DEPARTMENT OF MECHANICAL ENGINEERING

COURSE STRUCTURE
&
DETAILED SYLLABUS
For
M.TECH

SPECIALIZATION

IN

HEAT POWER ENGINEERING

(Effective from 2016-17)

VEER SURENDRA SAI UNIVESITY OF TECHNOLOGY
BURLA, SAMBALPUR
PIN-768018

VEER SURENDRA SAI UNIVESITY OF TECHNOLOGY, BURLA
COURSE STRUCTURE FOR 2-YEARS M.Tech. DEGREE COURSE in
MECHANICAL ENGINEERING ON HEAT POWER ENGINEERING SPECIALISATION

TO BE EFFECTIVE FROM (2016-17)

Code	1ST Year (First Semester)	L-T-P	CR	1ST Year (Second Semester)	L-T-P	CR
MME2121	Advanced Engineering Thermodynamics	4-0-0	4	Convective Heat and Mass Transfer	4-0-0	4
MME2122	Conduction and Radiation Heat Transfer	4-0-0	4	Computational Heat and fluid flow	4-0-0	4
MME2128	Advanced Fluid Mechanics	4-0-0	4	Experimental Techniques for Thermal Engineering	4-0-0	4
	Elective-I	4-0-0	4	Elective-III	4-0-0	4
	Elective-II	4-0-0	4	Elective-IV	4-0-0	4
Sessional				**Sessional**		
MME2191	Engg. Software Lab-I	0-0-3	2	Engg. Software Lab-II	0-0-3	2
MME2172	Heat Power Lab	0-0-3	2	Heat Transfer Lab	0-0-3	2
MME2173	Seminar-I	0-0-3	2	Seminar-II	0-0-3	2
MME2174	Comprehensive Viva-voce-I		2	Comprehensive Viva-voce-II		2
Total		**20-0-9**	**28**	**Total**	**20-0-9**	**28**

2nd Year (Third Semester)			2nd Year (Fourth Semester)		
DissertationInterim Evaluation		10	Dissertation Open Defence		5
Comprehensive Viva-voce		3	Dissertation evaluation		20
Seminar on Dissertation		2			
Total		**15**	**Total**		**25**

Elective Subjects

Elective-I & Elective-II	Elective-III & Elective-IV
1. Cryogenics Technology	1. Air Conditioning Engineering
2. Solar Engineering	2. Thermal system Simulation and design
3. Gas Dynamics	3. Microfluidics
4. Finite Element Method	4. I.C.Engines
5. Refrigeration Engineering	5. Two Phase Flow

ADVANCE ENGINEERING THERMODYNAMICS

Course Objectives:

- The course introduces advance concepts in thermodynamics.
- It is an extension to the introductorytheory of energy analysis.
- Strong emphasis on the concepts of availability and irreversibility

Course Contents:

MODULE – 1 **(10 Hours)**

Recapitulations of fundamentals, Analysis of simple closed and open systems, Properties of Pure substance, First law of Thermodynamics applied to closed systems, First law applied to steady flow processes, Analysis of variable flow process, Second law of Thermodynamics, Entropy: Entropy generation, Relationship between entropy generation and viscous dissipation, Entropy balance for closed and open systems.

MODULE – 2 **(12 Hours)**

Exergy: Concept of reverible work and Irreversibility, Second law efficiency, Exergy change of a system: Closed and open systems, Exergy transfer by heat, work and mass, Irreversibility and GouyStodola theorem, Application of GouyStodola Theorem, Exergy destruction, Exergy balance in closed and open systems.

MODULE - 3 **(08 Hours)**

Properties of gas mixtures: equation of state and properties of ideal gas mixtures, Change in entropy of mixing, Real gases, Generalized compressibility charts, General conditions for Thermodynamic equilibrium, Criterion for equilibrium under various conditions of isolation.

MODULE – 4 **(10 Hours)**

Chemical equilibrium: Concept of fugacity and activity, Thermodynamic of reactive systems, stoicheometry, Enthalpy of formation and Enthalpy of combustion, First and Second Law analysis of chemical reactions,

Text books:

1. Fundamentals of Engineering Thermodynamics (7th Edition) by Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner, Margaret B. Bailey, Wiley Publication.
2. Fundamentals of Thermodynamics (6th Edition)by Richard E. Sonntag, Claus Borgnakke, Gordon J. Van Wylen, Wiley Publication

Course Outcomes:

- Apply first and second law analysis on thermal systems.
- Find the stoichiometic ratio for complete combustion of fuels.

CONDUCTION AND RADIATION HEAT TRANSFER

Course Objectives:

- Impart knowledge on steady and transient Conduction
- Study on phase change problems
- Radiation in transparent and participating medium in different enclosure

Course Contents:

MODULE 1: (10Hours)

Introduction to conduction**:** Derivation of energy equation for conduction in three dimensions – Initial and boundary conditions.

