

DEPARTMENT OF MECHANICAL ENGINEERING
M TECH. (Heat Transfer in Energy Systems)
SCHEME OF INSTRUCTION AND EXAMINATION
(with effect from 2015-16 academic year)

I – SEMESTER

| Code No. | Course title | Scheme of Instruction | | | Scheme of Examination | | | Total | Credits |
|--------------|---|-----------------------|----------|-----------|-------------------------|--------------------|------------|------------|-----------|
| | | Lec. | Tut. | Total | Duration of Exam. (hrs) | Theory /Lab./ Viva | Sess. | | |
| HTES1.1 | Mathematical Methods in Engineering | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES1.2 | Conduction and Radiation Heat Transfer | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES1.3 | Advanced Fluid Mechanics | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES1.4 | Measurements in Heat Transfer | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES1.5 | Elective Subject 1 a)Advanced Optimization Techniques b) Gas Turbines and Jet Propulsion c)Gas Dynamics | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES1.6 | Elective Subject 2 a)Solar Energy Technology b) Energy Conservation and Recovery Systems c) Introduction to Turbulence | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES1.7 | Thermo Fluids Lab | -- | 3 | 3 | Viva-Voce | 50 | 50 | 100 | 2 |
| HTES1.8 | Seminar 1 | | 3 | 3 | Viva-Voce | 50 | 50 | 100 | 2 |
| Total | | 24 | 6 | 30 | | 520 | 280 | 800 | 28 |

Note : The viva-voce for the labs / seminars shall be held with the course instructor/ faculty member and an external examiner nominated by the university from any academic institution / industry / R & D organization.

II – SEMESTER

| Code No. | Course title | Scheme of Instruction | | | Scheme of Examination | | | Total | Credits |
|--------------|---|-----------------------|----------|-----------|-------------------------|-------------------|------------|------------|-----------|
| | | Lec. | Tut. | Total | Duration of Exam. (hrs) | Theory Lab./ Viva | Sess. | | |
| HTES2.1 | Convection Heat Transfer | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES2.2 | Thermal Environmental Engineering | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES2.3 | Design of Thermal Equipment | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES2.4 | Boiling and Two-phase Flow Heat Transfer | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES2.5 | Elective - I a)Advanced Finite Element Analysis b) Turbo machines c) Hydel Power and Wind Energy | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES2.6 | Elective - II a) Energy Management b)Computational Fluid Dynamics c)Thermal and Nuclear Power Plants | 4 | -- | 4 | 3 | 70 | 30 | 100 | 4 |
| HTES2.7 | Computational Lab | -- | 3 | 3 | Viva-Voce | 50 | 50 | 100 | 2 |
| HTES2.8 | Seminar 2 | | 3 | 3 | Viva-Voce | 50 | 50 | 100 | 2 |
| Total | | 24 | 6 | 30 | | 520 | 280 | 800 | 28 |

Note : The viva-voce for the labs / seminars shall be held with the course instructor/ faculty member and an external examiner nominated by the university from any academic institution / industry / R & D organization.

III – SEMESTER

| Code No | Course title | Scheme of Examination | Total Marks | Credits |
|---------|----------------------------|-----------------------|-------------|-----------|
| DXX3.1 | Dissertation (Preliminary) | Viva-voce | 100 | 12 |

Note : The Dissertation shall be evaluated through Viva–Voce examination by a committee with HOD, Chairman, Board of studies and Research Guide as members. The marks shall be awarded in the ratio of 30, 30, and 40 percent by the members respectively.

IV – SEMESTER

| Code No | Course title | Scheme of Examination | Total Marks | Credits |
|---------|----------------------|-----------------------|-------------|-----------|
| DXX4.1 | Dissertation (Final) | Viva-voce | 100 | 12 |

Note: The Dissertation shall be evaluated through Defence and Viva–Voce examination by a committee with an External Examiner nominated by University, HOD, Chairman, Board of studies and Research Guide as members. The marks shall be awarded in the ratio of 20, 20, 20, and 40 percent by the members respectively.

