

**ADITYA INSTITUTE OF TECHNOLOGY AND MANAGEMENT, TEKKALI**

***(An Autonomous Institution)***

# M.TECH COURSE STRUCTURE

# THERMAL ENGINEERING

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **M. Tech (TE) - I SEMESTER** | | | | | | | |
| **S. No** | **Code** | | **Subjects** | **L** | **P** | **C** | **INT** | **EXT** |
| 1 | 16MTE1001 | | Optimization Techniques & Applications | 4 | - | 4 | 40 | 60 |
| 2 | 16MTE1002 | | Advanced Thermodynamics | 4 | - | 4 | 40 | 60 |
| 3 | 16MTE1003 | | Advanced Heat & Mass Transfer | 4 | - | 4 | 40 | 60 |
| 4 | 16MTE1004 | | Advanced Fluid Mechanics | 4 | - | 4 | 40 | 60 |
| 5 | **Elective – I** | | | | | | | |
| 16MTE1005 | | Turbo-Machines |  | - | 4 | 40 | 60 |
| 16MTE1006 | | Cryogenics Engineering | 4 |
| 16MTE1007 | | Solar Energy Technology |  |
| 6 | **Elective – II** | | | | | | | |
| 16MTE1008 | | Advanced I.C. Engines |  | - | 4 | 40 | 60 |
| 16MTE1009 | | Non-Conventional Energy Sources | 4 |
| 16MTE1010 | | Material Science for Thermal Engineering |  |
| 7 | 16MTE1101 | | Thermal Engineering Lab |  | 4 | 2 | 40 | 60 |
|  | **Total** | | | | | **26** | **280** | **420** |
|  | **M. Tech (TE) – II SEMESTER** | | | | | | | |
| **S. No** | **Code** | | **Subjects** | **L** | **P** | **C** | **INT** | **EXT** |
| 1 | 16MTE1011 | | Fuels, Combustion & Environment | 4 | - | 4 | 40 | 60 |
| 2 | 16MTE1012 | | Energy Management | 4 | - | 4 | 40 | 60 |
| 3 | 16MTE1013 | | Finite Element Analysis | 4 | - | 4 | 40 | 60 |
| 4 | 16MTE1014 | | Computational Fluid Dynamics | 4 | - | 4 | 40 | 60 |
| 5 | **Elective – III** | | | | | | | |
| 16MTE1015 | | Equipment Design for Thermal Systems |  | - | 4 | 40 | 60 |
| 16MTE1016 | | Convective Heat Transfer | 4 |
| 16MTE1017 | | Thermal & Nuclear Power Plants |  |
| 6 | **Elective – IV** | | | | | | | |
| 16MTE1018 | | Thermal Measurements Process Controls |  | - | 4 | 40 | 60 |
| 16MTE1019 | | Refrigeration & Air-Conditioning | 4 |
| 16MTE1020 | | JET Propulsion & Rocketry |  |
| 7 | 16MTE1102 | | Computational Methods Lab |  | 4 | 2 | 40 | 60 |
|  | **Total** | | | | | **26** | **280** | **420** |
| **M. Tech. (TE) - III SEMESTER** | | | | | | | | |
| **S. No** | | **Code** | **Subject** | **L** | **P** | **C** | **INT** | **EXT** |
| 1 | | 16MTE2201 | Technical Seminar | - | - | 2 | 100 | - |
| 2 | | 16MTE2202 | Project work phase-1 | - | - | 12 | - | - |
|  | | **Total** | | | | **14** | **100** | **-** |
| **M. Tech (TE) - IV SEMESTER** | | | | | | | | |
| **S. No** | | **Code** | **Subject** | **L** | **P** | **C** | **INT** | **EXT** |
| 1 | | 16MTE2203 | Project work phase-2 | - | - | 14 | - | - |
|  | | **Total** | | | | **14** | **-** | **-** |

**L – Lecture hours/Week; P – Practical hours/ Week; C – Credits; INT – Internal Marks; EXT – External Marks;**

# OPTIMIZATION TECHNIQUES AND APPLICATIONS

## SUBJECT CODE: 16MTE1001

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| --- | --- | --- | --- | --- |
| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To be able to formulate linear or nonlinear optimization problems as a solution for industrial problems.
* To be able to solve various kinds linear and nonlinear, single and multiple variable, unconstrained and constrained optimization problems using standard optimization algorithms.

## COURSE OUTCOMES:

* Solve single variable non-linear unconstrained optimization problems using elimination, interpolation and gradient-based methods..
* Calculate optimum solution of unconstrained and constrained geometric programming problems.
* Perform multi-stage decision processes using dynamic programming including applications like inventory, allocation, replacement.
* Conduct sensitivity analysis of multi-variable linear programming problems. Perform Monte-Carlo simulation on inventory, queuing problems.
* Solve integer programming optimization problems using Gomory's cutting plane and branch and bound methods.
* Perform stochastic linear dynamic programming problems using probability theory.

## UNIT-I

**SINGLE VARIABLE NON-LINEAR UNCONSTRAINED OPTIMIZATION:**

One dimensional Optimization methods:- Uni-modal function, elimination methods, Fibonacci method, golden section method, interpolation methods – quadratic & cubic interpolation methods. Multi variable non-linear unconstrained opt imization: Direct search method – Univariant method - pattern search methods – Powell’s- Hook -Jeeves, Rosenbrock search methods- gradient methods, gradient of function, steepest decent method, Fletcher Reeves method, variable metric method.

## UNIT-II

**GEOMETRIC PROGRAMMING:**

Polynomials – arithmetic - geometric inequality – unconstrained G.P- constrained G.P

## UNIT-III

**DYNAMIC PROGRAMMING:**

Multistage decision process, principles of optimality, examples, conversion of final problem to an initial value problem, application of dynamic programming, production inventory, allocation, scheduling replacement.

## UNIT-IV

**Linear programming** – Formulation – Sensivity analysis. Change in the constraints, cost coefficients, coefficients of the constraints, addition and deletion of variable, constraints. Simulation – Introduction – Types- steps – application – inventory – queuing – thermal system

## UNIT-V

**Integer Programming**- Introduction – formulation – Gomory cutting plane algorithm – Zero or one algorithm, branch and bound method.

## UNIT-VI

**Stochastic programming:**

Basic concepts of probability theory, random variables- distributions-mean, variance, correlation, co variance, joint probability distribution- stochastic linear, dynamic programming.

## TEXT BOOKS:

1. Optimization theory & Applications / S.S.Rao / New Age International.
2. Introductory to operation Research / Kasan & Kumar / Springar
3. Optimization Techniques theory and practice / M.C.Joshi, K.M.Moudgalya/ Narosa Publications

## REFERENCE BOOKS:

1. S.D.Sharma / Operations Research
2. Operation Research / H.A.Taha /TMH
3. Optimization in operations research / R.LRardin
4. Optimization Techniques /Benugundu & Chandraputla / Pearson Asia

# ADVANCED THERMO DYNAMICS

## SUBJECT CODE: 16MTE1002

|  |  |  |  |  |
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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* Develop an ability to identify, formulate, and solve engineering problems
* Develop an ability to apply knowledge of mathematics, interdisciplinary science, and engineering

## COURSE OUTCOMES:

* Understand laws of thermodynamics, availability, Maxwell's relations and evaluate thermodynamic properties of working substance.
* Construct PVT surface for real gases. Determine non-reactive mixture thermodynamic and psychrometric properties.
* Describe combustion reactions including enthalpy of formation, heat of reaction. Determine properties for chemical equilibrium of ideal gases.
* Perform second law analysis of binary vapour cycles including cogeneration and combined cycles, and on refrigeration cycles.
* Discuss applicability of phenomenological relations for irreversible processes, and thermo-electric circuits.
* Describe the mechanisms of various direct energy conversion devices like fuel cells, magneto-hydrodynamic generator and photo-voltaic cells.

## UNIT-I

**Review of Thermo dynamic Laws and Corollaries** – Transient Flow Analysis – Second law of thermodynamics – Entropy - Availability and unavailability – Irreversibility – Thermo dynamic Potentials – Maxwell Relations – Specific Heat Relations – Mayer’s relation - Evaluation of Thermodynamic properties of working substance

## UNIT-II

**P.V.T. surface** – Equations of state – Real Gas Behaviour – Vander Waal’s equation - Generalised compressibility Factor – Energy properties of Real Gases – Vapour pressure – Clausius – Clapeyron Equation – Throttling – Joule – Thompson coefficient.

Non-reactive Mixture of perfect Gases – Governing Laws – Evaluation of properties – Pychrometric Mixture properties and psychrometric chart – Air conditioning processes – Cooling Towers – Real Gas Mixture.

## UNIT-III

**Combustion** – Combustion Reactions – Enthalpy of Formation – Entropy of Formation – Reference Levels for Tables – Energy of formation – Heat of Reaction – Aiabatic flame Temperature General product – Enthalpies – Equilibrium.

Chemical Equilibrium of Ideal Gases – Effects of Non-reacting Gases Equilibrium in Multiple Reactions. The vant Hoff’s Equation. The chemical potential and phase Equilibrium

– The Gibbs phase Rule.

