

Extended Surfaces or Fins: Extended Surfaces or Fins of various geometries – Uniform Fins, like Straight Rectangular and Circular Fins, Non-Uniform Fins, like Annular Fins and Triangular Fins, Corrected fin-length concept of Harper and Brown, Fin Efficiency and Fin Effectiveness, Numerical Problems covering all the topics.

Steady-state two-dimensional heat conduction problems: Steady-state two-dimensional heat conduction problems in Cartesian and Cylindrical co-ordinates, Use of Bessel's functions, Numerical Problems.

Transient [Unsteady-state] heat conduction: Transient heat conduction, Different cases - Negligible internal thermal resistance, Negligible surface resistance, Comparable internal thermal and surface resistances, Lumped body, Infinite plate of finite thickness and Semi-infinite Solid, Numerical problems, Heisler and Grober charts for Transient Conduction – Solution to (i) One-dimensional, (ii) Two-dimensional and (iii) Three-dimensional problems using the charts, Numerical problems.

Forced Convection: Forced Convection Flow over a flat plate, Boundary Layer Theory, Velocity and Thermal Boundary Layers, Prandtl number, Governing Equations – Continuity, Navier-Stokes and Energy equations, Boundary layer assumptions, Integral and Analytical solutions to above equations, Turbulent flow, Various empirical solutions, Numerical Problems concerning the above topics, Forced convection flow over cylinders and spheres, Internal forced convection flows – Constant wall temperature and Constant wall heat flux boundaries, laminar and turbulent flow solutions, Numerical Problems.

Free convection: Laminar and Turbulent flows, analytical and empirical solutions, Numerical Problems.

Thermal Radiation : Prevost's theory, Theories of propagation of thermal radiation, Fundamental principles - White, Opaque, Transparent, Black and Gray bodies, Spectral and Total emissive powers, Wien's, Rayleigh-Jeans and Planck's laws, Spectral energy distribution of a black body, Stefan-Boltzmann law for the total emissive power of a black body, Emissivity – types of emissivity, Numerical Problems, View factor, View factor algebra, Summation rule, Reciprocity Theorem, Hottel's crossed-string method, Electrical resistance concept to tackle two-body enclosures, Numerical problems.

Mass Transfer: Definition, Examples, Fick's law of diffusion, Fick's law as referred to ideal gases, Steady-state Isothermal Equi-molal counter diffusion of ideal gases, Mass diffusivity, Gilliland's equation, Isothermal evaporation of water and its subsequent diffusion into dry air, Mass transfer coefficient, Numerical problems.

READING:

1. Sadik Kakac and Yaman Yener: Heat Conduction, Hemisphere, 2nd Edition, 2001.
2. Kays, W. M. and Crawford, M. E., Convective Heat and Mass Transfer, Tata McGraw Hill, 4th Edition, 2012.
3. Siegel, R. and Howell, J. R., Thermal Radiation Heat Transfer, Taylor and Francis, 4th Edition, 2002.

ME5104	FINITE ELEMENT METHOD FOR THERMAL ENGINEERING	PCC	4-0-0	4 Credits

PRE-REQUISITES: None

COURSE OUTCOMES: At the end of the course the student will be able to

CO1	Establish the mathematical models for the complex analysis problems and predict th nature of solution
CO2	Formulate element characteristic matrices and vectors.
CO3	Identify the boundary conditions and their incorporation in to the FE equations
CO4	Solve the problems with simple geometries, with hand calculations involving the fundamental concepts
CO5	Interpret the analysis results for the improvement or modification of the system.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction: Historical Perspective of FEM and applicability to Thermal Engineering problems.

Conduction Heat Transfer and Formulation: Modelling heat conduction; formulation of governing equation, differential and Variational formulation. Initial, boundary and interface conditions. Approximate methods, Ritz and Galerkin's methods, Finite element approximation and basic concepts.

Linear Steady state problems: Problems with one dimensional linear element, Formulation of element characteristic matrices and vectors. Assembly considerations and boundary conditions. Quadratic elements and their advantages and disadvantages. Two dimensional elements; triangular and quadrilateral elements, natural coordinates, parametric representation, Subparametric, superparametric and Isoparametric elements. Formulation of conductive, convective matrices and nodal heat rate vectors. Analysis procedure for 2 D conduction with convection

Nonlinear Heat conduction Analysis: Galerkin's method to nonlinear transient heat conduction; Governing equation with initial and boundary conditions, one dimensional nonlinear steady-state problems and transient state problems.

Viscous Incompressible Flows: Governing equations, weak form, finite element model, penalty finite element models, problems in two dimensional flow fields, finite element models of porous flow

Convective Heat Transfer: Basic equations, steady convection diffusion problems and transient convection-diffusion problems, Velocity-pressure-temperature formulation, Examples of heat transfer in a fluid flowing between parallel planes.

Structural problems: Finite element formulation for structural problems, 1 dimensional stress analysis problems with bar, beam, truss and frame elements, FE formulation in plane stress, plane strain and axi-symmetric problems. Introduction to plate bending and shell elements.

READING:

1. Reddy J.N.,Gartling. D.K., *The Finite Element Method in Heat Transfer and Fluid dynamics*, CRC Press, 2007.
2. Lewis R.W., et al.. *The Finite Element method in Heat Transfer Analysis*, John Wiley & Sons
3. Singiresu S.Rao, *Finite element Method in Engineering*, 5ed, Elsevier, 2012
4. Zeincowicz, *The Finite Element Method*, 4 Vol set. 4th Edition, Elsevier 2007.

ME5111	COMBUSTION	DEC	3-0-0	3 Credits

PREREQUISITES: None

COURSE OUTCOMES: At the end of the course student will be able to:

CO1	Understand the concepts of combustion phenomena in energy conversion devices.
CO2	Apply the knowledge of adiabatic flame temperature in the design of combustion devices
CO3	Identify the phenomenon of flame stabilization in laminar and turbulent flames.
CO4	Analyze the pollution formation mechanisms in combustion of solid, liquid and gaseous fuels.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction: Overview of the course-Thermo chemistry of combustion-Concept of Adiabatic Flame Temperature-Numerical Problems

Chemical Kinetics: Differences between equilibrium and rate controlled reactions- Global versus Elementary Reactions. Elementary reaction rates, bimolecular reactions and collision theory, other elementary reactions, Relation between rate coefficients and equilibrium constants, Steady-state Approximation. The mechanism for Uni-molecular reactions, Chain and Chain-Branching reactions.

Introduction to species Mass Transfer: Rudiments of Mass Transfer, Mass Transfer Rate Laws, and Species Conservation. The Stefan Problem, Liquid-vapor interface boundary conditions, Droplet evaporation, Numerical.

Simplified Conservation Equations for Reacting Flows: Overview-Overall Mass Conservation(Continuity)Species mass Conservation(Species Continuity) Momentum Conservation,1-D and 2-D forms, Energy Conservation-General 1-D Form, Shvab- Zeldovich Forms, Definition of Mixture Fraction.

Laminar Premixed Flames: Physical Description, Definition, Principal characteristics, Typical Laboratory Flames. Simplified Analysis, Assumptions, Conservation Laws, Solution, Factors Influencing flame velocity and Thickness: temperature, pressure, Equivalence ratio, fuel type, Flame speed Correlations for Selected fuels, Quenching, Flammability, and Ignition Flame lift-off (Blow-off) and flash back, Concept of Flame stretch-Karlovitz number, Flame Stabilization.

Introduction to Turbulent Flames: Turbulent length and time scales, Weak turbulent flames. Wrinkled Reaction Sheets, Distributed Reaction zones.

Pollutant Emissions: Effects of emissions, Quantification of Emissions, Emission Indices, Corrected concentrations, Various Specific emission measures-Emissions from Premixed

Combustion: Oxides of Nitrogen, Carbon Monoxide, Unburned Hydrocarbons, Catalytic After-treatment, Particulate Matter.Emissions from non-Premixed Combustion: Oxides of Nitrogen, Unburned Hydrocarbons and Carbon Monoxide, Particulate Matter and Oxides of Sulfur, Numerical Problems

READING:

1. Stephen, R. Turns., Combustion, McGraw Hill, 2005.
2. Mishra, D.P., Introduction to Combustion, Prentice Hall,2009
3. Sharma, S. P., Fuels and Combustion, Tata McGraw Hill, New Delhi, 2001.
4. Heywood Internal Combustion Engine Fundamentals, McGraw Hill Co.1988
5. Warnatz, Ulrich Maas and Robert W. Dibble Combustion: Physical and Chemica Fundamentals, Modelling and Simulation, Experiments, Pollutant Formation, 1999.