Solution of simple problems in steady state conduction with analytical solutions – Concept of electrical analogy – fin heat transfer and concept of fin efficiency and fin effectiveness.

Unsteady conduction: Concept of Biot number – Lumped capacitance formulation – simple problems – unsteady conduction from a semi-infinite solid- solution by similarity transformation method. Solution of the general 1D unsteady problem by separation of variables and charts.

MODULE 2: (8 Hours)

2D steady conduction and phase change problems: Laplace equation – solution by variable separable method – concept of superposition and homogeneous boundary conditions.

Phase change problems – The Stefan and Neumann problems – analytical solutions.

MODULE 3: (15 Hours)

Importance of radiation, Mechanism of radiation, Electromagnetic spectrum, Concept of black body, derivation of black body radiation laws from first principles – Planck's law, Stefan Boltzmann law, Wien's displacement law, Universal black body function, F function charts. Radiative properties of non-black surfaces**:** Spectral directional emissivity, definition of total and hemispherical quantities, hemispherical total emissivity. Spectral directional absorptivity, Kirchoff law, directional and hemispherical absorptivity, hemispherical total absorptivity, View factors.

MODULE 4: **(7 Hours)**

Enclosure with Transparent Medium – Enclosure analysis for diffuse-gray surfaces and non-diffuse, non-gray surfaces, net radiation method.

Enclosure with Participating Medium - Radiation in absorbing, emitting and scattering media. Absorption, scattering and extinction coefficients, Radiative transfer equation

Text Books:

1. Conduction Heat Transfer, D. Poulikakos, Prentice Hall, 1994.
2. Thermal Radiation Heat Transfer, R. Siegel and J. R. Howell, Taylor & Francis, 2002.

Reference Books:

1. Heat Conduction, S. Kakac and Y. Yener, Taylor and Francis, 1994.
2. Conduction Heat Transfer, V.S. Arpaci, Addison Wesley, 1996 (Abridged edition Ginn press 1998)
3. Heat Transfer, A.J.Chapman, Macmillan, 1984.

Course Outcomes:

- Ability to apply the knowledge in analyzing the heat transfer performance for thermal systems
- Analytical and numerical analysis with respect to conduction and radiation for different geometry

ADVANCE FLUID MECHANICS

Course Objectives:

- Derive continuity, momentum and energy equations of fluid flow.
- Learn concept of Irrotational flows, flow past cylinders and rankine body.
- Concepts of boundary layer, prandtl mixing length, turbulent theory, universal velocity profile

Course Contents:

MODULE 1:

Concept of continuum and definition of a fluid. Body and surface forces, stress tensor, principle of local stress equilibrium. Scalar and vector fields, Eulerian and Lagrangian description of flow. Motion of fluid element: translation, rotation and deformation; vorticity and strain-rate tensors. Continuity equation, Cauchy's equations of motion, Transport theorems. Constitutive equations- Stokes law of viscosity. Derivation of N-S equations for compressible flow **(12 Hours)**

MODULE 2:

Exact solutions of Navier-Stokes equations: plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between twoconcentric rotating cylinders, Stokes first and second problems, Hiemenz stagnation-point flow, flow near a rotating disk, flow in convergent-divergent channels. Slow viscous flow: Stokes and Oseens approximation, theory of hydrodynamic lubrication. **(10 Hours)**

MODULE 3:

Boundary layer: Derivation, exact solutions, Blasius, Falkner Skan series solution and numerical solutions. Approximate methods. Momentum integral method. Introduction to hydrodynamic stability, Orr-Sommerfeld equation, neutral curve of linear stability for plane Poiseuille flow

(10 Hours)

MODULE 4:

Description of turbulent flow, velocity correlations, Reynolds stresses. Equations for turbulence kinetic energy and kinetic energy of mean flow. Eddy viscosity models of turbulence: zero equation, one-equation and two-equation models. Prandtls Mixing Length Theory. Empirical laws: law of the wall, velocity defect law, universal velocity distribution. **(08 Hours)**

Text Book:

1. Fluid Mechanics, R.N. Fox and A.T McDonald, (John Wiley & Sons)
2. Fluid Mechanics, P.K. Kundu, I.M. Kohen & D.R. Dowling, Academic Press

Reference Books:

1. Incompressible flow by R L Panton(John Wiley & Sons)
2. Viscous Fluid Flow by Frank M White (McGraw-Hill)
3. An Introduction to Fluid Dynamics by G K Batchelor (Cambridge University Press)
4. Viscous Fluid Flow by Frank M White (McGraw-Hill)
5. Boundary Layer Theory by H Sctllichting (McGraw-Hill)

Course Outcomes:

- Ability to apply continuity equation to solve numerical flow problems
- Apply momentum equation to determine velocity distribution in the fluid flow
- Analyze flow using boundary layer theory

CRYOGENIC TECHNOLOGY

Course Objectives:

- Impart knowledge on information concerning low temperature process and technique
- Study gas separation and purification system
- Measurement system for low temperature

Course Contents:

MODULE-1: Introduction; Low temperature properties,Mechanical , Thermal , Electric and Magnetic Properties , Properties of cryogenic fluids**(06 Hours)**

MODULE-2: Gas liquificationsystems ; simple Linde – hompson system , precooled Lindehompson systems for Ne, H_2 , He ; Collins Helium liquefaction systems , critical components of liquefaction systems .**(10 Hours)**

MODULE-3: Gas separation and purification systems ; properties of mixtures . principle of gas separation ,i.e , simple condensation of evaporation , rectification . Air separation systems, Argon separation systems , Helium separation systems .Gas purification methods, Cryogenic refrigeration systems (Liquid and gas as refrigerant); Joule Thomson refrigeration systems, cascade or precooled Joule –Thomson refrigeration systems , cold gas refrigeration system .(solid as working media) ; Magnetic cooling , its thermodynamics aspect . Magnetic refrigeration system , thermal valves , nuclear demagnetization**(15 Hours)**

MODULE-4: Measurement system for low temperature ; Temperature , pressure flow rate , Applications ; super conducting Bearings , motors , cryotrons , chemical rockets, space simulation , nuclear rockets , Blood and tissue preservation .**(09 Hours)**

Text Books:

Cryogenics by R. Barron (Mc- Graw Hill Publishing Company Ltd.)

Course Outcomes:

- Ability to apply properties of material at low temperature. Pressure, temperature, flow, fluidquality and liquid level measurement at low temperature.
- Different types of cryogenic insulations. Different cryogenic applications. Low temperaturehazards

SOLAR ENGINEERING

Course Objectives:

- To impart knowledge on the solar energies
- To impart knowledge different types of solar cooling and dehumidification systems
- To expose the students towards the current developments in solar technologies.

Course Contents:

MODULE 1: Solar passive heating and cooling (10 Hours)

Thermal comfort - Heat transmission in buildings - Bioclimatic classification. Passive heating concepts - Direct heat gain, indirect heat gain, isolated gain and sunspaces. Passive cooling concepts - Evaporative cooling, radiative cooling, application of wind, water and earth for cooling, roof cooling, earth air-tunnel. Energy efficient landscape design - Concept of solar temperature and its significance, calculation of instantaneous heat gain through building envelope.

MODULE 2: Solar liquid and air heating system (10 Hours)

Flat plate collector – Liquid and air heating - Evacuated tubular collectors - Overall heat loss coefficient, heat capacity effect - Thermal analysis. Design of solar water heating systems, with natural and pump circulation. Solar dryers and applications. Thermal energy storage systems.

MODULE 3: Solar cooling and dehumidification (10 Hours)

Solar thermo-mechanical refrigeration system – Carnot refrigeration cycle, solar electric compression air conditioning, simple Rankine cycle air conditioning system. Absorption refrigeration – Thermodynamic analysis –Energy and mass balance of Lithium bromide-water absorption system, Aqua-ammonia absorption system, Calculations of HCOP and second law efficiency. Solar desiccant dehumidification.

MODULE 4: Solar thermal applications (10 Hours)

Solar systems for process heat production - Solar cooking – Performance and testing of solar cookers. Seawater desalination – Methods, solar still and performance calculations. Solar pond - Solar greenhouse.

Text Books:

1. Kalogirou S.A., "Solar Energy Engineering: Processes and Systems", Academic Press, 2009.

2. Goswami D.Y., Kreith F., Kreider J.F., "Principles of Solar Engineering", 2nd ed., Taylor and Francis, 2000, Indian reprint, 2003.

Reference books:

1. Duffie J. A, Beckman W. A., "Solar Engineering of Thermal Process", Wiley, 3rd ed. 2006.

2. Khartchenko N.V., "Green Power: Eco-Friendly Energy Engineering", Tech Books, Delhi, 2004.

3. Garg H.P., Prakash J., "Solar Energy Fundamentals and Applications", Tata McGraw-Hill, 2005.

Course Outcomes:

- Ability to recognize the need of solar energy sources for the present day energy crisis
- Employ solar energy technology in a given situation.
- Work for the future development of solar energy technologies.

GAS DYNAMICS

Course Objectives:

- To impart knowledge on concepts for the compressible flow of gases
- Study of conservation laws, normal and oblique shock waves and applications
- Study of Prandtl-Meyer flow and simple flows such as Fanno flow and Rayleigh flow with applications

Course Contents:

MODULE 1: (6 Hours)

Fundamental Aspects of Gas Dynamics: Introduction, Isentropic flow in a stream tube, speed of sound, Mach waves .One dimensional Isentropic Flow: Governing equations, stagnation conditions, critical conditions, maximum discharge velocity, isentropic relations

MODULE 2: (10 Hours)

Normal Shock Waves: Shock waves, stationary normal shock waves, normal shock wave relations in terms of Mach number, Oblique Shock Waves: Oblique shock wave relations, reflection of oblique shock waves, interaction of oblique shock waves, conical shock waves Expansion Waves: Prandtl-Meyer flow, reflection and interaction of expansion waves, flow over bodies involving shock and expansion waves