## UNIT-IV

**Power cycles**, Review Binary vapour cycle, co-generation and Combined cycles – Second law analysis of cycles – Refrigeration cycles.

## UNIT-V

Thermo Dynamics off irreversible processes – Introduction – phenomenological laws – Onsagar Reciprocity Relation – Applicability of the phenomenological Relations – Heat Flux and Entropy Production – Thermo dnamic phenomena – Thermo electric circuits.

## UNIT-VI

**Direct Energy Conversion Introduction –** Fuel Cells - Thermo electric energy – Thermo- ionic power generation -Thermodynamic devices Magneto Hydrodynamic Generations – Photo voltaic cells.

## TEXT BOOKS:

1. Basic and Applied Thermodynamics, P.K. Nag, TMH
2. Thermo dynamics / Holman, Mc Graw Hill

## REFERENCE BOOKS:

1. Thermo dynamics / Doolittle – Messe
2. Thermo dynamics / Sonnatag & Van Wylen
3. Irreversible Thermo Dynamics / HR De Groff.
4. Engg. Thermo dynamics /PL.Dhar

# ADVANCED HEAT AND MASS TRANSFER

## SUBJECT CODE: 16MTE1003

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To familiarize concept of heat conduction equation for cylinder and sphere
* To understand steady state and transient heat conduction.
* To develop the concept of finite difference methods for conduction.
* To develop depth knowledge on free and forced convection.

## COURSE OUTCOMES:

* Analyze 1D and 2D, steady and transient, explicit and implicit, heat conduction problems using finite difference methods. Derive non-dimensionalized governing equations for forced convection.
* Evaluate heat transfer coefficient for laminar external and internal flows using integral method.
* Develop concept of boundary layer formation over heated surfaces during forced and free convection, formulation of momentum and energy equations of the laminar boundary layers and their solution by approximate method.
* Evaluate Nusselt numbers for boiling and condensation for various geometries.
* Derive expressions for radiant heat exchange in grey, non-grey bodies with transmitting, reflecting and absorbing media. Describe diffusion and convective mass transfer using analogies.
* Analyze 1D and 2D, steady and transient, explicit and implicit, heat conduction problems using finite difference methods. Derive non-dimensionalized governing equations for forced convection.

## UNIT-I

**Brief Introduction to different modes of heat transfer**; Conduction: General heat conduction equation-Initial and Boundary conditions **Steady State Heat Transfer**: Simplified heat transfer in 1D and 2D – Fins **Transient heat conduction**; Lumped system analysis- Heisler charts-semi infinite solid-use of shape factors in conduction - 2D transient heat conduction – product solutions

## UNIT - II

**Finite Difference methods for Conduction**: 1D & 2D steady state and simple transient heat conduction problems – implicit and explicit methods.

**Forced Convection**: Equations of Fluid Flow – Concepts of Continuity, momentum equations – Derivation of Energy equation - Methods to determine heat transfer coefficient:

Analytical Methods - Dimensional Analysis and concept of exact solution. Approximate Method – Integral

analysis

## UNIT - III

**External flows**: Flow over a flat plate: Integral method for laminar heat transfer coefficient for different velocity and temperature profiles. Application of empirical relations to variation geometrics for Laminar and Turbulent flows.

**Internal flows**: Fully developed flow: Integral analysis for laminar heat transfer coefficient – Types of flow – Constant Wall Temperature and Constant Heat Flux Boundary Conditions - Hydrodynamic & thermal entry lengths; use of empirical correlations.

## UNIT - IV

**Free convection:** Approximate analysis on laminar free convective heat transfer – Boussinesque Approximation - Different geometries – combined free and forced convection

## UNIT - V

**Boiling and condensation**: Boiling curve – Correlations- Nusselt’s theory of film condensation on a vertical plate – Assumptions & correlations of film condensation for different geometrics.

## UNIT - VI

**Radiation Heat Transfer:** Radiant heat exchange in grey, non-grey bodies, with transmitting, reflecting and absorbing media, specular surfaces, gas radiation – radiation from flames.

**Mass Transfer**: Concepts of mass transfer – Diffusion & convective mass transfer Analogies – Significance of non-dimensional numbers.

## TEXT BOOKS:

1. Heat Transfer – Necati Ozisik (TMH)
2. Heat and Mass Transfer – O P Single (Macmillan India Ltd)
3. Heat Transfer – P.S. Ghoshdastidar (Oxford Press)
4. Engg. Heat & Mass Transfer- Sarit K. Das (Dhanpat Rai)

## REFERENCE BOOKS:

1. Fundamentals of Heat & Mass Transfer – Incroera Dewitt (Jhon Wiley)
2. Heat Transfer : A basic approach – Yunus Cangel (MH)
3. Heat & Mass Transfer – D.S. Kumar
4. Heat Transfer – P.K. Nag(TMH)
5. Principle of Heat Transfer – Frank Kreith & Mark.Bohn.

**ADVANCED FLUID MECHANICS**

## SUBJECT CODE: 16MTE1004

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To develop Knowledge on viscous flow
* To develop depth of knowledge on boundary layer theory
* To develop fundamental knowledge on turbulence
* To understand the thermodynamic applications in fluid mechanics

## COURSE OUTCOMES:

* Describe Lagrangian and Eulerian fluid motion, stream and velocity potential functions, Euler and Bernouli equations, continuity and momentum equations.
* Derive Navier-Stokes equations for viscous compressible flow and solve for simple cases like Plain and Hagen Poisoulle flow, Coutte flow, Blasius solution.
* Derive Prandtl boundary layer theory and its approximate solutions for creeping motion. Compute drag coefficients for different velocity profiles.
* Describe fundamental concepts of turbulence including Van Driest model, k-epsilon model, Karman vortex trail. Calculate friction for internal flow using Moody's diagram.
* Explain basic concepts of compressible fluid flow including governing equations, flow regimes, mach cone.
* Design nozzles, diffusers for compressible flows using Fanno and Releigh Lines. Describe governing equations for expansion and compressible shocks, supersonic wave drag.

## UNIT-I

**Non – viscous flow of incompressible Fluids:**

Lagrangian and Eulerain Descriptions of fluid motion- Path lines, Stream lines, Streak lines, stream tubes – velocity of a fluid particle, types of flows, Equations of three dimensional continuity equation- Stream and Velocity potential functions.

## Basic Laws of fluid Flow:

Condition for irrotationality, circulation & vorticity Accelerations in Cartesystems normal and tangential accelerations, Euler’s, Bernouli equations in 3D– Continuity and Momentum Equations

## UNIT-II

**Principles of Viscous Flow:**

Derivation of Navier-Stoke’s Equations for viscous compressible flow – Exact solutions to certain simple cases : Plain Poisoulle flow - Coutte flow with and without pressure gradient - Hagen Poisoulle flow - Blasius solution.

## UNIT-III

**Boundary Layer Concepts**

Prandtl’s contribution to real fluid flows – Prandtl’s boundary layer theory - Boundary layer thickness for flow over a flat plate – Approximate solutions – Creeping motion (Stokes) – Oseen’s approximation - Von-Karman momentum integral equation for laminar boundary layer –– Expressions for local and mean drag coefficients for different velocity profiles.

## UNIT-IV

**Introduction to Turbulent Flow:**

Fundamental concept of turbulence – Time Averaged Equations – Boundary Layer Equations - Prandtl Mixing Length Model - Universal Velocity Distribution Law: Van Driest Model –Approximate solutions for drag coefficients – More Refined Turbulence Models – k- epsilon model - boundary layer separation and form drag – Karman Vortex Trail, Boundary layer control, lift on circular cylinders

**Internal Flow**: Smooth and rough boundaries – Equations for Velocity Distribution and frictional Resistance in smooth rough Pipes – Roughness of Commercial Pipes – Moody’s diagram.

## UNIT-V

**Compressible Fluid Flow – I:**

Thermodynamic basics – Equations of continuity, Momentum and Energy - Acoustic Velocity Derivation of Equation for Mach Number – Flow Regimes – Mach Angle – Mach Cone – Stagnation State

## UNIT-VI

**Compressible Fluid Flow – II:**

Area Variation, Property Relationships in terms of Mach number, Nozzles, Diffusers – Fanno and Releigh Lines, Property Relations – Isothermal Flow in Long Ducts – Normal Compressible Shock, Oblique Shock: Expansion and Compressible Shocks – Supersonic Wave Drag.

## TEXT BOOKS:

1. Schlichting H – Boundary Layer Theory (Springer Publications).
2. Convective Heat and Mass Transfer – Oosthigen, McGrawhill
3. Convective Heat and Mass Transfer – W.M. Kays, M.E. Crawford, McGrawhill

## REFERENCE BOOKS:

1. Yuman S.W – Foundations of Fluid Mechanics.
2. An Introduction to Compressible Flow – Pai.
3. Dynamics & Theory and Dynamics of Compressible Fluid Flow – Shapiro.