ME5112	POWER PLANT ENGINEERING	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

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

CO1	Understand analytical and technological aspects of power plant design, systems and their effects.
CO2	Describe the working of power plants based on type of fuel.
CO3	Explain the working of the hydro electric power plants.
CO4	Analyse economic feasibility and its implications on power generating units.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction: Energy resources and their availability, types of power plants, selection of the plants, review of basic thermodynamic cycles used in power plants.
Hydro Electric Power Plants: Rainfall and run-off measurements and plotting of various curves for estimating stream flow and size of reservoir, power plants design, construction and operation of different components of hydro-electric power plants, site selection, comparison with other types of power plants.

Steam Power Plants: Flow sheet and working of modern-thermal power plants, super critical pressure steam stations, site selection, coal storage, preparation, coal handling systems, feeding and burning of pulverized fuel, ash handling systems, dust collection-mechanical dust collector and electrostatic precipitator.

Steam generators and their accessories: High pressure Boilers, Accessories, Fluidized bed boiler.

Condensers: Direct Contact Condenser, Surface Condensers, Effect of various parameters on condenser performance, Design of condensers, Cooling towers and cooling ponds

Combined Cycles: Constant pressure gas turbine power plants, Arrangements of combined plants (steam & gas turbine power plants), re-powering systems with gas production from coal,using PFBC systems, with organic fluids, parameters affecting thermodynamic efficiency of combined cycles.

Nuclear Power Plants: Principles of nuclear energy, basic nuclear reactions, nuclear reactorsPWR, BWR, CANDU, Sodium graphite, fast breeder, homogeneous; gas cooled. Advantages and limitations, nuclear power station, waste disposal.

Power Plant Economics: load curve, different terms and definitions, cost of electrical energy, tariffs methods of electrical energy, performance & operating characteristics of power plants- incremental rate theory, input-output curves, efficiency, heat rate, economic load sharing, Problems.

READING:

1. Power plant engineering by 'Arrora&Domkundwar', DhanpatRai& Sons, New Delhi, 2008.
2. Power plant Technology by 'M.M.Ei-Wakil', McGraw Hill Com., 1985.
3. Power plant engineering by 'P C Sharma', S.K. Kataria& Sons, New Delhi, 2010.

ME5113	ENERGY SYSTEMS AND MANAGEMEN	DEC	3-0-0	3 Credits

PREREQUISITE: None

COURSE OUTCOMES: At the end of the course the student will be able to:

CO1	Explain the fundamentals of energy management and its influence on environment
CO2	Describe methods of energy production for improved utilization.
CO3	Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.
CO4	Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.
CO5	Assess energy projects on the basis of economic and financial criteria.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction to Thermodynamics, Fluid Flow and Heat Transfer

Heat transfer media: Water, steam, Thermal fluids, Air-water vapor mixtures

Heat transfer equipment: Heat exchangers, Steam plant

Energy storage systems: Thermal energy storage methods, Energy saving, Thermal energy storage systems

Energy conversion systems: Furnaces, turbines

Heat recovery systems: Incinerators, regenerators and boilers

Energy Management: Principles of Energy Management, Energy demand estimation, Organizing and Managing Energy Management Programs, Energy pricing

Energy Audit: Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries

Economic Analysis: Scope, Characterization of an Investment Project
Case studies

READING:

1. Turner, W. C., Doty, S. and Truner, W. C., Energy Management Hand book, 7th edition, Fairmont Press, 2009.
2. De, B. K., Energy Management audit & Conservation, 2nd Edition, Vrinda Publication, 2010.
3. Murphy, W. R., Energy Management, Elsevier, 2007.
4. Smith, C. B., Energy Management Principles, Pergamon Press, 2007.

ME5114	ADVANCED REFRIGERATION AND AIR-CONDITIONING	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

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

CO1	Understand physical and mathematical aspects of refrigeration and air-conditioning systems.
CO2	Apply theoretical and mathematical principles to simple, complex vapour compression and vapour absorption refrigeration systems.
CO3	Understand conventional and alternate refrigerants and their impact on environment.
CO4	Design air-conditioning systems.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Refrigeration cycles – analysis: Development of Vapor Compression Refrigeration Cycle from Reverse Carnot Cycle- conditions for high COP-deviations from ideal vapor compression cycle ,Multipressure Systems , Cascade Systems-Analysis.

Main system components: Compressor- Types , performance , Characteristics of Reciprocating Compressors , Capacity Control , Types of Evaporators & Condensers and their functional aspects , Expansion Devices and their Behaviour with fluctuating load.

Refrigerants: Classification of Refrigerants, Refrigerant properties, Oil Compatibility, Environmental Impact-Montreal/ Kyoto protocols-Eco Friendly Refrigerants. Different Types of Refrigeration Tools, Evacuation and Charging Unit, Recovery and Recycling Unit, Vacuum Pumps.

Other refrigeration cycles: Vapor Absorption Systems-Aqua Ammonia &LiBr Systems, Steam Jet Refrigeration Thermo Electric Refrigeration, Air Refrigeration cycles.

Psychrometry: Moist Air properties , use of Psychrometric Chart , Various Psychrometric processes , Air Washer , Adiabatic Saturation.
Summer and winter air conditioning:

Air conditioning processes-RSHF, summer Air conditioning, Winter Air conditioning, Bypass Factor. Applications with specified ventilation air quantity- Use of ERSHF, Application with low latent heat loads and high latent heat loads.

Load estimation & air conditioning control: Solar Radiation-Heat Gain through Glasses, Heat transfer through roofs and walls, Total Cooling Load Estimation. Controls of Temperature, Humidity and Air flow.

Air distribution: Flow through Ducts , Static & Dynamic Losses , Air outlets , Duct Design–Equal, Friction Method , Duct Balancing , Indoor Air Quality , Thermal Insulation , Fans & Duct System Characteristics , Fan Arrangement Variable Air Volume systems , Air Handling Units and Fan Coil units.

READING:

1. Roy J. Dossat, Principles of Refrigeration, Wiley Limited
2. Arora C.P., Refrigeration and Air-conditioning, Tata McGraw –Hill, New Delhi
3. Stoecker W.F., and Jones J.W., Refrigeration and Air-conditioning, McGraw - Hill, New Delhi
4. **Data Books:** Refrigerant and Psychrometric Properties (Tables & Charts) SI Units, Mathur M.L. & Mehta F.S., Jain Brothers.

ME5418	**OPTIMIZATION METHODS IN ENGINEERIN**	**DEC**	**3-0-0**	**3 Credits**

PREREQUISITE: None

COURSE OUTCOMES: At the end of the course the student will be able to:

CO1	Explain an overview of modeling of constrained decision making.
CO2	Develop a mathematical model for a given problem.
CO3	Solve practical problems using suitable optimization technique.
CO4	Analyze the sensitivity of a solution to different variables.
CO5	Use and develop optimization simulation software for variety of industrial problems.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction to the course: Statement of an optimization problem and classification of optimization problems.

Optimization Techniques: Single-Variable Optimization, Multivariable Optimization without any Constraints, with Equality and Inequality Constraints.

Linear Programming: Simplex Methods, Sensitivity Analysis, Transportation Problem

Integer Programming: Graphical Representation, Integer Polynomial Programming

Geometric Programming: Formulation and Solutions of Unconstrained and Constrained geometric programming problem.

Dynamic Programming: Multistage Decision Processes
One-Dimensional Minimization Methods: Elimination methods: Fibonacci Method, Golden Section Method, Interpolation methods: Quadratic Interpolation Method, Cubic Interpolation Method

Unconstrained Optimization Techniques: Univariate, Conjugate Gradient Method and Variable Metric Method.

Constrained Optimization Techniques: Characteristics of a constrained problem; Direct Method of feasible directions; Indirect Method of interior and exterior penalty functions.

READING:

1. Rao, S. S., Optimization Theory and Applications, Wiley Eastern Ltd., 2nd Edition, 2004.
2. Fox, R. L., Optimization Methods for Engineering Design, Addison Wesley, 2001.