I SEMESTER

HTES 1.1 Mathematical Methods in Engineering

System of Simultaneous equations: Consistency of Linear System of equations (non-homogeneous and homogeneous), solving linear system of equations: Gauss elimination method, Gauss-Jordan method,, Numerical methods, Jacobs Gauss-Siedal method, LU factorization method, characteristic equation, Eigen values and Eigen vectors of a matrix, their properties, finding the largest Eigen value of a matrix, Rayleigh's power method. (two questions to be set from this unit)

Partial Differential Equations: Formation of PDE, Solution of a PDE, linear equations of first order, Lagrange's linear equations, solving equations of the type $(dx/P) = (dy/P) = (dz/R)$ by methods of grouping and multipliers, non-linear equations of first order, Charpit's method. (one question from this unit)

Partial Differential Equations of second and higher order: Homogeneous linear equations with constant coefficients of any order, non-homogeneous linear equations (reducible and irreducible), non-linear equations of second order, Monge's method. (one question from this unit)

Applications of Partial Differential Equations: Method of separation of variables, PDE of engineering vibrations of a stretched string wave equation, one dimensional heat flow, two dimensional heat flow in the steady state, solution of Laplace equation in Cartesian and polar co-ordinates, (two questions to be set from this unit)

Numerical solutions of Partial differential equations: classification of second order PDE's, elliptic equations, solution of Laplace equation and Poisson's equation using Jacob and Gauss-Seidal methods, Parabolic equations, solution of heat equation, Schmidt explicit formula, Crank-Nicolson formula, Bendre-schmidt recurrence relation, Hyperbolic equations, solution of wave equation.(Two questions to be set from this unit)

Reference books:

1. Higher Engineering Mathematics – B.S. Grewal
2. Numerical Methods in Engineering – S.S.Sastry
3. Numerical Methods in Engineering and Science – B.S.Grewal
4. Partial Differential Equations - Raisinghania

HTES 1.2 Conduction and Radiation Heat Transfer

Conduction: heat equation in Cartesian, cylindrical and spherical coordinates –Steady one dimensional heat conduction with and without heat generation in different geometries, thermal resistance network, composite systems, effect of variable thermal conductivity, heat transfer in common configurations, conduction shape factor. Steady two dimensional heat conduction: solution by method of separation of variables.

Extended surfaces heat transfer: different fin geometries, differential equation for fin of uniform and variable cross sections, solution of fin equation for different boundary conditions, fin performance.

Transient conduction: lumped system analysis, transient conduction in various geometries, one term approximate solutions, use of Heisler's charts, semi infinite solids, transient conduction in

multi dimensional systems: product solution for transient conduction in various geometries, Conduction with phase change - integral method, solidification and melting - numerical methods.

Radiation: Review of radiation principles - laws of thermal radiation - surface properties - radiative heat exchange among diffuse, gray and non-gray surfaces separated by non-participating media - gas radiation and radiation transfer in enclosures containing absorbing and emitting media - interaction of radiation with conduction and convection.

References:

1. Analysis of heat and mass transfer by Eckert and Drake, McGraw-Hill
2. Fundamentals of heat transfer by Grober, Erk and Grigull, McGraw-Hill
3. Fundamentals of heat transfer by Incropera and Hewitt
5. Conduction heat transfer by Schneider, Eddison Wesley
6. Radiation heat transfer by Sparrow and Cess, McGraw-Hill
7. Radiation heat transfer by H.C. Hottel and A.F. Sarofin
8. Thermal radiation by Siegel and Howell.