# TURBO MACHINES

**(Elective-I)**

## SUBJECT CODE: 16MTE1005

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* Appreciate the role of fluid mechanics and thermodynamics mechanics in engineering.
* Discern the importance of basic similarity parameters such as specific speed and flow coefficients.
* Demonstrate comprehension of the Euler Turbomachinery Equations, derive from the angular momentum equation, and apply to problems encompassing the operation of the basic elements of turbomachinery.
* Gain an integrated view of the common principles of turbomachine stage performance: expansion, diffusion and extraction or addition of energy and angular momentum. Apply cycle modeling and efficiencies for performance projections.
* Demonstrate and apply comprehension of the fluid mechanics responsible for limits of turbomachinery operability and stability, particularly, stall, surge, cavitation, and choke. Study unsteady effects.
* Gain understanding of the energy and power density implications of hydroelectric and wind power plants.
* Understand the principles of loss calculations in axial and radial units.

## COURSE OUTCOMES:

* Perform thermodynamic analysis of turbo-machines including isentropic flow, Euler's flow through variable cross sectional area, and unsteady flow.
* Design convergent, convergent-divergent nozzle. Perform thermodynamic analysis on impulse and reaction steam turbines and design them.
* Understand normal shock relations for perfect gas, oblique shock waves, normal shock recovery, detached shocks and aerofoil theory.
* Calculate performance of centrifugal compressors using Stanitz and Stodolas formulae including effects of inlet mach number, prewhirl, pressure recovery.
* Perform thermodynamic analysis on axial flow compressors and cascade analysis on free and forced vortex blades.
* Perform thermodynamic flow analysis on axial flow gas turbines. Determine blade stresses, materials, cooling performance. Match compressor and turbine.

## UNIT – I

**Fundamentals of Turbo machines:** Classification, Applications Thermodynamic analysis; Isentropic flow, Energy transfer; Efficiencies; static and Stagnation conditions; continuity equation; Euler’s flow through variable cross sectional area; unsteady flow in turbo machines.

## UNIT –II

**Steam Nozzles:** Convergent and Convergent – Divergent nozzles; Energy balance; effect of back – pressure on the analysis; Design of nozzles.

**Steam Turbines :**Impulse Turbines: Compounding; work done and velocity triangles; Efficiencies; Constant Reaction Blading; Design of blade passages, angles and height; Secondary flow; leakage losses; Thermodynamic analysis of steam turbines.

## UNIT – III

**Gas Dynamics:** Fundamentals thermodynamic concepts; Isentropic conditions; Mach number and Area – Velocity relation; Dynamic pressure; normal shock relations for perfect gas; supersonic flow, oblique shock waves ; normal shock recovery ; detached shocks ; Aerofoil theory.

## UNIT – IV

**Centrifugal Compressor**: Types; Velocity triangles and efficiencies; Blade passage design; Diffuser and pressure recovery; slip factor; stanitz and stodolas formulae; Effect of inlet mach number; Prewirl; performance.

## UNIT – V

**Axial Flow Compressors:** Flow analysis, work and velocity triangles ; Efficiencies; Thermodynamic analysis; stage pressure rise ; Degree of reaction ; stage loading ; general design, effect of velocity incidence ; performance.

**Cascade Analysis:** Geometry and Terminology; Blade forces, Efficiency; losses; free and forced vortex blades.

## UNIT – VI

**Axial Flow Gas Turbines:** Work done; velocity triangles and efficiencies; thermodynamic flow analysis; degree of reaction; Zweifels relation; Design cascade analysis – Soderberg – Hawthrone – ainley-correlations; secondary flow; Free-vortex blades; Blade angles for variable degree of reaction; Actuator disc theory; stresses in blades; Blade assembling; materials and cooling of blades; performance; Matching of compressor and turbine; off- design performance.

## TEXT BOOKS:

1. Fundamentals of Turbo machines – Shephard
2. Practise on Turbomachines – G. Gopalakrishnan & D. Prithviraj, SciTech Publishers, Chennai.
3. Theory and practice of steam turbines – Kearton
4. Gas Turbines – Theory and practice – Zucrow

## REFERENCE BOOKS:

1. Elements of Gas Dynamics – Liepman and Roshkow
2. Elements of Gas Dynamics – Yahya
3. Turbines, Pumps, Compressors – Yahya
4. Axial Flow Compressors – Horlock.
5. Gas Turbines- Cohen, Roger & Sarvanamuttu

# CRYOGENIC ENGINEERING

**(Elective-I)**

## SUBJECT CODE: 16MTE1006

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To develop knowledge on different properties of cryogenic fluids
* To provide knowledge on liquefaction system for different components
* To provide application knowledge for concept of cryogenic systems

## COURSE OUTCOMES:

* Describe the properties of cryogenic fluids.
* Describe the methods to produce low temperature liquefaction systems for gases by using adiabatic expansion.
* Describe components of liquefaction systems including heat exchangers, compressors, expanders, expansion valves, along with their losses.
* Understand different gas separation and purification systems and principles of gas and air separation.
* Understand cryogenic refrigeration systems, cryogenic fluid storage and transfer, cryogenic storage systems including insulation and fluid transfer mechanisms.
* Understand applications of cryogenics in space technology, gas industry, biology, medicine and electronics.

## UNIT -I

Introduction to CRYOGENIC Systems – Mechanical Properties at low temperatures Properties of cryogenic fluids.

## UNIT - II

**Gas Liquefaction:** Minimum work for liquefaction – Methods to produce low temperature – Liquefaction systems for gases other than Neon, Hydrogen and Helium

## UNIT - III

Liquefaction systems for Neon, Hydrogen and Helium Components of Liquefaction systems

– Heat Exchangers – Compressors and Expanders – expansion valve – Losses for real machines

## UNIT - IV

Gas separation and purification systems – Properties of mixtures – Principles of mixtures – Principles of gas separation – Air separation systems

## UNIT - V

Cryogenic Refrigeration Systems – Working media – Solids, Liquids and gases-Cryogenic fluid storage & transfer – Cryogenic storage systems – Insulation – Fluid transfer mechanisms – Cryostat – Cryo C

## UNIT - VI

Applications – Space technology – In-flight air seperation and collection of LOX – Gas Industry – Biology – Medicine - Electronics

## TEXT BOOK:

1. Cryogenic Systems – R.F. Barron, Oxford University Press

## REFERENCE BOOKS:

1. Cryogenic Research and Applications – Marshall Sitting, Von Nostrand Inc, New Jersey
2. Cryogenics Engineering Edit by B.A.Hands, Academic Press, 1986
3. Cryogenics Engineering – R. B. Scott, Von Nostrand Inc, New Jersey, 1959
4. Experimental Techniques in Low Temperature Physics – G.K. White, Oxford Press, 1968
5. Cryogenics process Engineering – K.D.Timmerhaus & TM Flynn, Plenum press, 1998
6. Cryogenic Heat Transfer - R.F. Baron.
7. Cryogenic Two Phase flow – N.N . Falina and J.G. Weisend –II
8. Cryogenic Regenerative Heat Exchangers – Robort Ackermann, Plenum Press, 1997
9. Cryogenic Engineering – Thomas M. Flynn
10. Safety in Handling of Cryogenic Fluids – Fredrick J. Edeskutty and Watter F. Stewart, Plenum Press,1996.
11. Hand Book of Cryogenic Engineering – J.G.Weisend –II, Taylor and Francis, 1998

# SOLAR ENERGY TECHNOLOGY

**(Elective-I)**

## SUBJECT CODE: 16MTE1007

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To know clear concept between sun and earth
* To design the different component for utilization of solar energy
* To design and develop different systems which are useful to store the energy.

## COURSE OUTCOMES:

* Differentiate between beam and diffuse solar radiation. Estimate average solar radiation on horizontal and titled surfaces.
* Conduct performance analysis on liquid flat plate collectors without and with plane reflectors, cylindrical parabolic collectors with orientation and tracking.
* Design a solar water heating system and layout including heliostats, receivers, power cycles, working fluids and prime movers.
* Describe sensible heat, latent heat and packaged bed storage devices. Describe other solar devices like stills, air heaters, dryers, solar ponds, solar refrigeration.
* Describe the principle, construction and applications of solar cells for direct energy conversion.
* Perform cost benefit analysis and optimization of solar system including discounted cash flow and life cycle costs.

## UNIT - I

**Introduction** – Solar energy option, specialty and potential – Sun – Earth – Solar radiation, beam and diffuse – measurement – estimation of average solar radiation on horizontal and tilted surfaces – problems – applications.

## UNIT - II

**Capturing solar radiation** – physical principles of collection – types – liquid flat plate collectors – construction details – performance analysis – concentrating collection – flat plate collectors with plane reflectors – cylindrical parabolic collectors – Orientation and tracking – Performance Analysis.

## UNIT - III

**Design of solar water heating system and layout**

Power generation – solar central receiver system – Heliostats and Receiver – Heat transport system – solar distributed receiver system – Power cycles, working fluids and prime movers.

## UNIT - IV

**Thermal energy storage** – Introduction – Need for – Methods of sensible heat storage using solids and liquids – Packed bed storage – Latent heat storage – working principle – construction – application and limitations.

Other solar devices – stills, air heaters, dryers, Solar Ponds & Solar Refrigeration.