ME5419	MICRO AND SMART SYSTEMS	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

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

CO1.	Classify the presently available micro sensors and actuators available in the market.
CO2.	Understand the conventional and silicon based micro machining technologies for smart structure development.
CO3.	Compute the coupled response of an electro mechanical smart system using finite element method.
CO4.	Identify the credibility of various electronic circuits and control methods used to develop micro and smart systems.
CO5.	Describe the methodology for micro and smart system integration.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	P11	P12
CO1	-	-	-	1	-	-	1	-	-	2	-	1
CO2	-	2	2	2	2	1	1	-	-	1	1	1
CO3	3	3	-	-	2	-	-	-	-	1	-	2
CO4	-	1	2	2	2	1	-	1	2	1	1	-
CO5	2	2	2	-	-	-	-	-	-	-	1	2

DETAILED SYLLABUS:

Introduction: Overview of Micro and smart systems, Processing of Sensors, Actuators and micro structures, Applications in diverse fields including Biomedical, Defence, Automobile and Aerospace Engineering.

Micro Fabrication Processes: Overview of Micro Machining Technologies, miaturization, conventional and silicon micro machining techniques, Ultrasonic machining, sandblasting, laser ablation, spark erosion and photo lithography.

Modelling and Mechanics: Solid mechanics concepts for Micro and smart systems, Solid Modeling in Micro systems.

Finite Element Method: FEM applications for modelling and analysis of Coupled Electromechanical Systems.

Electronics and Packaging: Integration of mechanical components with electronics, Electronic circuits and control for micro and smart systems, scaling effects.

READING:

1. G. K. Anantha Suresh, Micro and Smart Systems, Wiley India Pvt. Ltd., 2010.
2. G. K. Anantha Suresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, V.

KasudevAatre, Micro and Smart Systems: Technology and Modeling, John Wiley & Sons, 2012.

3. Tai-Ran Hsu, MEMS and Microsystems: Design and Manufacture, Tata McGraw Hill Education Private Limited, 2002.

ME5421	MECHANICAL VIBRATIONS	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

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

CO1	Understand the causes and effects of vibration in mechanical systems
CO2	Formulate the governing equations of motion.
CO3	Understand the Rotating/reciprocating systems and abele to compute the critical speeds.
CO4	Analysis and design of machine supporting structures, Vibration Isolators, Vibration Absorbers
CO5	Calculate Free and forced vibration responses through model Analysis.
C06	Understand the principles of continuous systems, their modeling and Analysis

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	-	-	1	-	-	-	-	-	-	-	-
CO2	2	-	-	1	-	-	-	-	-	-	-	-
CO3	2	-	-	1	-	-	-	-	-	-	-	1
CO4	1	-	-	1	-	-	-	-	-	-	-	1
CO5	2	-	-	1	-	-	-	-	-	-	-	1
CO6	1	-	-	1	-	-	-	-	-	-	-	1

DETAILED SYLLABUS:

Introduction: Causes and effects of vibration, Classification of vibrating system, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, linearization of nonlinear systems, Physical models, Schematic models and Mathematical models**.**

SDF systems: Formulation of equation of motion: Newton –Euler method, De Alembert's method, Energy method,

Free Vibration: Undamped Free vibration response, Damped Free vibration response, Case studies on formulation and response calculation.

Forced vibration response: Response to harmonic excitations, solution of differential equation of motion, Vector approach, Complex frequency response, Magnification factor Resonance, Rotating/reciprocating unbalances, Force Transmissibility, Motion Transmissibility, Vehicular suspension, Vibration measuring instruments, Case studies on forced vibration.

Two degree of freedom systems: Introduction, Formulation of equation of motion: Equilibrium method, Lagrangian method, Case studies on formulation of equations of motion
Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Response to initial

conditions, free vibration response case studies, Forced vibration response, undamped vibration absorbers, Case studies on undamped vibration absorbers.

Multi degree of freedom systems: Introduction, Formulation of equations of motion, Free vibration response, Natural modes and mode shapes, Orthogonally of model vectors, normalization of model vectors, Decoupling of modes, model analysis, mode superposition technique, Free vibration response through model analysis, Forced vibration analysis through model analysis, Model damping, Rayleigh's damping, Introduction to experimental model analysis.

Continuous systems: Introduction to continuous systems, Exact and approximate solutions, free vibrations of bars and shafts, Free vibrations of beams, Forced vibrations of continuous systems Case studies, Approximate methods for continuous systems and introduction to Finite element method.

READING:

1. L. Meirovich, Elements of Vibration analysis, 2nd Ed. Tata Mc-Grawhill 2007
2. Singiresu S Rao, Mechanical Vibrations. 4th Ed. , Pearson education 2011
3. W.T., Thompson, Theory of Vibration,. CBS Publishers
4. Clarence W. de Silva , Vibration: Fundamentals and Practice, CRC Press LLC, 2000

ME5105	THERMAL ENGINEERING LABORATORY	PCC	0-0-3	2 Credits

PREREQUISITES: None

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

CO1	Perform experiments to determine the properties of fuels and oils.
CO2	Determine the volumetric efficiency of a two-stage reciprocating air compressor as a function of receiver pressure.
CO3	Evaluate heat transfer coefficient using forced convection set-up.
CO4	Interpret the theoretical and experimental findings of free convection experiments.
CO5	Apply Fourier law of conduction for composite slab and Newton's law of cooling for pin-fin apparatus.
CO6	Perform experiments on engines and draw characteristics.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	-	-	1	1	-	1	-	-	-	1
CO2	3	1	-	-	1	-	-	1	-	-	-	1
CO3	2	2	-	-	3	-	-	2	-	-	-	1
CO4	2	1	-	-	3	-	-	2	-	-	-	1
CO5	2	2	-	-	3	-	-	1	-	-	-	1
CO6	2	1	-	-	3	-	-	1	-	-	-	1

DETAILED SYLLABUS:

Pin-Fin Apparatus: Determination of temperature distribution, efficiency and effectiveness of the fin working in forced convection environment.

Natural Convection Apparatus: Determination of experimental and empirical values of convection heat transfer coefficient from a Vertical Heated Cylinder losing heat to quiescent air.

Forced Convection Apparatus: Determination of theoretical, experimental and empirical values of convection heat transfer coefficient for internal forced convection through a circular GI pipe

Abel's apparatus: Determination of flash and fire points of a given oil sample

Redwood Viscometer No. 1: Determination of kinematic and absolute viscosities of an oil sample given

Distillation apparatus: Determination of distillation characteristic of a given sample of gasoline

Two-Stage Reciprocating Air-Compressor: Determination of volumetric efficiency of the compressor as a function of receiver pressure

Lister and Textool IC Engines: Valve and Port Timing Diagrams on 4-stroke and 2-stroke IC Engines.

Lister Engine: Valve Timing Diagrams on 4-stroke CI Engine.

Single-Cylinder Kirloskar CI Diesel Engine: Constant Speed Performance Test on Single-Cylinder Kirloskar CI Diesel Engine.

Single-Cylinder Kirloskar CI Diesel Engine: Motoring Test on Single-Cylinder Kirloskar CI Diesel Engine.

Single-Cylinder Kirloskar CI Diesel Engine: Retardation Test on Single-Cylinder Kirloskar CI Diesel Engine.

READING:

1. M. Necati Ozisik, Heat Transfer – A Basic Approach, McGraw Hill, New York, 2005.
2. Incropera, F. P. and De Witt, D. P., Fundamentals of Heat and Mass Transfer, 5th Edition, John Wiley and Sons, New York, 2006.
3. Holman, J. P., Heat Transfer, 9th Edition, McGraw Hill, 2008.
4. Ganesan, V., Fundamentals of IC Engines, Tata McGraw Hill, 2003

ME5106	CFD LABORATORY-I	PCC	0-0-3	2 Credits

PREREQUISITE: None

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

CO1	Develop codes for numerical methods to tackle simple problems.
CO2	Build up the skills in the actual implementation of CFD methods (1D and 2D heat conduction and convection problems) by attempting to write their own codes.
CO3	Analyze and validate output of written codes with analytical solution.
CO4	Obtain experience in the application of CFD analysis to real engineering designs.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

1. Solution of 1D heat conduction problem using TDMA and LU decomposition.
2. Solution of 2D parabolic equations
   (a) Explicit
   (b) Implicit (ADI)
3. Grid generation (rectangular and circular)

READING:

1. Versteeg, H. K. and Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd Edition, Pearson, 2010.
2. Tannehill, J. C., Anderson, D. A. and Pletcher, R. H., Computational Fluid Mechanics and Heat Transfer, McGraw Hill, 2002.
3. Blazek, J., Computational Fluid Dynamics: Principles and Applications, 2nd Edition, Elsevier Science & Technology, 2006.
4. Chung, T. J., Computational Fluid Dynamics, Cambridge University Press, 2003.

