Thermal Science and Engineering

Subject Name	Code	L-T-P	Credit	Contact Hours
Semester-1				
Advanced Fluid Dynamics	ME6L101	3-1-0	4	4
Computational Methods in Thermo-Fluids Engineering	ME6L102	3-1-0	4	4
Experimental Techniques for Thermo-fluids	New code	3-0-0	3	3
DE 1	Elective	3-0-0	3	3
DE 2	Elective	3-0-0	3	3
Advanced Thermo-fluid Laboratory	New code	0-0-3	2	3
Scientific Computing Laboratory	New code	0-0-3	2	3
Total			21	23
Semester-2				
Advanced Thermodynamics	ME6L105	3-0-0	3	3
Advanced Heat Transfer	ME6L151	3-1-0	4	4
DE 3	Elective	3-0-0	3	3
DE 4	Elective	3-0-0	3	3
Applied Computational Laboratory	New code	0-0-3	2	3
Energy Systems Laboratory	New code	0-0-3	2	3
Total			17	19
Semester-3				
Thesis Part – II	ME6D002		15	
Total			15	
Semester-4				
Thesis Part – III	ME6D003		15	
Total			15	
		Total Credits:	**68**	

***The students may opt for either an open elective or an elective from another department (with the consent of the teaching faculty and the faculty advisor) against any one of the department electives.**

Syllabus

Subject Code: ME6L101 Prerequisites: None	Name: Advanced Fluid Dynamics	L – T – P : 3 – 1 – 0	Credits: 4

Introduction to Tensors & Tensors Equations; Concept of continuum and definition of a fluid. Eulerian and Lagrangian description of flow, streamlines, streaklines, and pathlines; Kinematics of fluids; Fluid statics, kinematics in streamline coordinates; Inviscid flow, Bernoulli equation, unsteady Bernoulli; Control volume theorems and applications; Navier Stokes equation, exact solutions to NS equations; Dimensional analysis, Buckingham Pi theorem, non-dimensionalization of NS equation; Complex viscous dominated flows; Lubrication analysis; Potential flow theory; Boundary layer theory; Introduction to Turbulence

Recommended Books:

1. *Incompressible Flow 3ed* - R. L. Panton – Wiley
2. *Viscous Fluid Flow 3ed* - F. M. White - McGraw-Hill
3. *Boundary Layer Theory 8 Ed* - H. Schlichting& K. Gersten – Springer
4. *An Introduction to Fluid Dynamics* – G. K. Batchelor – Cambridge University Press
5. *Turbulent Flows* – S. B. Pope – Cambridge
6. *Vectors, Tensors and the Basic Equations of Fluid Mechanics* – Rutherford Aris - Dover
7. *Fluid Mechanics with Multimedia DVD, 4ed* - Pijush K. Kundu, Ira M. Cohen – AP / Elsevier
8. *Fundamentals of Fluid Mechanics 6ed* - Bruce R. Munson, Donald F. Young, Theodore H. Okiishi, Wade W. Huebsch - Wiley
9. *Turbulence, An Introduction for Scientists and Engineers* – P. A. Davidson – Oxford
10. *The Structure of Turbulent Shear Flows* – A. A. Townsend

Subject Code: ME6L102 Prerequisites: None	Name: Computational Methods in Thermal & Fluid Engineering	L – T – P : 3 – 1 – 0	Credits: 4

A brief overview of the basic conservation equations for fluid flow and heat transfer, classification of partial differential equations and pertinent physical behaviour, parabolic, elliptic and hyperbolic equations, role of characteristics. Common methods of discretization: an overview of finite difference, finite element and finite volume methods. Numerical solution of parabolic partial differential equations using finite-difference and finite-volume methods: explicit and implicit schemes, consistency, stability and convergence. Numerical solution of systems of linear algebraic equations: general concepts of elimination and iterative methods, Gaussian elimination, LU decomposition, tri-diagonal matrix algorithm, Jacobi and Gauss-Seidel iterations, necessary and sufficient conditions for convergence of iterative schemes. The finite volume method of discretization for diffusion problems: one-dimensional steady diffusion problems, specification of interface diffusivity, source-term linearization. Discretization of transient one-dimensional diffusion problems. Discretization for multi-dimensional diffusion problems. Solution of discretized equations using point and line iterations, strongly implicit methods and pre-conditioned conjugate gradient methods.

Convection-diffusion problems: Central difference, upwind, exponential, hybrid and power-law schemes, concept of false diffusion. Numerical solution of the Navier-Stokes system for incompressible flows: stream-function vorticity and artificial compressibility methods, requirement of a staggered grid. SIMPLE, SIMPLEC and SIMPLER algorithms.Special topics: phase-change problems, interface/free-surface tracking methods.