## UNIT - V

**Direct energy conversion** – solid-state principles – semiconductors – solar cells – performance – modular construction – applications.

## UNIT - VI

**Economics –** Principles of Economic Analysis – Discounted cash flow – Solar system – life cycle costs – cost benefit analysis and optimization – cost based analysis of water heating and photo voltaic applications.

## TEXT BOOKS:

1. Principles of solar engineering – Kreith and Kerider
2. Solar energy thermal processes – Duffie and Beckman
3. Solar energy – Sukhatme

## REFERENCE BOOKS:

1. Solar energy – Garg
2. Solar energy – Magal
3. Soloar energy – Tiwari and Suneja
4. Power plant technology – El Wakil

# ADVANCED I.C. ENGINES

**(Elective-II)**

## SUBJECT CODE: 16MTE1008

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| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* This course is designed to give students an understanding of the principles and design concepts as well as practices associated with modern mobility power systems. Emphasis is given to state of the art and emerging energy conversion science and technologies such as those applied to modern and advanced automotive (i.e. self-propelled) vehicle.

## COURSE OUTCOMES:

* Understand the differences between ideal and real engine cycles. Understand thermo-chemistry of fuel-air mixtures.
* Understand gas exchange processes like flow through ports, supercharging and turbo-charging. Determine turbulent characteristics of swirl, squish, pre-chamber engine flows.
* Understand the mechanism of combustion in SI engines including abnormal combustion and MPFI, and CI engines including fuel spray behavior and common rail fuel injection.
* Describe emissions measurement, and various exhaust gas treatment devices and methods.
* Describe fuel supply systems for SI and CI engines to use alternate gaseous fuels like LPG, CNG and Hydrogen.
* Understand modern trends in IC engines like lean burning, adiabatic concepts, rotary engines, biofuels, HCCI and GDI concepts.

## UNIT – I

Introduction – Historical Review – Engine Types – Design and operating Parameters.

**Cycle Analysis:** Thermo-chemistry of Fuel – Air mixtures, properties – Ideal Models of Engine cycles – Real Engine cycles - differences and Factors responsible for – Computer Modeling.

## UNIT – II

**Gas Exchange Processes:** Volumetric Efficiency – Flow through ports – Supercharging and Turbo charging.

**Charge Motion**: Mean velocity and Turbulent characteristics – Swirl, Squish – Pre-chamber Engine flows.

## UNIT – III

**Engine Combustion in S.I engines:** Combustion and Speed – Cyclic Variations – Ignition – Abnormal combustion Fuel factors, MPFI, SI engine testing.

**Combustion in CI engines**: Essential Features – Types off Cycle. Pr. Data – Fuel

Spray Behavior – Ignition Delay – Mixing Formation and control, Common rail fuel injection system

## UNIT – IV

**Pollutant Formation and Control:** Nature and extent of problems – Nitrogen Oxides, Carbon monoxide, unburnt Hydrocarbon and particulate – Emissions – Measurement – Exhaust Gas Treatment, Catalytic converter, SCR, Particulate Traps, Lean, NOx, Catalysts.

## UNIT - V

Fuel supply systems for S.I. and C.I engines to use gaseous fuels like LPG, CNG and Hydrogen.

## UNIT - VI

**Modern Trends in IC Engines**

Lean Burning and Adiabatic concepts, Rotary Engines, Modification in I.C engines to suit Bio – fuels, HCCI and GDI concepts

## TEXT BOOKS:

1. I.C. Engines Fundamentals/Heywood/Mc Graw Hill
2. The I.C. Engine in theory and Practice Vol.I / Teylor / IT Prof. And Vol.II
3. I.C. Engines: Obert/Int – Text Book Co.

## REFERENCE BOOKS:

1. I.C. Engines: Maleev
2. Combustion Engine Processes: Lichty
3. I.C. Engines: Ferguson
4. Scavenging of Two – stroke Cycle Engines – Switzer.
5. I.C.Engines by V.Ganesan

# NON CONVENTIONAL ENERGY RESOURCES

**(Elective-II)**

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

## SUBJECT CODE: 16MTE1009

**COURSE OBJECTIVES:**

* To know the relation between sun and earth and application of solar energy
* To know the concept and how to develop geothermal energy
* To know the principle of bio mass energy and its development
* To develop the wind, tidal and ocean energy

## COURSE OUTCOMES:

* Analyze energy demand and energy resources of the world and nation. Understand the amount of solar radiation received by earth, and radiation measuring instruments.
* Describe solar energy applications like solar water heating, space heating, solar stills and ponds, solar refrigeration and photo-voltaic generation.
* Estimate geothermal potential using analytical methods. Describe geothermal harnessing techniques and electricity generating systems.
* Describe nuclear fusion, fuel cells, photo-voltaic cells, MHD generator, hydrogen fuel based IC engines.
* Discuss bioenergy generation including bio-conversion processes, bio-gas plant technology, biomass gasification and economics of biomass systems.
* Compute characteristics of wind energy conversion systems using various coefficients. Describe energy extracting devices from tidal and wave energy.

## UNIT – I

**Introduction** – Energy Sinario - Survey of Energy Resources – Classification – Need for Non-Conventional Energy Resources. **Solar Energy:** The Sun – Sun-Earth Relationship – Basic matter to waste heat energy circuit – Solar radiation – Attention – Radiation measuring instruments.

## UNIT – II

**Solar Energy Applications:**

Solar water Heating, space heating – active and passive heating – energy storage – selective surface – solar stills and ponds – solar refrigeration – photovoltaic generation .

## UNIT - III

**Geothermal Energy:**

Structure of Earth – Geothermal Regions – Hot springs – Hot Rocks – Hot Aquifers – Analytical Methods to estimate Thermal Potential – Harnessing Techniques – Electricity Generating Systems.

## UNIT -IV

**Direct Energy Conversion: Nuclear Fusion:**

Fusion – Fusion Reaction- P-P Cycle carbon Cycle, Deuterium cycle – condition for controlled Fusion.

Fuel Cells and Photovoltaic –Thermionic and Thermoelectric Generation – MHD Generator. **Hydrogen gas a Fuel** – Production methods – Properties – I.C. Engines Applications – Utilization Strategy – Performances.

## UNIT – V

**Bio – Energy:**

Biomass Energy Sources – Plant Productivity, Biomass Wastes – Aerobic and Anaerobic bio-conversion processes – Raw Materials and properties of Bio-gas-Bio-gas plant Technology and Status – The Energetics and Economics of Biomass Systems – Biomass gasification.

## UNIT – VI

**Wind Energy:**

Wind – Beaufort number – characteristics – wind energy conversion systems – types – Betz model – Interference Factor – Power Coefficient – Torque Coefficient and thrust coeff.- Lift machines and drag machines – matching – electricity generation.

## Energy from Oceans:

Tidal Energy; Tides – Diurnal and Semi – Diurnal Nature – Power from Tides.

Wave Energy ; Waves – Theoretical Energy Available – Calculation of period and phase velocity of waves – wave power systems – submerged devices. Ocean Thermal Energy : principles – Heat Exchangers – Pumping requirements – Practical Considerations.

## TEXT BOOK:

1. Renewable Energy Resources – Basic Principles and Applications – G.N.Tiwari and M.K.Ghosal, Narosa Pub

## REERENCE BOOKS:

1. Renewable Energy Resources / John Twidell & Tony Weir
2. Biological Energy Resources / Malcolm Flescher & Chrris Lawis

# MATERIAL SCIENCE FOR THERMAL ENGINEERING

**(Elective-II)**

## SUBJECT CODE: 16MTE1010

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To introduce the students to the relationships that exists between the structure and properties of engineering materials.
* To introduce the students to the production, properties and application of the major groups of engineering materials
* To allow the students to interpret the phase diagrams of metals and alloys and use them in thermal processing of the materials.
* To introduce the students to the basic principles involved in materials selection based on the properties of materials and failure in service.

## COURSE OUTCOMES:

* Describe the production, properties and applications of stainless steel and cast iron.
* Describe the production, properties and applications of super alloys and titanium & its alloys.
* Describe the production, properties and applications of grahite, oxide ceramides and borides.
* Describe the production, properties and applications of nitrides, silicides, refractory metals and alloys (W, Ta, Cb, Rh, Mo).
* Describe the production, properties and applications of cermets, composites, C-C composites.
* Describe the production, properties and applications of ablative materials.

## UNIT-I

Introduction–Materials used in Thermal Engineering applications, Stainless steels, Cast Iron,

## UNIT-II

Super Alloys and Titanium and its alloys

## UNIT-III

Graphite, Oxide Ceramides, Borides

## UNIT-IV

Nitrides, Silicides, Refractory Metals and alloys ( W, Ta, Cb, Rh & Mo)

## UNIT-V

Cermets, Composites, C-C Composites

## UNIT-VI

Ablation & Ablative Materials.

## TEXT BOOK:

1. High temperature materials technology – Campbell E.E. and Sherwood – John Wiley and Sons, 1967

## REFERENCE BOOKS:

1. High temperature technology – Campbell I.E. – John Wiley
2. High temperature materials – Hehmann R.F. – Wiley and sons, 1967.
3. Behaviour of high temperature alloys – Proceeding of International conference, 1979.