MODULE 3: (12 Hours)

Variable Area Flow: Equations for variable area flow, operating characteristics of nozzles, convergent-divergent supersonic diffusers; Adaiabatic Flow in a Duct with Friction: Flow in a constant area duct, friction factor variations, the Fanno line, Flow with Heat addition or removal: One-dimensional flow in a constant area duct neglecting viscosity, variable area flow with heat addition, one-dimensional constant area flow with both heat exchanger and friction

MODULE 4: (12 Hours)

Generalized Quasi-One-Dimensional Flow: Governing equations and influence coefficients, solution procedure for generalized flow with and without sonic point, Two-Dimensional Compressible Flow: Governing equations, vorticity considerations, the velocity potential, linearized solutions, linearized subsonic flow, linearized supersonic flow, method of characteristics

Text Books:

1. F. M. White, Viscous Fluid Flow. 2nd ed. New York: McGraw-Hill, 1991.

2. A.H. Shapiro, Compressible Fluid Flow 1 and 2. Hoboken NJ: John Wiley.

Reference Books:

1. L. D. Landau and E. M. Lifshitz, Fluid Mechanics. 2nd ed., Butterworth-Heinemann, 1995.

2. H. W. Liepmann, and A. Roshko, Elements of Gas Dynamics, Dover Pub, 2001.

3. P. H. Oosthuizen and W. E. Carscallen, Compressible Fluid Flow, NY, McGraw-Hill, 1997.

Course Outcomes:

- Formulate and solve problems in one -dimensional steady compressible flow

- Gain knowledge about main properties which are used for analyzing or modeling of compressible flow.

FINITE ELEMENT METHOD

Course Objectives:

- To impart knowledgeon fundamental concepts of the theory of the finite element method
- Study of solution of Linear equations, automatic mesh generation

Course Contents:

MODULE -1: Fundamental Concept: Strain displacement relation , stress- strain relation . Plane stress, Plane strain problem minimization of total potential energy **(8 Hours)**

MODULE-2: Concept of an Element; Displacement model , Shape functions for one Dimensional and two Dimensional problems , Constant strain Triangle . Iso parametric representation, Generalized co-ordinates, Element stiffness Matrix: Assembly procedure, Treatment of Boundary condition. Elimination approach,Penalty approach, some practical application.**(12 Hours)**

MODULE-3: Solution of Linear Equations: Gauss Elimination Method, Gauss seidelmethod . Convergence criteria.Scalar field problems: Variation formulation, Application to steady stae heat transfer in one and two dimension , simple problem on fluid flow, steam function formulation**(10 Hours)**

MODULE-4: Computer method and Computer programmes, Automatic mesh generation, Data input, stiffness generation, solution of equations.**(10 Hours)**

TextBooks:

1. Abel and Desai: Introduction to finite element method (EWPPublications)

2. Chandrupatla and Belegundu; Introduction to finite elements in Engineering (PHIPublications)

Course Outcomes:

- Ability to obtain an understanding of the fundamental theory of the FEA method;
- To develop the ability to generate the governing FE equations for thermal systems
- To understand the application of the FE method for heat transfer and fluid flow problems

REFRIGERATION ENGINEERING

Course Objectives:

- To impart knowledge on refrigeration systems
- Understand vapour compression refrigeration and vapour absorption system
- Applications of refrigeration system

Course Contents:

MODULE-1

I. **Thermodynamic properties of pure and mixed refrigerants and their Selection**:Recapitulation of thermodynamics of refrigeration systems, Refrigerants: Introduction, Desirable properties of an Ideal Refrigerant, Physical, Chemical & thermodynamic properties of a refrigerant, Classification of Refrigerants: Primary & Secondary, Designation System of Refrigerants, Properties of Refrigerants, Uses of Important Refrigerants, Secondary Refrigerants – Brine**(5 Hours)**

II. **Vapour compression Refrigeration system**: Analysis of Theoretical vapour Compression cycle, Types of vapour Compression cycles, Representation of the cycle on P-H, T-S and P-V diagrams, Simple Saturation Cycle, Sub-cooled cycles and superheated cycle, Effect of suction and discharge pressure on performance. Actual Vapour compression Cycle, Use of flash coolers, Advantages and disadvantages of Vapour Compression Systems **(6 Hours)**

III. **Multistage compression systems**: Introduction, Methods of improving COP – Optimum Interstage, Pressure for Two-Stage Refrigeration System, Single load systems, Multi load systems with single Compressor, Multiple Evaporator and Compressor systems, Dual Compression systems **(5 Hours)**

MODULE-2

IV. **Vapour Absorption Refrigeration system**: Introduction, simple vapour Absorption system, Practical Vapour Absorption System, Advantages of Vapour Absorption sytem over vapour compression system. Coefficient of Performance of an Ideal Vapour Absorption Refrigeration System. Electrolux (Ammonia-Hydrogen) Refrigerator, Lithium Bromide Absorption Refrigeration System**(5 Hours)**