ME5151	INTERNAL COMBUSTION ENGINES	PCC	4-0-0	4 Credits

PRE-REQUISITES: None

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

CO1	Apply thermodynamic analysis to IC engines and describe combustion phenomena in spark ignition and compression ignition engines.
CO2	Describe the working of major systems used in conventional and modern engines.
CO3	Summarize the methods used to improve engine performance and estimate performance parameters.
CO4	Describe engine emission control techniques and implement viable alternate fuels.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction: Overview of the course, Examination and Evaluation patterns-Historical Perspective-Differences between external combustion and Internal combustion engines-Engine classification – Air standard cycle, Thermodynamic analysis of Otto, Diesel, Dual and Miller Cycle Definition of Engine Performance Parameters and their significance.

Two-stroke cycle engines: Classification 2-s cycle engines based on scavenging-Theoretical Scavenging Processes-Practical Scavenging Systems- Kadenacy effect.

Spark Ignition Engines: Flame Propagation ,Normal and abnormal combustion-Factors affecting Abnormal Combustion(Detonation)-Role of fuels in avoiding detonation-Additives, Ignition Quality-Octane number, Performance Number, Highest Useful Compression Ratio(HUCR)-Characteristics of a Good Combustion chamber(Ricardo),Classification of Combustion Chambers-Fast burn chambers-Carburetion, Mixture Strength diagram, Fuel Metering (Quantity governing)-Description of a Simple Carburettor, Limitations of a Simple Carburettor, Compensating devices. Classification of Automotive Carburettors, Importance of Fuel Injection(MPFI and GDI)-Electronic Injection. Numerical problems.

Compression Ignition Engines: Importance of air motion and Compression Ratio, Mixture Preparation inside the CC-Combustion phenomena(Normal and Abnormal),P-θ diagram and Way's-Heat Release rate diagram-Factors affecting Abnormal Combustion(Knocking)-Role of fuels in avoiding Knocking-Additives, Ignition Quality, Characteristics of a Good Combustion Chamber-Classification of Combustion Chambers(DI and IDI) Fuel Metering(Quality governing)-Fuel Pump(Air Injection and Solid Injection)-Size of fuel droplet(SMD) to atomize the fuel, Spray Patterns (Hiroyasu)Description of a Fuel Injection Pump-Contribution by Robert Bosch, MICO-Pumps;

Description of Fuel injection Systems -Individual, Unit and Common Rail (CRDI)Fuel Injectors-Nozzle types-Electronic Control Unit(ECU) -Numerical Problems on Fuel Injection.

Supercharging of Engines: Methods of increasing performance of engines, need of Supercharging and advantages-Configurations of Supercharger and Engine-Modification required on engine to incorporate Supercharger-Numerical Problems.

Engine Heat Transfer: Need for engine cooling, energy balance diagrams-Heat transfer models for calculations for SI engine and CI engine-Numerical problems.

Pollutant Emissions from IC Engines: Introduction to clean air, Pollutants from SI Engines: Carbon monoxide, UBHCs, Oxides of nitrogen(NO-NO_X) and particulate matter. Mechanism of formation of emissions-CO,HCs and NOx, Measuring instrumentation, Pollution Control Strategies, Emission norms-EURO and Bharat stage-Numerical problems.

Performance of Engines: Measurement of Power(bp, ip and fp),Calculation of efficiencies and Specific fuel consumption, Factors affecting performance-Heat loss, Air-fuel ratio, Pumping loss, Energy Balance: Pi and Sankey diagrams-Numerical problems.

Alternate Fuels: Need for Alternate fuels, Desirable Characteristics of a good Alternate Fuel (Petroleum and non-petroleum fuels)-Liquid and Gaseous fuels for SI and CI Engines, Kerosene, LPG, Alcohols, Bio-fuels, Natural gas, Hydrogen and use of these fuels in engines. Emissions from Alternate fuels, Status of Alternate Fuels in India.

Alternative Engine Technologies: Limitations with gasoline engines and diesel engines Stratified charge engines-Lean Burn engine-Stratification-methods(By carburetion and Combination),Texaco Combustion Process (TCP),Rotary combustion engine-Wankel Engine, Merits and limitations of Alternative Engines

READING:

1. J.B. Heywood Internal Combustion Engine Fundamentals, McGraw Hill Co.1988
2. H.N.Gupta Fundamentals of Internal Combustion Engines ,PHIPvt Ltd.2006.
3. W.W.Pulkrabek Engineering Fundamentals of IC Engine, PHI Pvt.Ltd 2002
4. E.F.Obert IC Engines and Air Pollution Harper and Row Publications,1973
5. V.GanesanIC Engines, Tata McGraw Hill Co.2003.

ME5152	GAS TURBINES AND JET PROPULSION	PCC	4-0-0	4 Credits

PRE-REQUISITES: None

COURSE OUTCOMES: At the end of the course the student will be able to:

CO1	Understand the ideal and real thermodynamic cycles of air-breathing engines and Industrial gas turbines
CO2	Design the blading, study the velocity triangles and estimate the performance of centrifugal and axial flow compressors.
CO3	Understand the combustion process and design the combustion chamber of a gas Turbine.
CO4	Design the blading, study the velocity triangles and estimate the performance of axial and radial in-flow turbines
CO5	Analyze the off-design performance and matching of the components of a gas turbine

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	P10	P11	P12
CO1	3	3	-	-	3	-	3	-	-	-	-	-
CO2	3	3	-	-	3	-	3	-	-	-	-	-
CO3	3	3	-	-	3	-	3	-	-	-	-	-
CO4	3	3	-	-	3	-	3	-	-	-	-	-
CO5	3	3	-	-	3	-	3	-	-	-	-	-

DETAILED SYLLABUS:

Introduction: Classification of Turbomachines, Applications of Gas Turbines, Assumptions for Air-Standard Cycles, Simple Brayton Cycle, Heat Exchange Cycle, Inter-cooling and Reheating Cycle, Comparison of Various Cycles.

Ideal Shaft Power Cycles and their Analysis: Assumptions for Air-Standard Cycles, Simple Brayton Cycle, Heat Exchange Cycle, Inter-cooling and Reheating Cycle, Comparison of Various Cycles.

Real Cycles and their Analysis: Methods of Accounting for Component Losses, Isentropic and Polytropic Efficiencies, Transmission and Combustion Efficiencies, Comparative Performance of Practical Cycles, Combined Cycles and Cogeneration Schemes.

Jet Propulsion Cycles and their Analysis: Criteria of Performance, Simple Turbojet Engine, Simple Turbofan Engine, Simple Turboprop Engine, Turbo-shaft Engine, Thrust Augmentation Techniques

Fundamentals of Rotating Machines: General Fluid Dynamic Analysis, Euler’s Energy Equation, Components of Energy Transfer, Impulse and Reaction Machines.

Centrifugal Compressors: Construction and Principle of Operation, Elementary Theory and Velocity Triangles, Factors Effecting Stage Pressure Ratio, The Diffuser, The Compressibility Effects, Pre-rotation and Slip Factor, Surging and Choking, Performance Characteristics.

Flow Through Cascades: Cascade of Blades, Axial Compressor Cascades, Lift and Drag Forces, Cascade Efficiency, Cascade Tunnel.
Axial Flow Compressors: Construction and Principle of Operation, Elementary Theory and Velocity Triangles, Factors Effecting Stage Pressure Ratio, Degree of Reaction, Work done factor, Three Dimensional Flow, Design Process, Blade Design, Stage Performance, Compressibility Effects, Off-Design Performance.

Combustion System: Operational Requirements, Classification of Combustion Chambers, Factors Effecting Combustion Chamber Design, The Combustion Process, Flame Stabilization, Combustion Chamber Performance, Some Practical Problems Gas Turbine Emissions.

Axial and Radial Flow Turbines: Construction and Operation, Vortex Theory, Estimation of Stage Performance, Overall Turbine Performance, Turbine Blade Cooling, The Radial Flow Turbine.
Off-Design Performance: Off-Design Performance of Single Shaft Gas Turbine, Off-Design Performance of Free Turbine Engine, Off-Design Performance of the Jet Engine, Methods of Displacing the Equilibrium Running Line

READING:

1. Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., *Gas Turbine Theory*, 6th Edition, Pearson Prentice Hall, 2008.
2. Dixon, S.L., *Fluid Mechanics and Thermodynamics of Turbomachinery*, 7^{th} Edition, Elsevier, 2014.
3. Flack, R.D., *Fundamentals of Jet Propulsion with Applications*, Cambridge University Press, 2011.
4. Ganesan, V., *Gas Turbines*, 3rd Edition, Tata McGraw Hill, 2010.
5. Yahya, S. M., *Turbines, Compressors and Fans*, 4th Edition, Tata McGraw Hill, 2010.
   Lefebvre, A.H., *Gas Turbine Combustion,* CRC Press, 2010.