# THERMAL ENGINEERING LABORATORY

## SUBJECT CODE: 16MTE1101

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| **L** | **P** | **C** | **INT** | **EXT** |
| **0** | **4** | **2** | **40** | **60** |

**COURSE OBJECTIVES:**

* To introduce the student the fundamental theories and the industrial applications of thermodynamics, heat transfer, and fluid mechanics. This laboratory supports the courses for the undergraduate and graduate studies. Moreover, this laboratory also supports the advanced research in the area of thermal engineering, heat transfer, and fluid mechanics.

## COURSE OUTCOMES:

* Measure compressibility factor of different real gases.
* Estimate dryness fraction of steam.
* Perform flame propagation analysis of gaseous fuels.
* Conduct performance test, heat balance sheet, exhaust gas analysis on an IC engine.
* Conduct performance analysis on vapour compression refrigeration unit, on air conditioning unit and on heat pipe.
* Determine efficiency of solar flat plate collector, and evacuative tube concentrator.

## LIST OF EXPERIMENTS:

1. Compressibility factor measurement of different real gases.
2. Dryness fraction estimation of steam.
3. Flame propagation analysis of gaseous fuels.
4. Performance test and analysis of exhaust gases of an I.C. Engine.
5. Heat Balance sheet, Volumetric Efficiency and air fuel ratio estimation of an I.C. Engine.
6. COP estimation of vapour compression refrigeration test.
7. Performance analysis of Air conditioning unit.
8. Performance analysis of heat pipe.
9. Solar Flat Plate Collector
10. Evacuative tube concentrator.

# FUELS, COMBUSTION AND ENVIRONMENT

## SUBJECT CODE: 16MTE1011

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To make students familiar with the basic energy transfer processes that govern existing and proposed methods of power generation for a global society.
* To make students familiar with the traditional and non-traditional fuel sources in terms of energy content, accessibility required processing steps and projected remaining reserves.
* To teach the evaluation of heat, work and energy transfer steps associated with advanced power train strategies and stationary power systems.
* To teach the fundamental thermodynamics, physics and chemistry relevant to evaluating combustion emissions and efficiencies.

## COURSE OUTCOMES:

* Describe origin, analysis, carborisation, liquification of coal. Describe gasification of coal including blast furnace gas, alcohols and biogas.
* Perform combustion chemical composition, flue gas, dew point and stoichiometric analysis.
* Understand theories of reaction kinetics and analyze chemical kinetics of complex and chain reactions. Determine oxidation behavior of hydrocarbons.
* Understand thermodynamics of combustion including enthalpy of formation, heating value of fuel, and adiabatic flame temperature.
* Determine laminar and turbulent flame propagation including burning velocity, combustion of fuel droplets and sprays, pulverized fuel furnaces, and fluidized bed systems.
* Understand the effect of air pollution on environment, human health and methods of emission control.

## UNIT – I

**Fuels –** detailed classification – Conventional and Unconventional Solid, Liquid, gaseous fuels and nuclear fuels – Origin of Coal – Analysis of coal.

Coal – Carborisation, Gasification and liquification – Lignite: petroleum based fuels – problems associated with very low calorific value gases: Coal Gas – Blast Furnace Gas Alcohols and Biogas.

## UNIT – II

**Principles of combustion** – Chemical composition – Flue gas anlaysis – dew point of products – Combustion stoichiometry.

## UNIT – III

Chemical kinetics – Rate of reaction – Reaction order – Molecularity – Zeroth, first, second and third order reactions - complex reactions – chain reactions. Theories of reaction Kinetics

– General oxidation behavior of HC’s.

## UNIT – IV

**Thermodynamics of combustion** – Enthalpy of formation – Heating value of fuel - Adiabatic flame Temperature – Equilibrium composition of gaseous mixtures.

## UNIT – V

**Laminar and turbulent flames propagation and structure** – Flame stability – Burning velocity of fuels – Measurement of burning velocity – factors affecting the burning velocity. Combustion of fuel, droplets and sprays – Combustion systems – Pulverised fuel furnaces – fixed, Entrained and Fluidised Bed Systems.

## UNIT – VI

**Environmental considerations** – Air pollution – Effects on Environment, Human Health etc. Principal pollutants – Legislative Measures – Methods of Emission control.

## TEXT BOOKS:

1. Combustion Fundamentals by Roger A strehlow – Mc Graw Hill
2. Fuels and combustion by Sharma and Chander Mohan – Tata Mc Graw Hill
3. Combustion Engineering and Fuel Technology by Shaha A.K. Oxford and IBH.
4. Principles of Combustion by Kanneth K.Kuo, Wiley and Sons.
5. Combustion by Sarkar – Mc. Graw Hill.

## REFERENCE BOOKS:

1. An Introduction to Combustion – Stephen R. Turns, Mc. Graw Hill International Edition.
2. Combustion Engineering – Gary L. Berman & Kenneth W. Ragland, Mc. Graw Hill International Edition.
3. Combustion- I. Glassman

# ENERGY MANAGEMENT

## SUBJECT CODE: 16MTE1012

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* Familiarizing with management, especially with management in energy sector engineering. Fundamentals of product strategy management. Studying methods of energy accounting and energy auditing in energy sector, industry and final consumption. Finding opportunities to increase the rational use of energy.

## COURSE OUTCOMES:

* Understand the principles of energy management and the role of energy manager various organizations.3
* Understand types of energy audits. Gather and analyze relevant data.
* Describe technologies for energy conservation. Assess critically energy usage using energy flow networks, optimization and technical analysis of options.
* Perform economic analysis including depreciation, risk analysis and budget considerations.
* Know common methods of evaluation of projects. Understand the need for energy consultant and his selection criteria.
* Understand alternative energy sources including solar and wind energies.

## UNIT-I

Introduction: Principles of Energy Management – Managerial Organization – Functional Areas for i. Manufacturing Industry ii. Process Industry iii. Commerce iv. Government.

Role of Energy Manager in each of these organization. Initiating, Organising and Managing Energy Management Programs

## UNIT-II

Energy Audit: Definition and Concepts, Types of Energy Audits – Basic Energy Concepts – Resources for Plant Energy Studies – Data Gathering – Analytical Techniques.

## UNIT-III

Energy Conservation: Technologies for Energy Conservation , Design for Conservation of Energy materials – energy flow networks – critical assessment of energy usage – formulation of objectives and constraints – synthesis of alternative options and technical analysis of options – process integration.

## UNIT-IV

Economic Analysis: Scope, Characterization of an Investment Project – Types of Deprecication – Time Value of money – budget considerations, Risk Analysis.

## UNIT-V

Methods of Evaluation of Projects : Payback – Annualised Costs – Investor’s Rate of return

– Present worth – Internal Rate of Return – Pros and Cons of the common methods of analysis – replacement analysis. Energy Consultant: Need of Energy Consultant – Consultant Selection Criteria.

## UNIT-VI

Alternative Energy Sources : Solar Energy – Types of devices for Solar Energy Collection – Thermal Storage System – Control Systems-

Wind Energy – Availability – Wind Devices – Wind Characteristics – Performance of Turbines and systems.

## TEXT BOOKS:

1. Energy Management Hand book by W.C. Turner (Ed)
2. Management by H.Koontz and Cyrill O Donnell

## REFERENCE BOOKS:

1. Financial Management by S.C. Kuchhal
2. Energy Management by W.R.Murthy and G.Mc Kay
3. Energy Management Principles by CB Smith.

# FINITE ELEMENT ANALYSIS

## SUBJECT CODE: 16MTE1013

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* Provide knowledge Finite Element Methods for solving various field problems.
* Provide knowledge to solve, one-dimensional, two-dimensional steady state heat analysis problems

## COURSE OUTCOMES:

* Explain variational principles, Galerkin's methods for finite element formulation. Compare FEM methods with other methods like FDM, FVM.
* Explain fundamental relations of elasticity, interpolation functions, formulation and assembly of matrices, solving system of linear equations.
* Analyze bar and truss problems without and with midside nodes. Analyze beam problems using Hermite shape functions.
* Analyze plane stress, plane strain and axisymmetric (2D) models. Also analyze 2D isoparametric problems, and 3D problems using tetrahedron element.
* Solve scalar field problems like 1D, 2D heat conduction fin problems, and torsion problems.
* Calculate natural frequencies and mode shapes of vibration using dynamic FEA using consistent mass matrix.

## UNIT -I

Introduction to FEM: basic concepts, historical back ground, application of FEM, general description, comparison of fem with other methods, variational approach, Galerkin Methods

## UNIT -II

Co-ordinates, basic element shapes, interpolation function. Virtual energy principle, Rayleigh- Ritz method, properties of stiffness matrix, treatment of boundary conditions, solution of system of equations, shape functions and characteristics, Basic equations of elasticity, strain displacement relations

## UNIT -III

1-D structural problems – axial bar element – stiffness matrix, load vector, temperature effects, Quadratic shape function. Analysis of Trusses – Plane Truss and Space Truss elements. Analysis of beams – Hermite shape functions – stiffness matrix – Load vector – Problems – analysis.