V. **Ejector refrigeration systems**: Principle and working, Advantages & disadvantage over existing systems, Alternative ejector types, Rotodynamic ejectors **(2 Hours)**

VI. **Vortex tubes:** Principle of working, Components, Phenomenon of energy transfer in vortex tubes, Analysis of temperature drop, adiabatic efficiency and COP, Advantages & applications **(2 Hours)**

MODULE-3

VII. **Principle of liquefaction of gases:** Isentropic expansion, Free, Irreversible expansion, Joule Thompson co-efficient, Inversion temperature, Linde-Hampson System for liquefaction of air, hydrogen & helium, Low temperature applications **(5 Hours)**

VIII. Solid ice production: Solid Carbon-dioxide as a refrigerant, Advantages & disadvantages, Manufacture of Solid Carbon-dioxide or dry Ice, , Use of water and flash intercooler for dry ice production **(3 Hours)**

IX. Expansion devices - Capillary tubes, Automatic and thermostatic expansion valves , Design of capillary tubes **(3 Hours)**

X. Thermal Design of evaporators & Condensers, Magnetic refrigeration systems , Analysis and thermal design of reciprocating centrifugal and screw compressors, Computer simulation of refrigerant compressors **(4 Hours)**

Textbooks:

1. C.P. Arora, Refrigeration & Air conditioning (TMH Publication)
2. Domkundwar&Arrora: Refrigeration & Air conditioning (Dhanpat Rai & Sons)

Reference Books:

1. Stoecker and Zones: Refrigeration & Air conditioning (Mc Graw Hill)
2. Monohar Prasad: Refrigeration & Air conditioning (EWP)
3. A text book of Refrigeration and Air-conditioning by R.S. Khurmi and J.K. Jai, S.Chand& Co.

Course Outcomes:

- Ability to Understand various refrigeration systems
- Demonstrate the working of refrigeration equipments
- Explain the refrigeration system equipment

CONVECTIVE HEAT AND MASS TRANSFER

Course Objectives:

- To impart knowledge on convection heat transfer.
- Study of turbulent flow and heat transfer.
- Study the principles of mass convection, boiling and condensation heat transfer

Course Contents:

MODULE 1:

Introduction: Convective heat transfer and its applications; Forced, free and mixed convection; internal and external flow; heat transfer coefficient and its physical significance; dimensional analysis in convective heat transfer. Mass, momentum, and energy equations. **(03 Hours)**

External Laminar Forced Convection: Boundary layer equations; energy equation for flow over flat plate; similarity solution for flow over a flat plate having various boundary conditions and Prandtl numbers; Scale analysis; Approximate method; Viscous dissipation effect of laminar boundary layer. **(10 Hours)**

MODULE 2:

Internal Laminar Forced Convection: Developing and developed flow and heat transfer in a duct and circular pipe under constant heat flux and constant wall temperature conditions.Steady forced convection in Hagen Poiseuille flow, Plane Poiseuille flow, and Couette flow and analytical evaluation of Nusselt numbers in limiting cases. **(08 Hours)**

Free and mixed convection: Boussinesq approximations, Free convection boundary layer equations: scale analysis, similarity solutions, Concept of thermal stability and Rayleigh Bernard convection, mixed convection and the corresponding governing equations. **(04 Hours)**

MODULE 3:

Turbulent Flow and Heat Transfer: Characteristics of turbulent flow and heat transfer; Reynolds stress N-S and energy equations, eddy viscosity based turbulence models, turbulent flow over flat plate (external), turbulent flow in pipe. **(04 Hours)**

Mass Convection: Various non-dimensional numbers and their analogy to those of heat transfer; Analogy friction, heat transfer and mass transfer coefficients; species equations; Examples of simultaneous heat and mass transfer. **(03 Hours)**

MODULE 4:

Boiling and Condensation Heat Transfer: Pool boiling regimes and the boiling curve; heat transfer correlations in pool boiling; flow boiling and its regimes, Condensation from vertical flat plate, multiple horizontal and vertical tubes. **(08 Hours)**

Text Book:

1. Convective Heat Transfer by Adrian Bejan (John Wiley and Sons)

Reference Books:

1. Introduction to Convective Heat Transfer Analysis by Patrick H. Oosthuizen and David Naylor (McGraw-Hill)
2. Convective Heat and Mass Transfer by Kays, Crawford and Weigand (4th Edition, McGraw-Hill)
3. Convective Heat Transfer by L. C. Burmeister (John Wiley and Sons)
4. Convective Heat Transfer by M Favre-Marinet and S Tardu (John Wiley and Sons)
5. Principles of Convective Heat Transfer by MassoudKaviany (2nd Edition, Springer)
6. Convective Heat Transfer by I. Pop and D. B. Ingham (Pergamon)
7. Heat Convection by Latif M Jiji (Springer)
8. Viscous Fluid Flow by Frank M White (McGraw-Hill)
9. Boundary Layer Theory by H Sctllichting (McGraw-Hill)