Recommended Books:

1. *Numerical Heat Transfer and Fluid Flow1ed*, 2004 - Suhas V. Patankar, - Taylor and Francis
2. *Introduction to Computational Fluid Dynamics*: The Finite Volume Method 2ed, 2008 - H. K. Versteeg and W. Malalasekera – Pearson
3. *Computational Fluid Dynamics1ed*, 1995 - D. A. Anderson Jr - McGraw-Hill
4. *Computational Fluid Mechanics and Heat Transfer* - John C. Tannehill, Dale A. Anderson and Richrad H. Pletcher - Taylor and Francis Group, 1997
5. *Introduction to Computational Fluid Dynamics 2005* - Anil W. Date, Cambridge University Press
6. *Computational Fluid Flow and Heat Transfer2ed, 2009* - K. Muralidhar and T. Sundararajan - Narosa
7. *Numerical Solution of Partial Differential Equations: Finite Difference Methods3ed*, 1986 - G. D. Smith - Oxford University Press

Subject Code: New code Prerequisites: None	Name: Experimental Techniques for Thermo-Fluids	L-T-P : 3 – 0 – 0	Credits: 3

Content: Introduction to experimental techniques, Lagrangian and Eulerian flow description. Generalized measurement system, calibration, dynamic characteristics. Zero, first and second order measurement systems, Uncertainty and error analysis. Pressure Measurement, Flow and Velocity Measurement, Hot-wire/Hot-Film & Cold-Wire/Cold-Film Anemometry,
Laser Doppler velocimetry, Full-field (2-D) quantitative imaging techniques like PIV, PLIF, Rayleigh Thermometry, Optical Density Based Techniques – Schlieren, Shadowgraph.
Temperature & Heat flux measurement, Thermocouple, Heat flux gauges, Thermal imaging, Infrared thermography.
Data acquisition, introduction to digital signal processing, filters, post-processing tools.

Recommended Books:

1. Tropea C et al, Springer Handbook of Experimental Fluid Mechanics, Springer
2. R. J. Goldstein, Fluid Mechanics Measurement, Hemisphere publishing
3. Müller U., Roesner K.G., and Schmidt B., Recent Developments in Theoretical and Experimental Fluid Mechanics: Compressible and Incompressible Flows, Springer.
4. Tavoularis S., Measurement in Fluid Mechanics, Cambridge Univ. Press.
5. Panton R.L., Incompressible Flow, Wiley.
6. White F.M., Viscous Fluid Flow, McGraw-Hill

Subject Code: New code Prerequisites: None	Name: Advanced Thermofluid Laboratory	L-T-P : 0 – 0 – 3	Credits: 2

1. To study the cooling characteristics of a Vortex Tube
2. To study the radiation error in temperature measurement
3. To study the thermal performance of a Plate Heat Exchanger/Shell & Tube Heat Exchanger
4. To study the effect of capillary tube length and diameter on COP of a Vapour Compression Refrigeration system
5. To study the cooling characteristics of a flooded evaporator
6. To study the thermal performance of a 2 stage reciprocating air compressor.
7. Measurement of Boundary layer thickness and natural convection phenomena using MZI.
8. Flow visualization,
9. Steady and unsteady pressure measurements,
10. Measurement of velocity and temperature in transitional and turbulent flow fields using Hot-wire/Hot-Film Anemometry,
11. Aerodynamic Experiments in wind Tunnel, Characterization of flows based on coherent structures using PIV and PLIF,
12. Thermocouple calibration,
13. Heat transfer studies using Infrared camera,
14. Qualitative and quantitative estimation of density gradients using Schlieren and Shadowgraph;
15. Spray Characterization Experiments: GDI vs PFI;
16. Flame characterization experiments: Premixed and Non-premixed Flames
17. Thermal characterization of melting and solidification process

Subject Code: **Prerequisites:** **ME6L151**	**Name: Advanced Heat Transfer**	**L-T-P :** **3 – 1 – 0**	**Credits: 4**

Introduction, Differential Heat Conduction Equation (Cartesian, cylindrical, and spherical coordinates); Different boundary conditions, 1D steady state conduction problems with homogeneous and non-homogeneous BCs; Integral solutions of conduction problems; 2D steady state conduction problems with homogeneous and non-homogeneous BCs; Transient conduction with time independent, and time dependent BCs, Duhamel's integral method; Conservation equations for fluid and energy; Laminar boundary layers: Non-dimensional equations, Order Analysis; Laminar external flow, Scale analysis: flow over flat plate(thin and thick BLs), Similarity solutions: flow over flat plate, flow over wedge, von Karman and energy Integral solutions: flow over flat plate (varying temperature BCs); Laminar internal flows; Natural convection; Turbulent thermal boundary layers, Radiation Heat Transfer.