## UNIT -IV

2-D problems –CST, force terms, Stiffness matrix and load vector, boundary conditions, Isoparametric element – quadrilateral element, Shape functions – Numerical Integration

3-D problems – Tetrahedran element – Jacobian matrix – Stiffness matrix

## UNIT -V

Scalar field problems - 1-D Heat conduction – 1-D fin element – 2-D heat conduction problems – Torsion.

## UNIT -VI

Dynamic considerations, Dynamic equations – consistent mass matrix – Eigen Values, Eigen Vector, natural frequencies – mode shapes – modal analysis.

## TEXT BOOKS:

1. Introduction to finite elements in engineering – Tirupathi K. Chandrupatla and Ashok D. Belagundu.
2. The finite element methods in Engineering – S.S. Rao \_ Pergamon, New York
3. An Introduction to Finite Element Methods – J. N. Reddy – Mc Grawhill

## REFERENCE BOOKS:

1. The Finite element method in engineering science – O.C. Aienkowitz, Mc Grawhill.
2. Concepts and applications of finite element analysis – Robert Cook
3. Finite Element Procedures in Engineering analysis – K.J Bathe

# COMPUTATIONAL FLUID DYNAMICS

## SUBJECT CODE: 16MTE1014

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* Should be able to solve a given partial differential equation using finite-difference and finite-volume methods
* Should be able to formulate various turbulence models and their solution procedures.

## COURSE OUTCOMES:

* Compare FD, FE, FV methods. Classify partial differential equations. Solve system of linear algebraic equations using direct and iterative approaches.
* Solve steady state and unsteady heat transfer problems using both explicit and implicit finite difference methods like Crank-Nicholson and ADI-ADE.
* Derive the basic rules for control volume approach using 1D steady heat conduction equation. Extend this to 2D & 3D steady and unsteady heat conduction problems.
* Apply finite volume method to problems containing both convection and diffusion. Assess various discretization schemes and treatment of boundary conditions.
* Formulate governing equations using stream function-vorticity method. Solve pressure-velocity coupled problems using SIMPLE and SIMPLER algorithms.
* Solve turbulent flows including direct numerical simulation, large eddy simulation, RANS models. Understand pressure-velocity-density coupling in compressible flows.

## UNIT-I

**Introduction to Numerical Methods** - Finite Difference, Finite Element and Finite Volume Methods – Classification of Partial Differential Equations – Solution of Linear Algebraic Equations – Direct and Iterative Approaches

## UNIT-II

**Finite difference methods:** Taylor’s series – FDE formulation for 1D and 2D steady state heat transfer problems – Cartesian, cylindrical and spherical co-ordinate systems – boundary conditions – Un steady state heat conduction – Errors associated with FDE - Explicit Method

– Stability criteria – Implicit Method – Crank Nickolson method – 2-D FDE formulation – ADI – ADE

## UNIT - III

**Finite Volume Method**: Formation of Basic rules for control volume approach using 1D steady heat conduction equation – Interface Thermal Conductivity - Extension of General Nodal Equation to 2D and 3D Steady heat conduction and Unsteady heat conduction

## UNIT-IV

**FVM to Convection and Diffusion**: Concept of Elliptic, Parabolic and Hyperbolic Equations applied to fluid flow – Governing Equations of Flow and Heat transfer – Steady 1D Convection Diffusion – Discretization Schemes and their assessment – Treatment of Boundary Conditions

## UNIT-V

**Calculation of Flow Field**: Vorticity & Stream Function Method - Staggered Grid as Remedy for representation of Flow Field - Pressure and Velocity Corrections – Pressure Velocity Coupling - SIMPLE & SIMPLER (revised algorithm) Algorithm.

## UNIT-VI:

**Turbulent Flows**: Direct Numerical Simulation, Large Eddy Simulation and RANS Models

**Compressible Flows**: Introduction - Pressure, Velocity and Density Coupling.

## TEXT BOOKS:

1. Computational Fluid Flow and Heat Transfer – Muralidharan & Sundarajan (Narosa Pub)
2. Numerical heat transfer and fluid flow – S.V. Patankar (Hemisphere Pub. House)
3. An Introduction to Computational Fluid Dynamics – FVM Method – H.K. Versteeg, W. Malalasekhara (PHI)
4. Computational Fluid Dynamics – Anderson (TMH)
5. Computational Methods for Fluid Dynamics – Ferziger, Peric (Springer)

## REFERENCE BOOKS:

1. Computational Fluid Dynamics, T.J. Chung, Cambridge University
2. Computaional Fluid Dynamics – A Practical Approach – Tu, Yeoh, Liu (Elsevier)
3. Text Book of Fluid Dynamics, Frank Chorlton, CBS Publishers

# EQUIPMENT DESIGN FOR THERMAL SYSTEMS

**(Elective-III)**

## SUBJECT CODE: 16MTE1015

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To familiarize the knowledge of simple heat exchangers and its design
* To design and develop the double pipe and shell& tube heat exchanger
* To design and develop different types of extended surfaces

## COURSE OUTCOMES:

* Classify various heat exchangers. Understand recuperation and regeneration.
* Perform heat exchanger design calculations using LMTD and NTU methods for various flow configurations.
* Perform design calculations on double pipe and shell & tube heat exchangers.
* Calculate condensation properties of single vapors in various types of condensers like horizontal, vertical, desuper heater type.
* Describe vaporizing processes occurring in both forced and natural circulation vaporizing exchanger. Calculate efficiencies for different types of fins.
* Analyze and design cooling towers including performance, heat balance, number of diffusion units required calculations.

## UNIT - I

**Classification of heat exchangers:** Introduction, Recuperation & Regeneration – Tubular heat exchangers: double pipe, shell & tube heat exchanger, Plate heat exchangers, Gasketed plate heat exchanger, spiral plate heat exchanger, Lamella heat exchanger, extended surface heat exchanger, Plate fin, and Tubular fin.

## UNIT -II

**Basic Design Methods of Heat Exchanger:** Introduction, Basic equations in design, Overall heat transfer coefficient – LMTD method for heat exchanger analysis – parallel flow, counter flow, multipass, cross flow heat exchanger design calculations.

## UNIT - III

**Double Pipe Heat Exchanger:** Film Coefficient for fluids in annulus, fouling factors, calorific temperature, average fluid temperature, the calculation of double pipe exchanger, Double pipe exchangers in series-parallel arrangements.

**Shell & Tube Heat Exchangers:** Tube layouts for exchangers, baffle Heat exchangers,

calculation of shell and tube heat exchangers – shell side film coefficients, Shell side equivalent diameter, the true temperature difference in a 1-2 heat exchanger, influence of approach temperature on correction factor, shell side pressure drop, tube side pressure drop, Analysis of performance of 1-2 heat exchanger, and design calculation of shell & tube heat exchangers. Flow arrangements for increased heat recovery, the calculations of 2-4 exchangers.

## UNIT - IV

**Condensation of single vapors:** Calculation of a horizontal condenser, vertical condenser, De-super heater condenser, vertical condenser – sub-cooler, horizontal condenser – subcooler, vertical reflux type condenser, condensation of steam.

## UNIT – V

**Vaporizers, Evaporators and Reboilers:** Vaporizing processes, forced circulation vaporizing exchangers, natural circulation vaporizing exchangers, calculations of a reboiler. **Extended Surfaces:** Longitudinal fins, weighted fin efficiency curve, calculation of a double pipe fin efficiency curve, calculation of a double pipe finned exchanger, calculation of a longitudinal fin shell and tube exchanger.

## UNIT -VI

**Direct Contact Heat Exchanger:** Cooling towers, relation between wet bulb & dew point temperatures, the Lewis number, and classification of cooling towers, cooling tower internals and the roll of fill, Heat balance, heat transfer by simultaneous diffusion and convection. Analysis of cooling tower requirements, Design of cooling towers, Determination of the number of diffusion units, calculation of cooling tower performance.

## TEXT BOOK:

1. Process Heat Transfer – D.Q. Kern, TMH.

## REFERENCE BOOKS:

1. Cooling Towers by J.D. Gurney
2. Heat Exchanger Design – A.P.Fraas and M.N. Ozisick. John Wiely & sons, New York.

# CONVECTIVE HEAT TRANSFER

**(Elective-III)**

## SUBJECT CODE: 16MTE1016

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To understand the problem of the calculation of the convection heat transfer.
* To learn the classification of the different convection types and how is possible their characterization.
* To know the non-dimensional numbers used to characterize the convection and the basic structure of the mathematical correlations for the different convection types.
* To know the phase change convection.
* To define the most used correlations for forced internal and external convection
* Description of the non-dimensional numbers characteristics at free convection.