HTES 1.3 Advanced Fluid Mechanics

Ideal and non-ideal flows, General equations of fluid motion, Navier-Stokes equations and their exact solutions, Boundary layer theory, solutions to flow over external surfaces, flow through internal surfaces, integral methods, steady laminar and turbulent incompressible flows, Introduction to compressible viscous flows, governing equations, Fanno and Rayleigh lines, normal and oblique shocks

Reference books:

1. Boundary layer theory, Schlichting by McGraw Hill
2. Foundations of fluid mechanics by Yuan, Prentice Hall
3. Turbulence, Bradshaw by Springer-Verlag

HTES 1.4 Measurements in Heat Transfer

Analysis of experimental data: Causes and types of experimental errors, Error analysis on a commonsense basis, Uncertainty analysis, Statistical analysis of experimental data probability distributions, The Gaussian or normal error distribution, Probability graph paper, The Chi-square test of goodness of fit, Method of least squares, Standard deviation of the mean, Graphical analysis and curve fitting, General considerations in data analysis.

Basic electrical measurements and sensing devices - Transducers, The variable - Resistance transducers, The differential transformer (LVDT), Capacitive transducers, Piezoelectric transducers, Photoelectric effects, Photoconductive transducers, Photovoltaic cells, Ionization transducers, Magnetometer search coil: Hall-effect transducers.

Pressure measurement: Dynamic response considerations, Mechanical pressure - Measurement devices, Dead-weight tester, Bourdon-tube pressure gauge, Diaphragm and bellows gauges, The Bridgman gauge, Low-pressure measurement. The McLeod gauge, Pirani thermal-conductivity gauge, The Knudsen gauge, The ionization gauge, The alphasatron.

Flow measurement: Positive displacement methods flow - Obstruction methods, Practical consideration for obstruction meters, The sonic nozzle. Flow measurement by drag effects, Hot-wire and hot-film anemometers, Magnetic flow meters, Flow- visualization methods, The shadowgraph, The schlieren, The interferometer, The Laser Doppler Anemometer (LDA), Smoke methods, Pressure probes, Impact pressure in supersonic flow.

The measurement of temperature: Temperature scales. The ideal-gas thermometer, Temperature measurement by mechanical effect. Temperature measurement by electrical effects, Temperature measurement by radiation, Effect of heat transfer on temperature measurement, Transient response of thermal systems, Thermocouple compensation, Temperature measurements in high-speed flow.

Thermal and transport Property measurement: Thermal conductivity measurements, Thermal conductivity of liquids and gases, Measurement of viscosity, Gas diffusion, Calorimetry, Convection heat-transfer measurements. Humidity measurements, Heat-flux meters.

Thermal radiation measurements: Detection of thermal radiation, Measurement of emissivity, Reflectivity and transmissivity measurements, Solar radiation measurements.

Reference books:

1. Experimental Methods for Engineers by Holman, J.P.
2. Mechanical Measurements by Thomas G. Beckwith, N. Newis Buck.
3. Measurements in Heat Transfer by Eckert and Goldstein.

HTES 1.5 Elective I

(a) Advanced Optimization Techniques

Geometric programming (G.P): Solution of an unconstrained geometric programming, differential calculus method and arithmetic method. Primal dual relationship and sufficiency conditions. Solution of a constrained geometric programming problem (G.P.P), Complementary Geometric Programming (C.G.P)

Dynamic programming(D.P): Multistage decision processes. Concepts of sub optimization and Principle of optimality, computational procedure in dynamic programming calculus method and tabular methods. Linear programming as a case of D.P. and continuous D.P.

Integer programming(I.P): Graphical representation. Gomory's cutting plane method. Bala's algorithm for zero-one programming problem. Branch-and-bound method, Sequential linear discrete Programming, Generalized penalty function method.

Stochastic Programming (S.P.): Basic Concepts of Probability Theory, Stochastic Linear programming.

Non-traditional optimization techniques: Multi-objective optimization - Lexicographic method, Goal programming method, Genetic algorithms, Simulated annealing, Neural Networks based Optimization.

Reference books:

1. Operations Research- Principles and Practice by Ravindran, Phillips and Solberg, John Wiley
2. Introduction to Operations Research by Hiller and Lieberman, Mc Graw Hill
3. Engineering Optimization - Theory and Practice by Rao, S.S., New Age International (P) Ltd. Publishers.