Course Outcomes:

- Ability to apply the knowledge in analyzing the heat transfer performance due to convective heat transferin thermal system

COMPUTATIONAL HEAT AND FLUID FLOW

Course Objectives:

- Impart knowledge on numerical simulation of heat and fluid flow problems
- Emphasis is put on learning the practical use of numerical methods
- To interpret the meaning of the numerical results in heat and fluid flow

Course Contents:

MODULE 1:

Model Equations – Wave equations - Numerical solution of parabolic equations – Stability Analysis – Advanced shock capturing schemes. Solutions of convection - Diffusion equation – Conservative and non-conservative schemes – concept of artificial viscosity and Numerical Diffusion. **(10 Hours)**

MODULE 2:

Brief Overview of Solution of Navier-Stokes and Scalar Transport Equations on Staggered Grid. Non-Staggered Grid Layout and Appreciation of Associated Problems. Evaluation of Cell-Face Velocities and Pressure. Solution of Navier-Stokes and Scalar Transport Equations on Non-Staggered Grid. Derivation of Appropriate Pressure Correction Equation on Non-Staggered Grid. Introduction to Numerical Grid Generation. Algebraic, Elliptic and Hyperbolic Grid Generation Methods. **(15 Hours)**

MODULE 3:

Derivation of Navier-Stokes and Scalar Transport Equations on Generalised Curvilinear Coordinates. Expressions of Base Vectors and Unit Vectors, Covariant and Contra-variant velocities, Gradient and Divergence of variables. **(10 Hours)**

Methods for Solving Phase Change and Two-Phase Flow Problems. Enthalpy-Porosity Formulation, Volume of Fluid (VOF) Methods. **(05 Hours)**

Text Books:

1. Tannehill, J.C., Anderson, D.A., and Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, 2nd ed., Taylor & Francis, 1997.

Reference Books:

1. Hoffmann, K.A. and Chiang, S.T., Computational Fluid Dynamics for Engineers, Engineering Education Systems, 2000.
2. Peyret, R. and Taylor, T. D., Computational Methods for Fluid Flow, Springer-Verlag, 1983.

Course Outcomes:

- Gain Knowledge on classification of the basic equations for fluid mechanics and heat transfer
- Apply Finite volume methods for heat transfer and fluid flow in one and more dimensions

- Ability to simulate and analyze two phase fluid flow

EXPERIMENTAL TECHNIQUES FOR THERMAL ENGINEERING

Course Objectives:

- Impart knowledge on basic concept of engineering experimentation.
- Study Measurement of temperature, pressure,velocity and flow rate.
- Study measurement of concentration & humidity of thermal system.

Course Contents:

MODULE-1

Measurement: Introduction, Basic concepts of measurement methods, single and multi-point measurement in space and time, Processing of experimental data, Process of Measurement, Methods of measurement, Types of measuring instruments, Scale Range & Scale span, Static Calibration, Error Calibration Curve, Static & Dynamic characteristics of measurement, Accuracy, Sensitivity, Reproducibility, Repeatability, Drift, Static error, Dead zone, Error analysis and estimation, Types of errors, Random error, Systematic error, True value, Absolute error, Relative static error ,Curve fitting, Regression analysis, Analog and Digital instruments, Noise, Signal to Noise ratio, various sources of Noise **(14 Hours)**

MODULE-2

Measurement of temperature: Thermocouple, analysis of effect of bead size and shielding on time constant and frequency response characteristics of thermocouples, Errors due to conduction and radiation in well type thermocouple, thermocouple installations, resistance and resonant quartz thermometer, Pyrometry, Low temperature measurement, Measurement of heat flux and thermal conductivity. **(10 Hours)**

MODULE-3

Measurement of pressure: Very low pressure measurement, Pirani gauge, McLeod Gauge, and other gauges **(5 Hours)**

Measurement of flow rate and velocity: Principle and theory of Rotameter, Venturi-meter, Nozzle, Orifice meter, Hot wire anemometer, Non-intrustive measurement. Gas-flow meter. **(6 Hours)**

MODULE-4

Principle and theory of measurement of concentration & humidity: Chromatography, Calorimetry **(2 Hours)**

Optical techniques: Shadograph, Schliren Technique, Interferometer **(3 Hours)**

Textbooks:

1. Mechanical Measurement by R.S. Sirohi, S.C. Radhakrishna (Wiley,1993)

2. Mechanical Measurements and Instrumentation by R.K.Rajput (S.K.Kataria& Sons, 2009)

Reference Books:

1. J.P.Holman, Mechanical Measurements (Mc Graw Hill – 1989)
2. E.O. Doeblin, Mechanical Measurements (Int. Edition, 1983)

Course Outcomes:

- Ability to understand the basic concept of engineering experimentation.
- Acknowledge, access and analysis various experimental techniques.
- Carry out Error and uncertainty analysis of thermal system.