## COURSE OUTCOMES:

* Derive equations of continuity, momentum and energy. Derive both laminar and turbulent boundary layer equations using differential and integral equations.
* Solve governing equations for external laminar and turbulent forced convection flows over a flat plate with viscous dissipation effects.
* Solve governing equations for internal laminar and turbulent flows in pipes and ducts with developing velocity and temperature fields.
* Develop and solve governing boundary layer equations for free convective laminar and turbulent flows through a vertical channel and horizontal enclosure.
* Develop and solve governing boundary layer equations for combined convection of external and internal flows.
* Analyze convective heat transfer through porous media including boundary layer solutions for 2D forced convection, and natural convection.

## UNIT-I

**Introduction:** Forced, free & combined convection – convective heat transfer coefficient – Application of dimensional analysis to convection – Physical interpretation of dimensionless numbers.

**Equations of Convective Heat Transfer:** Continuity, Navier-Strokes equation & energy equation for steady state flows – similarity – Equations for turbulent convective heat transfer – Boundary layer equations for laminar, turbulent flows – Boundary layer integral equations.

## UNIT-II

**External Laminar Forced Convection:** Similarity solution for flow over an isothermal plate – integral equation solutions – Numerical solutions – Viscous dissipation effects on flow over a flat plate.

**External Turbulent Flows:** Analogy solutions for boundary layer flows – Integral equation solutions – Effects of dissipation on flow over a flat plate.

## UNIT-III

**Internal Laminar Flows:** Fully developed laminar flow in pipe, plane duct & ducts with other cross-sectional shapes – Pipe flow & plane duct flow with developing temperature field

– Pipe flows & plane duct flow with developing velocity & temperature fields.

**Internal Turbulent Flows:** Analogy solutions for fully developed pipe flow –Thermally developing pipe & plane duct flow.

## UNIT – IV

**Natural Convection:** Boussineq approximation – Governing equations – Similarity – Boundary layer equations for free convective laminar flows – Numerical solution of boundary layer equations.

Free Convective flows through a vertical channel across a rectangular enclosure – Horizontal enclosure – Turbulent natural convection.

## UNIT – V

**Combined Convection:** Governing parameters & equations – laminar boundary layer flow over an isothermal vertical plate – combined convection over a horizontal plate – correlations for mixed convection – effect of boundary forces on turbulent flows – internal flows - internal mixed convective flows – Fully developed mixed convective flow in a vertical plane channel & in a horizontal duct.

## UNIT - VI

**Convective Heat Transfer Through Porous Media:** Area weighted velocity – Darcy flow model – energy equation – boundary layer solutions for 2-D forced convection – Fully developed duct flow – Natural convection in porous media – filled enclosures – stability of horizontal porous layers.

## TEXT BOOK:

1. Introduction to Convective Heat Transfer Analysis – Patrick H. Oosthuigen & David Naylor (MCH)

## REFERENCE BOOK:

1. Convective Heat & Mass Transfer – Kays & Crawford (TMH)

# THERMAL AND NUCLEAR POWER PLANTS

**(Elective-III)**

## SUBJECT CODE: 16MTE1017

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To know the principle of combustion and its analysis
* To gain the concept of all the cycles and its application for power generation
* To provide the students with an introduction to nuclear reactor technology with particular emphasis of power generation
* To know that the factors affecting the economy of power generation

## COURSE OUTCOMES:

* Perform volumetric, gravimetric and flue gas analysis on combustion of coal.
* Understand working of a steam power plant including subsystems like fuel handling, boilers, ash handling, cooling towers, turbines and condensers.
* Perform thermal analysis of combined cycle gas turbine power plant including cogeneration, waste heat recovery, fluidized bed combustion and IGCC power plants.
* Describe methods of enriching uranium, applications, safety, economics and future of nuclear power plants.
* Perform economics of power generation including load factor, utilization factor, economic load sharing, depreciation, specific economic energy.
* Describe various pressure, temperature and flow measuring instruments. Analyze combustion gases for pollutants.

## UNIT –I

**Introduction** – Sources of Energy, types of Power Plants, Direct Energy Conversion System, Energy Sources in India, Recent developments in Power Generation. Combustion of Coal, Volumetric Analysis, Gravimetric Analysis, Flue gas Analysis.

## UNIT –II

**Steam Power Plants: Introduction** – General Layout of Steam Power Plant, Modern Coal- fired Steam Power Plants, Power Plant cycles, Fuel handling, Combustion Equipment, Ash handling, Dust Collectors.

Steam Generators: Types, Accessories, Feed water heaters, Performance of Boilers, Water Treatment, Cooling Towers, Steam Turbines, Compounding of Turbines, Steam Condensers, Jet & Surface Condensers.

## UNIT - III

**Gas Turbine Power Plant**: Cogeneration, Combined cycle Power Plants, Analysis, Waste- Heat Recovery, IGCC Power Plants, Fluidized Bed Combustion – Advantages & Disadvantages.

## UNIT -IV

**Nuclear Power Plants**: Nuclear Physics, Nuclear Reactors, Classification – Types of Reactors, Site Selection, Methods of enriching Uranium, Applications of Nuclear Power Plants.

Nuclear Power Plants Safety: By-Products of Nuclear Power Generation, Economics of Nuclear Power Plants, Nuclear Power Plants in India, Future of Nuclear Power.

## UNIT -V

**Economics of Power Generation:** Factors affecting the economics, Load Factor, Utilization factor, Performance and Operating Characteristics of Power Plants. Economic Load Sharing, Depreciation, Energy Rates, Criteria for Optimum Loading, Specific Economic energy problems.

## UNIT - VI

**Power Plant Instrumentation:** Classification, Pressure measuring instruments, Temperature measurement and Flow measurement. Analysis of Combustion gases, Pollution

* Types, Methods to Control.

## TEXT BOOKS:

* 1. Power Plant Engineering / P.K. Nag / TMH.
  2. Power Plant Engineering / R.K. Rajput / Lakshmi Publications.

## REFERENCEBOOKS:

1. Power Plant Engineering / P.C.Sharma / Kotaria Publications.
2. Power Plant Technology / Wakil.

# THERMAL MEASUREMENTS AND PROCESS CONTROLS

**(Elective-IV)**

## SUBJECT CODE: 16MTE1018

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* To improve concept and design of different pressure measuring instruments
* To improve concept and design of different flow measuring instruments
* To improve concept and design of different temperature measuring instruments
* To improve concept and design of level measurement by using different methods

## COURSE OUTCOMES:

* Understand general concepts in measuring instruments including static and dynamic characteristics.
* Understand various static and dynamic, vacuum, low and high pressure measuring instruments.
* Understand various flow measuring devices like obstruction meters, pressure probes, thermal anemometers, compressible fluid flow measurement instruments.
* Understand various temperature measuring instruments like thermometers, thermocouples, pyrometers.
* Understand various instruments that measures fluid level, density, velocity, viscosity, moisture content, humidity, thermal conductivity.
* Understand process control design tools like transfer functions, signal flow graphs. Evaluate control system stability using steady state and transient regulations.

## UNIT-I

**General concepts –** fundamental elements of a measuring instrument. Static and dynamic characteristics – errors in instruments – Different methods of measurement and their analysis

* Sensing elements and transducers.

## UNIT-II

**Measurement of pressure** – principles of pressure measurement, static and dynamic pressure, vacuum and high pressure measuring – Measurement of low pressure, Manometers, Calibration methods, Dynamic characteristics- design principles.

## UNIT-III

**Measurement of Flow**: Obstruction meters, variable area meters. Pressure probes, compressible fluid flow measurement, Thermal anemometers, calibration of flow measuring instruments. Introduction to design of flow measuring instruments.

## UNIT-IV

**Temperature Measurement**: Different principles of Temperature Measurement, use of bimetallic thermometers – Mercury thermometers, Vapor Pressure thermometers,

Thermo positive elements, thermocouples in series & parallel, pyrometry, measurement of heat flux, calibration of temperature measuring instruments. Design of temperature measuring instruments.

## UNIT-V

**Level Measurement:** Direct & indirect methods, manometric methods, float level meters, electrical conductivity, Capacitive, Ultrasonic, and Nucleonic Methods.

Measurement of density – Hydrometer, continuous weight method, Gamma rays, Gas impulse wheel.

Velocity Measurement – Coefficient of viscosity, Ostesld method, free fall of piston under gravity, torque method.

Measurement of moisture content and humidity. Measurement of thermal conductivity of solids, liquids and gases.

## UNIT-VI

**Process Control**: Introduction and need for process control principles, transfer functions, block diagrams, signal flow graphs, open and closed loop control systems – Analysis of First & Second order systems with examples of mechanical and thermal systems.

Control System Evaluation – Stability, steady state regulations, and transient regulations.

## TEXT BOOK:

1. Measurement System, Application & Design – E.O. Doeblin.

## REFERENCE BOOKS:

1. Mechanical and Industrial Measurements – R.K. Jain – Khanna Publishers.
2. Mechanical Measurements – Buck & Beckwith – Pearson.
3. Control Systems, Principles & Design, 2nd Edition – M. Gopal – TMH.

# REFRIGERATION AND AIR CONDITIONING

**(Elective-IV)**

## SUBJECT CODE: 16MTE1019

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

This course deals with the design and implementation of refrigeration and air conditioning systems.