ME5153	RENEWABLE SOURCES OF ENERGY	PCC	4-0-0	4 Credits

PRE-REQUISITES: None

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

CO1	Identify the renewable energy sources and their utilization
CO2	Understand the basic concepts of the solar radiation and analyze the solar Thermal systems for their utilization
CO3	Understand the principle of working of solar cells and their modern manufacturing techniques
CO4	Understand the concepts of the ocean thermal energy conversion systems and their applications
CO5	Outline the methods of energy storage and identify the appropriate methods of energy storage for specific applications
CO6	Understand the energy conversion from wind energy, geothermal energy, biomass, biogas, fuel cells and hydrogen

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	2	-	-	1	1	3	-	2
CO2	2	3	2	2	3	-	-	2	2	3	-	2
CO3	2	3	2	2	1	-	-	2	1	3	-	2
CO4	2	3	1	2	1	-	-	2	1	3	-	2
CO5	2	3	2	2	1	-	-	2	2	3	-	2
CO6	2	3	2	2	1	-	-	2	2	3	-	2

DETAILED SYLLABUS:

Introduction: Overview of the course, Examination and Evaluation patterns. Classification of energy resources, energy scenario in the world and India

Basic sun-earth relationships: Definitions. Celestial sphere, altitude-azimuth, declination-hour angle and declination-right ascension coordinate systems for finding the position of the sun, celestial triangle and coordinates of the sun. Greenwich Mean Time, Indian Standard Time, Local Solar Time, sun rise and sun set times & day length. Numerical problems

Solar radiation: Nature of solar radiation, solar radiation spectrum, solar constant, extra-terrestrial radiation on a horizontal surface, attenuation of solar radiation, beam, diffuse and global radiation. Measurement of global, diffuse and beam radiation. Prediction of solar radiation; Angstrom model, Page model, Hottel's model, Liu and Jordan model etc. Insolation on an inclined surface, angle of incidence, Illustrative problems

Solar thermal systems: Principle of working of solar water heating systems, solar cookers, solar desalination systems, solar ponds, solar chimney power plant, central power tower power plants etc.

Solar concentrating collectors: Classification of solar concentrators, Basic definitions such as concentration ratio, angle of acceptance etc., Tracking of the sun; description of different tracking modes of a solar collectors and the determination of angle of incidence of insolation in different tracking modes. Illustrative problems

Photovoltaic energy conversion: Introduction. Single crystal silicon solar cell, i-v characteristics, effect of insolation and temperature on the performance of silicon cells. Different types of solar cells. Modern technological methods of producing these cells. Indian and world photovoltaic energy scenario.

Energy storage: Necessity for energy storage. Classification of methods of energy storage. Thermal energy storage; sensible heat storage, latent heat storage. Reversible chemical reaction storage. Electromagnetic energy storage. Hydrogen energy storage. Chemical battery storage. Pumped hydel energy storage etc.

Wind energy : Origin of winds, nature of winds, wind data measurement, wind turbine types and their construction, wind-diesel hybrid system, environmental aspects, wind energy programme in India and the world.

Ocean energy : Ocean thermal energy; open cycle & closed cycle OTEC plants, environmental impacts, challenges, present status of OTEC systems. Ocean tidal energy; single basin and double basin plants, their relative merits. Ocean wave energy; basics of ocean waves, different wave energy conversion devices, relative merits

Fuel cells: Introduction, applications, classification, different types of fuel cells such as phosphoric acid fuel cell, alkaline fuel cell, PEM fuel cell, MC fuel cell. Development and performance fuel cells.

Biomass: Introduction, photosynthesis, biofuels, biomass resources, biomass conversion technologies, urban waste to energy conversion, biomass to ethanol conversion, biomass energy scenario in India

Biogas: Biogas production, constant pressure and constant volume biogas plants, operational parameters of the biogas plant

Geothermal energy: Origin, applications, types of geothermal resources, relative merits

READING:

1. B.H.Khan, Non conventional Energy Resources, Tata McGraw Hill, New Delhi, 2012
2. S.Rao and B.B.Parulekar, Energy Technology: Non-Conventional, Renewable and Conventional, Khanna Publishers, 2010
3. S.P.Sukhatme and J.K.Nayak, Solar Energy-Principles of Thermal Collection and Storage, TMH, 2008
4. J.A.Duffie and W.A.Beckman, Solar Energy Thermal Processes, John Wiley, 2010

ME5161	CRYOGENICS	DEC	3-0-0	3 Credits

PREREQUISITES: ME5103: Advanced Heat and Mass Transfer

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

CO1	Understand concepts of cryogenic systems.
CO2	Relate air-liquefaction processes to practical situations.
CO3	Interpret and analyze helium liquefaction techniques.
CO4	Classify cascade refrigeration systems.
CO5	Understand principles of ultra-low temperature systems and their applications.
CO6	Assess storage systems and insulation techniques used in cryogenic applications.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	-	1	2	-	-	1	-	-	-	1
CO2	3	2	-	2	1	-	-	2	-	-	-	1
CO3	1	1	-	1	2	-	-	1	-	-	-	1
CO4	2	1	-	2	1	-	-	3	-	-	-	1
CO5	2	1	-	1	2	-	-	1	-	-	-	1
CO6	1	1	-	1	1	-	-	2	-	-	-	1

DETAILED SYLLABUS:

Introduction: Definition and Engineering Applications of Cryogenics, Properties of solids for cryogenic systems

Refrigeration and Liquefaction: Simple Linde cycle, Pre-cooled Joule-Thomson cycle, dual-pressure cycle, Simon helium liquefier, classical cascade cycle, mixed-refrigerant cascade cycle

Ultra-low-temperature refrigerators: Definition and Fundamentals regarding ultra-low-temperature refrigerators, Equipment associated with low-temperature systems, Various Advantages and Disadvantages

Storage and Handling of Cryogenic Refrigerants: Storage and Transfer systems, Insulation, Various Types of Insulation typically employed, Poly Urethane Foams (PUFs) and Polystyrene Foams (PSFs), Vacuum Insulation, and so on

Applications: Broad Applications of Cryogenic Refrigerants in various engineering systems

READING:

1. Traugott H.K. Frederking and S.W.K. Yuan, Cryogenics - Low Temperature Engineering and Applied Sciences, Yutopian Enterprises, 2005.
2. Arora, C.P., Refrigeration and Air-conditioning, Tata-McGraw Hill, 2008.
3. A. R. Jha, Cryogenic Technology and Applications, Butterworth-Heinemann, 2005.

ME5162	ALTERNATE FUELS	DEC	3-0-0	3 Credits

PREREQUISITES: None

COURSE OUTCOMES: At the end of the course the student will be able to:

CO1	Identify the need of alternate fuels and list out some prospective alternate fuels
CO2	Categorize, interpret and understand the essential properties of fuels for petrol and diesel engines
CO3	Infer the storage and dispensing facilities requirements
CO4	Analyze the implement limitations with regard to performance, emission and materials compatibility
CO5	Identify and understand possible harmful emissions and the legislation standards

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction: Estimation of petroleum reserve – Need for alternate fuels – Availability and properties of alternate fuels, ASTM standards

Alcohols: General Use of Alcohols – Properties as Engine fuel – Gasolene and alcohol blends – Performance in SI Engine – Methanol and Gasolene blend – Combustion Characterstics in engine – emission characterstics

Vegetable oils: Soyabeen Oil, Jatropha, Pongamia, Rice bran, Mahuaetc as alternate fuel and their properties, Esterification of oils

Natural Gas, LPG: Availability of CNG, properties, modification required to use in engines – performance and emission characterstics of CNG using LPG in SI & CI engines.

Hydrogen: Hydrogenproduction, Hydrogen as an alternative fuel, fuel cell

Electric and Solar powered vehicles: Layout of an electric vehicle – advantage and limitations- specificatios –system component – electronic control system – High energy and power density batteries – Hybrid vehicle – solar powered vehicles

Automobile emissions & its control: Need for emission control -Classification/ categories of emissions -Major pollutants - control of emissions – Evaluating vehicle emissions – EURO I,II,III,IV standards – Indian standards

READING:

1. Alternate Fuels Guide BookAuthors:Richard L. Bechhold P.E.Publisher: Society of Automotive Engineers, 1997
2. Hydrogen fuel for surface transportationAuthors: Norbeck, Joseph M.Publisher: Society of Automotive Engineers, 1996
3. History of the Electric Automobiles: Hybrid Electric Vehicles, Authors: Wakefield, Earnest Henry
4. Engine Emissions: Pollutant formation and advances in control TechnologyAuthors: NorbePundir B.R.Publisher:Narosa Publishing House
5. Air Pollution and its Control, Authors: S.C. Bhatia, Publisher: Atlantic Publications, 2007
6. Automotive Fuel and Emission Control systemAuthors: James D. Halderman, James LinderPublisher: Prentice Hall.