AIR-CONDITIONING ENGINEERING

Course Objectives:

- Impart knowledge on Air-conditioning systems
- Psychrometry concepts and applications of air-conditioning systems.
- Study of air distribution systems

Course Contents:

MODULE-1 **(12 Hours)**

Psychometry: Definition, Psychometric terms, Degree of saturation, Humidity, Absolute Humidity, Relative humidity, dry bulb temperature, wet bulb temperature, wet bulb depression, Dew point temperature, Dew point depression, Dalton's law of Partial pressure, Psychometric Relations, Humidity ratio, Psychometer, Psychometric chart, Psychometric Processes, Sensible heating, Sensible cooling, By-pass factor of heating and cooling coils, Dehumidification and humidification , Methods of humidification and dehumidification

MODULE-2 **(08 Hours)**

Air-conditioning systems: Introduction, Air conditioning system and equipments used in air-conditioning system, Various types of air-conditioning systems, Comfort Air-conditioning, Factors affecting effective optimum temperature, Factors affecting comfort air-conditioning, Room Sensible heat factor and Grand sensible heat factor

MODULE-3 **(10 Hours)**

Cooling Load estimation: Air-conditioning calculations, Comfort scales and measures concepts of effective temperatures, Solar heat gains through gains through glass, buildings, heat storage, diversity and stratification, Internal heat gains: Sensible heat, Latent heat, Cooling towers, spray chambers, Cooling and humidifying coils, Design of air-duct system, Room air distribution principles, Temperature, pressure and humidity controls, Various types of system controls, Building automation systems.

MODULE-4 **(10 Hours)**

Ducts: Introduction, Classification, Material of duct, construction, shape, pressure in ducts, Continuity equation and Bernoulli's equation for ducts, Pressure losses inducts: Frictional losses & Dynamic losses, Duct design, pressure loss due to enlargement in area and static regain

Textbooks:

1. C. P. Arora, Ref & Air Conditioning (TMH Publication)
2. A text book of Refrigeration and Air-conditioning by R.S. Khurmi and J.K. Jai, S.Chand& Co.

Reference Books:

1. Stoecker and Zones: Refrigeration and Air Conditioning (Mc Graw Hill)
2. Manohar Prasad: Refrigeration and Air Conditioning (EWP)
3. W.P. Zones: Air Conditioning Engg. (Edward Arnold Press)

Course Outcomes:

- Ability to apply thermodynamic principles to various air-conditioning system
- Design of air-conditioning systems
- Analyze fan and duct system

THERMAL SYSTEM SIMULATION AND DESIGN

Course Objectives:

- To impart knowledge on thermal system simulation and optimization methods for design
- Study of optimization methods such as integer programming and linear programming

Course Contents:

MODULE 1:

Formulation of the design problem: design variables, constraints and limitations, requirements and specifications; Conceptual design, Steps in the design process (examples from thermal systems), Material selection. **(06 Hours)**

Modeling of thermal systems: types of models, mathematical modeling, physical modeling and dimensional analysis, curve fitting. **(06 Hours)**

Acceptable design of a thermal system: initial design, design strategies, some application illustrations (cooling of electronic equipment, heat transfer equipment, fluid flow systems etc.). **(06 Hours)**

MODULE 2:

Problem formulation for optimization: optimization in design, final optimized design, objective function, constraints, operating conditions, types of thermal systems, practical aspects in optimal design (choice of variables for optimization, sensitivity analysis, dependence on objective function and change of concept or model), Knowledge-based design and additional considerations, professional ethics. **(10 Hours)**

Optimization of unconstrained problems, optimization of constrained problems, applicability to thermal systems, search methods (single variable problem, unconstrained search with multiple variables and multivariable constrained optimization). **(06 Hours)**

MODULE 3:

Integer programming - penalty function method. Use of artificial intelligence techniques (neural network, fuzzy logic and genetic algorithm) in thermal systems design and optimization (simple examples). **(06 Hours)**

Text Books:

1. Y. Jaluria, Design and Optimization of Thermal Systems, CRC Press, 2007.
2. S. S. Rao, Optimization methods, PHI, 1998

Reference Books:

1. W.F. Stoecker, Design of Thermal Systems - McGraw-Hill, 1971.
2. Bejan, G. Tsatsaronis, M.J. Moran, Thermal Design and Optimization - Wiley, 1996.
3. R. F. Boehm, Developments in the Design of Thermal Systems - Cambridge University

Course Outcomes:

- Ability to create alternative designs of thermal systems that are able to fulfill the desired functionality in an optimal manner for given objectives

MICROFLUIDICS

Course Objectives:

- To impart knowledge on the physics involved in fluid flow in microchannels, including differentmicro flow devices and their applications

Course Contents:

MODULE 1: **(15 Hours)**

Introduction: Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws.