Recommended Books:

1. Heat Conduction, 2nd edition by M.N. Özisik.
2. Conduction Heat Transfer by V.S. Arpaci.
3. Convection Heat Transfer by V.S. Arpaci.
4. A Heat Transfer Textbook, 4th Edition by J.H. Lienhard.
5. Convection Heat Transfer, 3rd Edition by A. Bejan.
6. Thermal Radiation Heat Transfer, Siegel Howell.

Subject Code: ME6L105 Prerequisites: None	Advanced Thermodynamics	L-T-P : 3 – 0 – 0	Credits: 3

Review of basic thermodynamics: Laws of thermodynamics, entropy, entropy balance for closed and open systems. Exergy: Concept of reversible work & irreversibility; Second law efficiency; Exergy change of a system: closed & open systems, exergy transfer by heat, work and mass, exergy destruction, exergy balance in closed & open systems; Exergy analysis of industrial systems â€“ power systems and refrigeration systems. Cycle analysis and optimization: Regenerative reheat Rankine cycle and Brayton cycle, combined cycle power plants, multi-stage refrigeration systems. Thermodynamic optimization of irreversible systems: Finite time thermodynamics principles, optimization studies of various thermal systems, Minimization of entropy generation principle. Properties of Gas Mixtures: Equation of state and properties of ideal gas mixtures; Change in entropy on mixing; Partial molal properties for non-ideal gas mixtures. Thermodynamics of Reactive System: Conditions of equilibrium of a multiphase - multicomponent system; Second law applied to a reactive system; Condition for reaction equilibrium. Statistical-mechanical evaluation of thermodynamic properties of gases, liquids, and solids, Elementary kinetic theory of gases and evaluation of transport properties. Non-Equilibrium Thermodynamics of small scale systems.

Recommended Books:

1. A. Bejan, *Advanced Engineering Thermodynamics*, 3rd edition, John Wiley and sons, 2006.
2. F.W.Sears and G. L. Salinger, *Thermodynamics, Kinetic Theory and Statistical Thermodynamics*, Narosa Publishing House, New Delhi, 3rd edition, 1998.
3. M.J.Moran and H.N.Shapiro, *Fundamentals Of Engineering Thermodynamics*, John Wiley and Sons.
4. M. W. Zemansky and R. H. Dittman, *Heat and Thermodynamics*, McGraw Hill International Editions, 7th edition, 2007.
5. I. K. Puri and K. Annamalai, *Advanced Engineering Thermodynamics*, CRC Press, 2001.

Subject Code: New code **Prerequisites: None**	**Name: Applied Computational Laboratory**	**L-T-P :** **0 – 0 – 3**	**Credits: 2**

Introduction

Introduction to Ansys modules including general steps for solving a problem.

Mesh Generation

Simple Finite Volume structured mesh generation algorithms for 1-D, 2-D and 3-D regular geometries with grid compression/expansion

Mesh generation using an appropriate commercial package (Ansys workbench and ICEM-CFD)

User Defined Function (UDF)

Introduction, UDF framework in Ansys: preparation and procedure for its attachment to the model problem, Global UDF and BC/IC UDF

Thermo-fluid Problems

Solving thermo-fluid problems using Commercial software package/s, such as
2-D heat conduction problem with different boundary and initial conditions
Flow and heat transfer in ducts: Model design in Ansys, Calculation of Nusselt under fully developed condition using Ansys post, and data analysis using Tecplot
Flow and Heat Transfer with Internal Obstacles: Physics-based approach (through UDF), simple geometry-based approach
Dynamic Mesh, Turbulence Modelling, Phase Change Problems: S/L Phase change model using Ansys, Species Transport Problems

Subject Code: New code Prerequisites: None	Name: Energy Systems Laboratory	L-T-P : 0 – 0 – 3	Credits: 2

Solar based Energy System

1. Solar thermal energy storage system (SHTES and LHTES (Single / Cascade / Concentric)) connected to flat plate collectors.
2. Solar thermal energy storage system (SHTES and LHTES (Single / Cascade / Concentric)) connected to a parabolic trough collector

Wind based Energy System

1. Design and Performance Analysis of Wind Turbines
2. Design and Integration of Wind and Solar PV hybrid system

Advanced Energy System

1. Characterization of Fuel Cell.
2. COP of Thermoelectric refrigeration system
3. Dual Fuel Combustion System
4. Batteries (Performance Testing)

Conventional Energy System

1. IC Engine
2. Gas Turbine
3. Vapour Absorption Refrigeration