ME5163	DESIGN OF HEAT TRANSFER EQUIPMENT	DEC	3-0-0	3 Credits

PREREQUISITES: ME – 5103: Advanced Heat and Mass Transfer

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

CO1	Understand the physics and the mathematical treatment of typical heat exchangers.
CO2	Apply LMTD and Effectiveness methods in the design of heat exchangers and analyze the importance of LMTD approach over AMTD approach.
CO3	Analyze the performance of double-pipe counter flow (hair-pin) heat exchangers.
CO4	Design and analyze the shell and tube heat exchanger.
CO5	Understand the fundamental, physical and mathematical aspects of boiling and condensation.
CO6	Classify cooling towers and explain their technical features.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	-	2	3	-	-	1	-	-	-	1
CO2	3	2	-	2	2	-	-	2	-	-	-	1
CO3	3	2	-	2	2	-	-	2	-	-	-	1
CO4	3	1	-	2	1	-	-	2	-	-	-	1
CO5	3	2	-	1	2	-	-	2	-	-	-	1
CO6	3	1	-	1	2	-	-	1	-	-	-	1

DETAILED SYLLABUS:

Introduction to Heat Exchangers: Definition, Applications, Various methods of classification of heat exchangers with examples

General Back-bone Equation for heat exchangers: Derivation from steady-state steady-flow considerations.

Mathematical treatment of Heat Exchangers: Concept of Overall Heat Transfer Coefficient, Derivation of the concerned equations, Fouling, Fouling Factor, Factors contributing to fouling of a heat exchanger, Ill-Effects of fouling, Numerical Problems

Mathematical treatment of Heat Exchangers: Concept of Overall Heat Transfer Coefficient, Derivation of the concerned equations, Fouling, Fouling Factor, Factors contributing to fouling of a heat exchanger, Ill-Effects of fouling, Numerical Problems

Concept of Logarithmic Mean Temperature Difference: Expression for the same for single-pass parallel-flow and single-pass counter flow heat exchangers – Derivation from first principles, Special Cases, LMTD for a single-pass cross-flow heat exchanger – Nusselt's approach, Chart solutions of Bowman et al. pertaining to LMTD analysis for various kinds of heat exchangers, Numerical Problems on all the above items, Arithmetic Mean Temperature Difference [AMTD], Relation between AMTD and LMTD, Logical Contrast between AMTD and LMTD, LMTD of a single-pass heat exchanger with linearly varying overall heat transfer coefficient [U] along the length of the heat exchanger.

Concept of Effectiveness: Effectiveness-Number of Transfer Units Approach, Derivations of expressions for effectiveness of single-pass parallel-flow and counter-flow heat exchangers, Physical significance of NTU, Heat capacity ratio, Different special cases of the above approach, Chart solutions of Kays and London pertaining to Effectiveness-NTU approach, Numerical Problems on the above.

Hair-Pin Heat Exchangers: Introduction to Counter-flow Double-pipe or Hair-Pin heat exchangers, Industrial versions of the same, Film coefficients in tubes and annuli, Pressure drop, Augmentation of performance of hair-pin heat exchangers, Series and Series-Parallel arrangements of hair-pin heat exchangers, Comprehensive Design Algorithm for hair-pin heat exchangers, Numerical Problems.

Shell and Tube Heat Exchangers: Single-Pass, One shell-Two tube [1S-2T] and other heat exchangers, Industrial versions of the same, Classification and Nomenclature, Baffle arrangement, Types of Baffles, Tube arrangement, Types of tube pitch lay-outs, Shell and Tube side film coefficients, Pressure drop calculations, Numerical Problems.

Principles of Boilers and Condensers: Boiling, Fundamentals and Types of boiling – Pool boiling curve, Various empirical relations pertaining to boiling, Numerical problems on the above, Condensation – Classification and Contrast, Types of condensers, Nusselt's theory on laminar film-wise condensation, Empirical Refinements, Several empirical formulae, Numerical problems on condensation and condensers.

Cooling Towers: Cooling towers – basic principle of evaporative cooling, Psychrometry, fundamentals, Psychrometric chart, Psychrometric Processes, Classification of cooling towers, Numerical problems on cooling towers.

READING:

1. Kays, W. M. and London, A. L., Compact Heat Exchangers, 2nd Edition, McGraw – Hill, New York.
2. Donald Q. Kern: Process Heat Transfer, McGraw – Hill, New York.
3. Incropera, F. P. and De Witt, D. P., Fundamentals of Heat and Mass Transfer, 4th Edition, John Wiley and Sons, New York.

ME5164	ADVANCED COMPUTATIONAL FLUID DYNAMICS	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

COURSE OUTCOMES: At the end of the course the student will be able to:

CO1	Understand the stepwise procedure to completely solve a fluid dynamics problem using computational methods
CO2	Derive the governing equations and understand the behaviour of the equations
CO3	Analyze the consistency, stability and convergence of various discretization schemes for parabolic, elliptic and hyperbolic partial differential equations.
CO4	Analyze variations of SIMPLE schemes for incompressible flows and variations of Flux Splitting algorithms for compressible flows.
CO5.	Analyze various methods of grid generation techniques and application of finite difference and finite volume methods to various thermal problems

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	P10	P11	P12
CO1	3	2	-	3	2	-	1	2	-	-	-	-
CO2	3	2	-	3	2	-	1	2	-	-	-	-
CO3	3	2	-	3	2	-	1	2	-	-	-	-
CO4	3	2	-	3	2	-	1	2	-	-	-	-
CO5	3	2	-	3	2	-	1	2	-	-	-	-

DETAILED SYLLABUS:

Introduction: Revision of pre-requisite courses.

Governing equations of fluid dynamics: The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Turbulence and its modeling: Characteristics of turbulence, Effect of turbulent fluctuations on mean flow, Turbulent flow calculations, Turbulence modeling, Large eddy simulation, Direct Numerical Simulation.

Finite volume method for diffusion problems: Finite volume method for 1-D steady state diffusion, 2-D and 3-D steady state diffusion, Example problems.

Finite volume method for convection-diffusion problems: Steady 1-D convection-diffusion, Conservativeness, Boundedness and Transportiveness, Central, Upwind, Hybrid and Power law schemes, QUICK and TVD schemes.

Pressure - velocity coupling in steady flows: Staggered grid, SIMPLE algorithm, Assembly of a complete method, SIMPLER, SIMPLEC and PISO algorithms, Worked examples of the above algorithms.

Finite volume method for unsteady flows: 1-D unsteady heat conduction, Explicit, Crank-Nicolson and fully implicit schemes, Transient problems with QUICK, SIMPLE schemes.

Implementation of boundary conditions: Inlet, Outlet, and Wall boundary conditions, Pressure boundary condition, Cyclic or Symmetric boundary condition.

Errors and uncertainty in CFD modeling: Errors and uncertainty in CFD, Numerical errors, Input uncertainty, Physical model uncertainty, Verification and validation, Guide lines for best practices in CFD, Reporting and documentation of CFD results.

Unstructured grid generation: Introduction, Domain nodalization, Domain triangulation, Advancing front methos, The Delaunay method, The respective algorithms with examples.

CFD modeling of combustion: Enthalpy of formation, Stoichiometry, Equivalence ratio, Adiabatic flame temperature, Equilibrium and dissociation, governing equations of combusting flows, modeling of a laminar diffusion flame, SCRC model for turbulent combustion.

CFD for radiation heat transfer: Governing equations for radiation heat transfer, Popular radiation calculation techniques using CFD, The Monte Carlo method, The discrete transfer method, Raytracing, The discrete ordinates method.

READING:

1. Versteeg, H. K. and Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd Edition, Pearson, 2010.
2. Tannehill, J. C., Anderson, D. A. and Pletcher, R. H., Computational Fluid Mechanics and Heat Transfer, McGraw Hill, 2002.
3. Blazek, J., Computational Fluid Dynamics: Principles and Applications, 2nd Edition, Elsevier Science & Technology, 2006.
4. Chung, T. J., Computational Fluid Dynamics, Cambridge University Press, 2003.