Micro-scale fluid mechanics: Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.

MODULE 2: **(07 Hours)**

Capillary flows: Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect.

MODULE 3: **(15 Hours)**

Electrokinetics:Electrohydrodynamics fundamentals. Electro-osmosis, Debye layer, Thin EDL limit, Ideal electroosmotic flow, Ideal EOF with back pressure, Cascade electroosmotic micropump, EOF of power-law fluids. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size. Dielectrophoresis, Induced polarization and DEP , Point dipole in a dielectric fluid, DEP force on a dielectric sphere, DEP particle trapping, AC DEP force on a dielectric sphere. Electro-capillary effects, Continuous electro-wetting, Direct electro-wetting, Electro-wetting on dielectric.

MODULE 4: **(03 Hours)**

Few applications of microfluidics: Drug delivery, Diagnostics, Bio-sensing.

Text Books:

1. Fundamentals and applications of Microfluidics, by Nguyen and Werely, Artech house Inc., 2002.
2. Introduction to microfluidics by Tabeling, Oxford University Press Inc., 2005.

Course Outcomes:

- Ability to analyzed physics involved in gas and liquid flow in microchannels, surface forces dominating in the microscale
- Solving simple problems of gas and liquid flows in microchannels,

- Designing a microchannel system, evaluation of the appropriate experimental technique for the study of a given flow problem.

I.C. ENGINES

Course Objectives:

- To impart knowledge on SI and CI Engines
- Study engine exhaust emission control and alternate fuels
- Study the recent developments in IC Engines

Course Contents:

MODULE – 1 **(10 Hours)**

Thermodynamics analysis of I C Engine cycles, Fuel-air cycles and actual cycles thermal efficiency and fuel consumption, Combustion in S.I engine and C.I engine, Use of combustion charts.

Super charging: Thermodynamic cycles with super charging , supercharging of S.I and C.I engines , effect of super charging on engine performance , limits of supercharging in C. I engines, method of super charging, superchargers.

MODULE – 2 **(12 Hours)**

Stratified charge engines: Methods of charge stratification, stratification by fuel injection and positive ignition, swirl stratified charge engine, general chacterstics of stratified charge engines.

Variable compression ratio engine; Theoretical analysis, method of obtaining variable compression ratio engine.

Dual fuel and multi fuel engines: The working principle , combustion in dual fuel engines , super charge dual fuel engines , knock control in dual fuel systems , performance of dual fuel engines ,characteristics of multi-fuel engine, performance of multi-fuel engines.

MODULE – 3 **(08 Hours)**

Engine Exhaust Emission Control:Formation of NOX , HC/CO mechanism , Smoke and Particulate emissions, Green House Effect, Methods of controlling emissions , Three way catalytic converter and Particulate Trap, Emission (HC,CO, NO and NOX) measuring equipments, Smoke and Particulate measurement, Indian Driving Cycles and emission norms.

MODULE – 4 **(10 Hours)**

Alternate Fuels: Alcohols, Vegetable oils and bio-diesel, Bio-gas, Natural Gas, Liquefied Petroleum Gas, Hydrogen, Properties, Suitability, Engine Modifications, Performance, Combustion and Emission Characteristics of SI and CI Engines using these alternate fuels.

Text books:

1. Internal Combustion Engines by Mathur and Sharma, Dhanpat Rai Publications.
2. Internal combustion engine fundamentals by J.B. Heywood, McGraw Hill Publications.

Course Outcomes:

- Ability to analyze performance of SI and CI Engines.
- Recognize emission control norms.
- Use alternate fuels in IC engines.

TWO-PHASE FLOWS

Course Objectives:

- To impart knowledge on two phase flow regime mappings.
- Modelling of two phase flow with different models
- Studyof measurement technique for multiphase flow.

Course Contents:

MODULE 1:

Introduction, different terminologies, flow regimes for single and two component vertical and horizontal flow, flow regime mappings. **(10 Hours)**

MODULE 2:

Conservation equations based on homogeneous flow, drift flux model, separated flow model (multi-fluid model), flooding, fluidization, two phase transportation. Brief discussion on critical flow condition. Introduction to Lockhart-Martinelli and other important correlations for pressure drop, correlations for void fraction. **(15 Hours)**

MODULE 3:

Hydrodynamics of solid-liquid and gas-solid flow, Principles of hydraulic and pneumatic transportation.

Measurement techniques for multiphase flow: Flow regime identification, pressure drop, void fraction and flow rate measurement. **(15 Hours)**

Text Books:

1. Two-phase flow and heat transfer by P. B. Whalley, Oxford University Press, USA.

2. Two-phase flow and heat transfer by D. Butterworth and G. F. Hewitt, Oxford University Press, USA.

Reference Books:

1. Two-Phase Flow: Theory and Applications by Cl Kleinstreuer, CRC Press.

Course Outcomes:

- Ability to analyze two phase flow patterns for thermal systems
- Apply analytical tools for design and performance assessment of two-phase devices