* + To understand the principles of refrigeration and air conditioning.
  + To calculate the cooling load for different applications.
  + To select the right equipment for a particular application.
  + To design and implement refrigeration and air conditioning systems using standards.
  + Energy Conservation and Management.

## COURSE OUTCOMES:

* Describe basic elements of vapour compression system like condenser, evaporator, expansion valve and refrigerant. Calculate performance and load balancing.
* Explain the principle of compound compression using multi-evaporator and multi-stage systems using flash inter-cooling.
* Describe low temperature production systems like liquefaction, cascade and dry ice systems. Understand vapor absorption system.
* Explain the working principle, calculations of air, steam jet and unconventional refrigeration systems like thermo-electric, vortex tube, pulse tube.
* Understand requirements of comfort air-conditioning. Perform cooling load estimation under various conditions.
* Calculate bypass factor, ADP, RSHF, ESHF, GSHF for different air-conditioning systems like fresh air, recirculated air, reheat systems.

## UNIT – I

**Vapour Compression Refrigeration :** Performance of Complete vapor compression system. **Components of Vapor Compression System:** The condensing unit – Evaporators Expansion valve – Refrigerants – Properties – ODP & GWP - Load balancing of vapor compression Unit.

## UNIT – II

**Compound Compression**

Flash inter-cooling – flash chamber – Multi-evaporator & Multistage systems.

## UNIT – III

**Production of low temperature –** Liquefaction system ;Cascade System – Applications.– Dry ice system.

**Vapor absorption system** – Simple and modified aqua – ammonia system – Representation on Enthalpy –Concentration diagram.

Lithium – Bromide system Three fluid system – HCOP.

## UNIT – IV

**Air Refrigeration :** Applications – Air Craft Refrigeration -Simple, Bootstrap, Regenerative and Reduced ambient systems – Problems based on different systems.

## Steam Jet refrigeration system

Representation on T-s and h-s diagrams – limitations and applications.

**Unconventional Refrigeration system** – Thermo-electric – Vortex tube & Pulse tube – working principles.

## UNIT – V

**Air –conditioning:** Psychrometric properties and processes – Construction of Psychrometric chart. Requirements of Comfort Air –conditioning – Thermodynamics of human body – Effective temperature and Comfort chart – Parameters influencing the Effective Temperature. Summer , Winter and year round air – conditioning systems.

Cooling load Estimation: Occupants, equipments, infiltration, duet heat gain fan load, Fresh air load.

## UNIT – VI

**Air –conditioning Systems:**All Fresh air , Re-circulated air with and without bypass, with reheat systems – Calculation of Bypass Factor, ADP,RSHF, ESHF and GSHF for different systems.

**Components:** Humidification and dehumidification equipment – Systems of Air cleaning – Grills and diffusers – Fans and blowers – Measurement and control of Temperature and Humidity.

## TEXT BOOKS :

1. Refrigeration & Air Conditioning – C.P. Arora(TMH)
2. Refrigeration & Air Conditioning – Arora & Domkundwar – Dhanpat Rai

## REFERENCE BOOKS:

1. Refrigeration and Air Conditioning :Manohar Prasad
2. Refrigeration and Air Conditioning : Stoecker – Mc Graw Hill
3. Principles of Refrigeration – Dossat (Pearson)
4. Refrigeration and Air Conditioning : Ananthanarayana (TMH)
5. Refrigeration and Air Conditioning : Jordan and – Prentice Hall, Preister
6. Refrigeration and Air Conditioning : Dossat – Mc Graw Hill

# JET PROPULSION AND ROCKETRY

**(Elective-IV)**

## SUBJECT CODE: 16MTE1020

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| **L** | **P** | **C** | **INT** | **EXT** |
| **4** | **0** | **4** | **40** | **60** |

**COURSE OBJECTIVES:**

* Given the basic geometry and idealized component performance, to be able to estimate the thrust and specific impulse of a gas turbine and a rocket engine from fluid and thermodynamic principles.

## COURSE OUTCOMES:

* Perform gas turbine cycle thermodynamic analysis including on compressors and turbines, blade aerodynamics.
* Understand fundamentals of jet propulsion, and classify them into turbojet, turbofan, turboprop, rocket, ramjet engines.
* Conduct performance analysis on subsonic and supersonic nozzles.
* Explain aero-thermo chemistry of combustion products. Describe composition and manufacturing methods of solid propellants.
* Perform design calculations for solid rocket motor design. Design injectors, propellant tank, pump and pressure feed systems, combustion chamber that uses liquid propellants.
* Design ramjet and integral rocket ramjet propulsion system for critical, super-critical and sub-critical operation of air intake.

## UNIT - I

**Turbo Jet Propulsion System:**

Gas turbine cycle analysis – layout of turbo jet engine. Turbo machinery- compressors and turbines, combustor, blade aerodynamics, engine off design performance analysis

## Flight Performance:

Forces acting on vehicle – Basic relations of motion – multi stage vehicles.

## UNIT - II

**Principles of Jet Propulsion and Rocketry:**

Fundamentals of jet propulsion, Rockets and air breathing jet engines – Classification – turbo jet , turbo fan, turbo prop, rocket (Solid and Liquid propellant rockets) and Ramjet engines.

## UNIT - III

**Nozzle Theory and Characteristics Parameters:**

Theory of one dimensional convergent – divergent nozzles – aerodynamic choking of nozzles and mass flow through a nozzle – nozzle exhaust velocity – thrust, thrust coefficient, Ac / At of a nozzle, Supersonic nozzle shape, non-adapted nozzles, summer field criteria, departure from simple analysis – characteristic parameters – 1) characteristic velocity, 2) specific impulse 3) total impulse 4) relationship between the characteristic parameters 5) nozzle efficiency, combustion efficiency and overall efficiency.

## UNIT - IV

**Aero Thermo Chemistry of the Combustion Products:**

Review of properties of mixture of gases – Gibbs – Dalton laws – Equivalent ratio, enthalpy changes in reactions, heat of reaction and heat of formation – calculation of adiabatic flame temperature and specific impulse – frozen and equilibrium flows.

## Solid Propulsion System:

Solid propellants – classification, homogeneous and heterogeneous propellants, double base propellant compositions and manufacturing methods. Composite propellant oxidizers and binders. Effect of binder on propellant properties. Burning rate and burning rate laws, factors influencing the burning rate, methods of determining burning rates.

## UNIT - V

Solid propellant rocket engine – internal ballistics, equilibrium motor operation and equilibrium pressure to various parameters. Transient and pseudo equilibrium operation, end burning and burning grains, grain design. Rocket motor hard ware design. Heat transfer considerations in solid rocket motor design. Ignition system, simple pyro devices.

## Liquid Rocket Propulsion System:

Liquid propellants – classification, Mono and Bi propellants, Cryogenic and storage propellants, ignition delay of hypergolic propellants, physical and chemical characteristics of liquid propellant. Liquid propellant rocket engine – system layout, pump and pressure feed systems, feed system components. Design of combustion chamber, characteristic length, constructional features, and chamber wall stresses. Heat transfer and cooling aspects. Uncooled engines, injectors – various types, injection patterns, injector characteristics, and atomization and drop size distribution, propellant tank design.

## UNIT - VI

**Ramjet and Integral Rocket Ramjet Propulsion System:**

Fuel rich solid propellants, gross thrust, gross thrust coefficient, combustion efficiency of ramjet engine, air intakes and their classification – critical, super critical and sub-critical operation of air intakes, engine intake matching, classification and comparison of IIRR propulsion systems.

## TEXT BOOKS:

1. Mechanics and Dynamics of Propulsion – Hill and Peterson
2. Rocket propulsion elements – Sutton

## REFERENCES BOOKS:

1. Gas Turbines – Ganesan (TMH)
2. Gas Turbines & Propulsive Systems – Khajuria & Dubey (Dhanpatrai)
3. Rocket propulsion – Bevere
4. Jet propulsion – Nicholas Cumpsty

# COMPUTATIONAL METHODS LABORATARY

## SUBJECT CODE: 16MTE1102

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| **L** | **P** | **C** | **INT** | **EXT** |
| **0** | **4** | **2** | **40** | **60** |

**COURSE OBJECTIVES:**

* Provide students with an understanding of the principles of fluid mechanics, heat transfer and the numerical procedures in CFD.
* Provide students with knowledge of scientific programming (in C/C++).
* Develop programming skills to solve some specific CFD problems.

## COURSE OUTCOMES:

* Design discretized models of various structures and components used in fluid mechanics and heat transfer.
* Solve problems related to fluid laminar and turbulent flows using computational fluid dynamics software package.
* Perform various analyses for the modes of heat transfer in different structures and components.
* Write C/Matlab Programs to solve differential equations using numerical methods.
* Design discretized models of various structures and components used in fluid mechanics and heat transfer.
* Solve problems related to fluid laminar and turbulent flows using computational fluid dynamics software package.

C Programming for problem solving.

Solving Thermal Engineering problems using available packages such as T K Solver, ANSYS, CFX, STARCD, MATLAB, FLUENT etc…

🡪Thermal CFD on Engine Simulation.

🡪 Flame Propagation in Engine Cylinder using CFD.