ME5165	CONVECTIVE HEAT TRANSFER	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

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

CO1	Understand the fundamental and advanced principles of forced and natural convection heat transfer processes.
CO2	Formulate and solve convective heat transfer problems
CO3	Apply the principles of convective heat transfer to estimate the heat dissipation from devices.
CO4	Evaluate the energy requirements for operating a flow system with heat transfer.
CO5	Relate to the current challenges in the field of convective heat transfer.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Introduction: Course structure, Basics of Thermodynamics, Fluid mechanics and Heat transfer

Fundamental Principles: Continuity, momentum and energy equations, Reynolds transport theorem, Second law of TD, Rules of Scale analysis, Concept of Heat line visualization
Laminar forced convection: External flows: Boundary layer concept, velocity and thermal boundary layer, Governing equations, Similarity solutions, various wall heating conditions, Flow over sphere, wedge and stagnation flow

Laminar forced convection: Internal flows: Fully developed laminar flow: Constant heat flux, Constant wall temperature, developing length

External Natural convection: Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Boundary layer equations, Scale analysis, Low and high Prandtl number fluids, vertical walls, horizontal walls, sphere

Internal Natural Convection: Natural convection in enclosures: isothermal and constant heat flux side walls, triangular enclosures, heated from below, inclined enclosures, annular space between horizontal cylinders, mixed convection heat transfer past vertical plate and in enclosures

Turbulent boundary layer flow: Boundary layer equations, mixing length model, flow over single cylinder, cross flow over array of cylinders, Natural convection along vertical walls, Turbulent duct flow

Convection in porous media: Basics of porous media, flow models (Darcy, Brinkmann, Forchheimer and Generalized non-Darcy model)

Mixed convection: Mixed convection in enclosures

READING:

1. Bejan, A., Convection Heat Transfer, John Willey and Sons, New York, 2001.
2. Louis, C. Burmeister, Convective Heat Transfer, John Willey and Sons, New York, 2003.
3. Kays, W.M. and Crawford, M. E., Convective Heat and Mass Transfer, McGraw Hill, New York, 2001.

ME5166	JET AND ROCKET PROPULSION	DEC	3-0-0	3 Credits

PREREQUISITES: None

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

CO1	Understand the applications of jet and rocket propulsion and their energy requirements.
CO2	Identify propellants available and factors influencing their burn rate and performance.
CO3	Classify nozzles and their requirements for the development of thrust and impulse.
CO4	Understand the principles of rocket propulsion, staging and boosting.
CO5	Evaluate burn rate, propulsive power, thrust and energy requirements in ideal cases of propulsion devices.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Motion in Space: Requirement for Orbit: Motion of Bodies in space, Parameters describing motion of bodies, Newton’s Laws of motion, Universal law of gravitational force, Gravitational field, Requirements of motion in space, Geosynchronous and geostationary orbits, Eccentricity and inclination of orbits, Energy and velocity requirements to reach a particular orbit, Escape velocity, Freely falling bodies, Means of providing the required velocities

Theory of Rocket Propulsion: Illustration by example of motion of sled initially at rest, Motion of giant squid in deep seas, Rocket principle and rocket equation, Mass ratio of rocket, Desirable parameters of rocket, Rocket having small propellant mass fraction, Propulsive efficiency of rocket, Performance parameters of rocket, Staging and clustering of rockets, Classification of rockets

Rocket nozzle and Performance: Expansion of gas from a high pressure chamber, Shape of the nozzle, Nozzle area ratio, Performance loss in conical nozzle, Flow separation in nozzles, Contour or bell nozzles, Unconventional nozzles, Mass flow rates and characteristics velocity, Thrust developed by a rocket; Thrust coefficient, Efficiencies, Specific impulse and correlation with C* and CF, General Trends

Chemical Propellants: Small value of molecular mass and specific heat ratio, energy release during combustion of products, Criterion for choices of propellants, Solid propellants, Liquid propellants, Hybrid propellants

Solid Propellants Rockets: Mechanism of burning and burn rate, Choice of index n for stable operation of solid propellant rockets, Propellant grain configuration, Ignition of solid propellant rockets, Pressure decay in chamber after propellant burnout, Action time and burn time, Factors influencing burn rate, Components of a solid propellant rocket

Liquid Propellant Rockets: Propellant feed system, Thrust chamber, Performance and choice of feed system cycle, Turbo pumps, Gas requirements for draining of propellants from storage tanks, Draining under microgravity condition, Trends in development of liquid propellant rockets

Hybrid Rockets: Working principle, Choice of fuels and oxidizer, Future of hybrid rockets

READING:

1. Barrere, M., Rocket Propulsion, EIsevier Pub. Co., 1990.
2. Sutton, G. P., Rocket Propulsion Elements, John Wiley, New York, 1993.
3. Ramamurthi K., Rocket Propulsion, Macmillan Publishers India Ltd., 2010
4. Feedesiev, V. I. and Siniarev, G. B., Introduction to Rocket Technology, Academic Press, New York, 2000.
5. Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Gas Turbine Theory, 6th Edition, Pearson PrenticeHall, 2008.

ME5167	CONJUGATE HEAT TRANSFER	DEC	3-0-0	3 Credits

PREREQUISITES: ME5103: Advanced Heat and Mass Transfer

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

CO1	Understand the principles of view factor calculations, enclosure analysis and radiosity - irradiation methods.
CO2	Apply finite volume and finite difference methods to solve heat transfer problems.
CO3	Interpret and analyze the two-mode heat transfer problems of conjugate convection heat transfer without radiation.
CO4	Formulate mathematical models for three-mode heat transfer problems of conjugate convection heat transfer with radiation.
CO5	Understand conjugate mixed convection without and with radiation.
CO6	Develop computer programs for solving conjugate heat transfer problems.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	-	3	1	-	-	1	-	-	-	1
CO2	3	1	-	3	2	-	-	3	-	-	-	1
CO3	2	2	-	2	2	-	-	3	-	-	-	1
CO4	2	1	-	2	1	-	-	2	-	-	-	1
CO5	2	1	-	1	2	-	-	3	-	-	-	1
CO6	1	1	-	1	1	-	-	3	-	-	-	1

DETAILED SYLLABUS:

Introduction: Definition of conjugate heat transfer, basics, applications in engineering practice and research.

Review of Fundamentals: Review of fundamentals of energy balance approach, view factor calculations, Algebra of view factors, Enclosure Analysis, Radiosity - irradiation methods.

Finite volume and finite difference methods: Principles and Applications of finite volume and finite difference methods, Practice of computer programs for simple problems

Two-mode heat transfer problems: Conjugate convection from different geometries without radiation, Applications in Electronics Cooling and other related appliances.

Three-mode heat transfer problems: Conjugate convection with radiation from various geometries, Applications in Electronics Cooling and other related appliances.

Conjugate mixed convection problems: Problems of the above kind as referred to Gas cooled nuclear reactors, Electronics cooling appliances, and so on.

READING:

1. SadikKakac and YamanYener, Heat Conduction, 2nd Edition, Hemisphere, 2001.

2. Kays, W. M. and Crawford, M. E., Convective Heat and Mass Transfer, 4th Edition, Tata McGraw Hill, 2012.
3. Siegel, R. and Howell, J. R., Thermal-Radiation Heat Transfer, 4th Edition, Taylor & Francis, 2002.
4. Incropera, F. P. and De Witt, D. P., Fundamentals of Heat and Mass Transfer, 5th Edition, John Wiley & Sons, New York, 2006.

ME5168	MEASUREMENTS IN THERMAL ENGINEERING	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

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

CO1	Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation and estimation of uncertainty.
CO2	Describe the working principles in the measurement of field and derived quantities.
CO3	Analyze sensing requirements for measurement of thermo-physical properties, radiation properties of surfaces, and vibration.
CO4	Understand conceptual development of zero, first and second order systems.
CO5	Interpret International Standards of measurements (ITS-90) and identify internationall accepted measuring standards for measurands.

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Basics of Measurements: Introduction, General measurement system, Signal flow diagram of measurement system, Inputs and their methods of correction

Analysis of experimental data: Causes and types of errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis, Statistical analysis of Experimental data.
Sensing Devices : Transducers-LVDT, Capacitive, piezoelectric, photoelectric, photovoltaic, Ionization, Photoconductive, Hall-effect transducers, etc.

Pressure measurement: Different pressure measurement instruments and their comparison, Transient response of pressure transducers, dead-weight tester, low-pressure measurement.

Thermometry: Overview of thermometry, temperature measurement by mechanical, electrical and radiation effects. Pyrometer, Thermocouple compensation, effect of heat transfer.

Flow Measurement: Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, flow measurement by drag effects, pressure probes, other methods.

Thermal and transport property measurement: Measurement of thermal conductivity, diffusivity, viscosity, humidity, gas composition, pH, heat flux, calorimetry, etc.

Nuclear, thermal radiation measurement: Measurement of reflectivity, transmissivity, emissivity, nuclear radiation, neutron detection, etc.Other measurements: Basics in measurement of torque, strain.

Air-Pollution: Air-Pollution standards, general air-sampling techniques, opacity measurement, sulphur dioxide measurement, particulate sampling technique, combustion products measurement.

Advanced topics: Issues in measuring thermo physical properties of micro and Nano fluids.
Design of Experiments: Basic ideas of designing experiments, Experimental design protocols with some examples and DAS

READING:

1. Mechanical Measurements by Thomas G Beckwith, Pearson publications
2. Measurement systems by Ernest O Doebelin, Tata McGraw Hill publications
3. Experimental Methods for Engineers, J P Holman, Tata McGraw Hill publications.

ME5154	ENERGY SYSTEMS LABORATORY	PCC	0-0-3	2 Credits

PRE REQUISITES: None

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

CO1	Perform constant speed and variable speed tests on SI and CI versions of IC engines.
CO2	Determine frictional power of single-cylinder and multi-cylinder CI engines for analyzing its nature of variation.
CO3	Analyze performance of MPFI version of Petrol Engine.
CO4	Correlate the theory and the experimentation pertaining to turbo machines.
CO5	Perform tests on solar energy simulator and fuel cell demonstrator

CO-PO MAPPING:

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

DETAILED SYLLABUS:

Hindustan Petrol Engine: Morse Test on 4-Cylinder Hindustan Petrol Engine.

Perkins CI Diesel Engine: Morse Test on 4-Cylnder Perkins CI Diesel Engine.

MPFI Petrol Engine: Performance Test on MPFI Petrol Engine.

Dual fuel operated Twin-Cylinder Kirloskar CI Diesel Engine: Performance Test on dual fuel operated Twin-Cylinder Kirloskar CI Diesel Engine.

Axial Flow Fan: Constant Speed Performance Test on Axial Flow Fan.

Centrifugal Blower: Constant Speed Performance Test on a Centrifugal Blower.

Solar Energy Simulator: Perform tests on solar energy simulator

Fuel cell Demonstrator: Perform tests on Fuel cell demonstrator

READING:

1. Heywood J.B., Internal Combustion Engine Fundamentals , McGraw Hill Book Company, New York, 1988.
2. Sukhatme S.P., Solar Energy: Principles of Thermal Collection and Storage , Tata McGraw-Hill Education, 2008.
3. Ganesan, V., Fundamentals of IC Engines, Tata McGraw Hill, 2003

ME5155	CFD LABORATORY-II	PCC	0-0-3	2 Credits

PRE-REQUISITES: None

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

CO1	Formulate problems in fluid flow and heat transfer.
CO2	Develop codes for numerical methods to solve 1D and 2D heat conduction and convection problems.
CO3	Use commercial software ANSYS for solving real life engineering problems.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1	-	-	-	-	-	-	-	-	-	1
CO2	1	2	3	3	2	-	2	3	3	-	2	1
CO3	1	2	3	3	2	-	3	3	3	-	3	1

DETAILED SYLLABUS:

Solution of 1D heat conduction problem using TDMA and LU decomposition

Solution of 2D parabolic equations

Explicit
Implicit (ADI)

Grid generation (rectangular and circular)

Introduction to ANSYS FLUENT

ANSYS FLUENT 1 (Laminar pipe Flow)
ANSYS FLUENT 2 (Turbulent Pipe Flow)
ANSYS FLUENT 3 (2D circular Cylinder)
ANSYS FLUENT 4 (2D aerofoil)
ANSYS FLUENT 5(Driven Cavity)

READING:

1. Versteeg, H. K. and Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd Edition, Pearson, 2010.
2. Tannehill, J. C., Anderson, D. A. and Pletcher, R. H., Computational Fluid Mechanics and Heat Transfer, McGraw Hill, 2002.
3. Blazek, J., Computational Fluid Dynamics: Principles and Applications, 2nd Edition, Elsevier Science & Technology, 2006.
4. Chung, T. J., Computational Fluid Dynamics, Cambridge University Press, 2003.

ME5467	CAD FOR THERMAL ENGINEERING	DEC	3-0-0	3 Credits

PRE-REQUISITES: None

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

CO1	Understand geometric transformation techniques in CAD.
CO2	Develop mathematical models to represent curves.
CO3	Design surface models for engineering applications.
CO4	Model engineering components using solid modeling techniques.
CO5	Design and analysis of engineering components.

CO-PO MAPPING:

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	P1O	P11	P12
CO1	-	-	-	2	-	-	1	-	-	-	-	1
CO2	-	-	-	2	-	-	2	-	-	-	-	-
CO3	-	-	-	2	-	-	2	-	-	-	-	-
CO4	-	-	-	2	-	-	2	-	-	-	-	-
CO5	-	-	-	2	3	-	2	2	-	-	1	1

DETAILED SYLLABUS:

Introduction to CAD: Introduction to CAD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modeling.

2D Transformations of geometry: 2D Translation, 2D Scaling, 2D Reflection, 2D Rotation, Homogeneous representation of transformation, Concatenation of transformations.

3D Transformations of geometry and Projections: 3D Translation, 3D Scaling, 3D Reflection, 3D Rotation, Homogeneous representation of transformation, Concatenation of transformations, Perspective, Axonometric projections, Orthographic and Oblique projections.

Design of Curves : Analytic Curves, PC curve, Ferguson, Composite Ferguson, curve Trimming and Blending, Bezier segments, de Castellan's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier, Splines, Polynomial Splines, B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS.

Design of Surfaces : Differential geometry, Parametric representation, Curves on surface, Classification of points, Curvatures, Developable surfaces, Surfaces of revolution, Intersection of surfaces, Surface modeling, 16-point form, Coons patch, B-spline surfaces.

Design of Solids: Solid entities, Boolean operations, B-rep of Solid Modeling, CSG approach of solid modeling, advanced modeling methods.

Data Exchange Formats and CAD Applications: Data exchange formats, Finite element analysis, reverse engineering, modeling with point cloud data, Rapid prototyping.

READING:

1. Ibrahim Zeid and Sivasubramanian, R., CAD/CAM Theory and Practice, Tata McGraw Hill Publications, New Delhi, 2009.
2. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.

ME5191	SEMINAR	PCC	0-0-3	2 Credits

COURSE OUTCOMES:

CO1	Identify and compare technical and practical issues related to the area of course specialization.
CO2	Outline annotated bibliography of research demonstrating scholarly skills.
CO3	Prepare a well organized report employing elements of technical writing and critical thinking
CO4	Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	2	1	1
CO2	2	2	2	2	2	2	2	3	2	2	1	1
CO3	1	1	1	1	1	1	1	3	2	2	1	1
CO4	1	1	1	1	1	1	1	3	2	2	1	1

ME6142	COMPREHENSIVE VIVA – VOCE	PCC	4 Credits

PRE-REQUISITES: None

COURSE OUTCOMES:

CO1	Comprehend the knowledge gained in the course work
CO2	Infer principles of working of thermal energy systems
CO3	Demonstrate the ability in problem solving and to communicate effectively

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	2	2	2	3	3	3	1	1
CO2	2	2	2	2	2	2	2	2	2	2	1	1
CO3	1	1	1	1	1	1	1	1	1	1	1	1

ME6249	DISSERTATION PART – A	PCC	8 Credits

COURSE OUTCOMES:

CO1	Identify a topic in advanced areas of thermal engineering
CO2	Review literature to identify gaps and define objectives & scope of the work
CO3	Employ the ideas from literature and develop research methodology
CO4	Develop a model, experimental set-up and / or computational techniques necessary t meet the objectives.

CO-PO MAPPING:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2	2	2	2	3	2	2	1	1
CO2	1	2	2	2	2	2	2	3	2	2	1	1
CO3	1	2	2	2	2	2	2	2	2	2	1	1
CO4	1	2	3	3	3	3	3	2	2	2	1	1

ME6299	DISSERTATION PART – B	PCC	18 Credits

PRE-REQUISITES: None

COURSE OUTCOMES:

CO1	Identify methods and materials to carry out experiments/develop code
CO2	Reorganize the procedures with a concern for society, environment and ethics
CO3	Analyze and discuss the results to draw valid conclusions
CO4	Prepare a report as per the recommended format and defend the work.
CO5	Explore the possibility of publishing papers in peer reviewed journals/conference proceedings.

CO-PO MAPPING:

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