4. Engineering Optimization By Kalyanmanai Deb, Prentice Hall of India, New Delhi.
5. Genetic Algorithms - In Search, Optimization and Machine Learning by David E. Goldberg, Addison-Wesley Longman (Singapore) Pvt. Ltd.

(b) Gas Turbines and Jet Propulsion

Thermodynamic cycle analysis of gas turbines; open and closed cycles, axial flow turbines, blade diagrams and design of blading, performance characteristics, **First-second and third laws of Thermodynamics.**

Centrifugal and axial flow compressors, blowers and fans, theory and design of impellers and blading, matching of turbines and compressors.

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

Thermodynamic cycle analysis and efficiencies of propulsive devices, thrust equation, classification and comparison of ram jets, turbojets, pulse jets and rockets.

Performance of turbo-prop, turbo-jet and turbo-fan engines, augmentation of thrust.

Reference books:

1. Fundamentals of Turbo machines – Shephard
2. Practise on Turbomachines – G. Gopalakrishnan & D. Prithviraj, SciTech Publishers, Chennai.
3. Elements of Gas Dynamics – Yahya
4. Gas Turbines – Theory and practice – Zucrow
5. Turbines, Pumps, Compressors – Yahya
6. Axial Flow Compressors – Horlock.
7. Gas Turbines- Cohen, Roger & Sarvanamuttu

c) Gas Dynamics

Conservation laws for compressible flow, Concepts of compressible flow, Effect of Mach number on compressibility, Isentropic flow with variable area, Effect of area variation, Impulse function, Fanno flow - Variation of flow properties, Variation of Mach number with duct length, Isothermal flow with friction, Rayleigh flow - Variation of flow properties, Maximum heat transfer, Normal shock waves-Variation of flow properties, Prandtl Meyer relation, Rankine-Hugoniot relations, strength of shock wave, Oblique shock waves – Governing equations, Variation in flow properties, **Propulsion Systems.**

Reference books:

1. Fundamentals of Compressible flow with Aircraft and Rocket Propulsion, S.M.Yahya, New age International (P) Ltd., Publishers
2. Fundamentals of Compressible fluid dynamics, P.Balachandran, PHI Learning (P) Ltd.,
3. Gas Dynamics: Theory and Applications, George Turrel, John Wiley & Sons, 1997
4. Fundamentals of Gas dynamics, Robert D Zucker and Oscar Biblazi, John Wiley & Sons, 2002
5. Molecular gas dynamics: theory, techniques and application, Yoshio Sone Birk Hauser,

- Boston,
6. Applied Gas Dynamics, Ethirajan Rathakrishnan, John Wiley & Sons, 2010.

HTES 1.6 Elective – II

a) Solar energy technology

Current alternate energy sources - thermodynamic view point and conversion methods. Solar Radiation, direct and diffuse radiation, measurement and estimation.

Components of solar energy systems, collector performance. Radiation and meteorological data processing, long term conversion factors. Water and air heating collectors. Concentrating collectors design procedure. Storage systems.

System configurations and system performance prediction, simulations, solar thermal systems applications to power generation, heating and cooling. Solar passive devices : solar stills, ponds, greenhouse, dryers. Trombe wall, overhangs and winged walls, **Solar Economics**.

Reference books:

1. Principles of solar engineering – Kreith and Kerider
2. Solar energy thermal processes – Duffie and Beckman
3. Solar energy – Sukhatme
4. Solar energy – Garg
5. Solar energy – Magal
6. Solar energy – Tiwari and Suneja
7. Power plant technology – El Wakil

(b) Energy Conservation and Recovery Systems

Basic principles of energy conservation - Energy analysis and application of laws of thermodynamics - Energy consumption and rejection patterns for different thermal processes such as air-conditioning, drying, thermal power generation, boilers, furnaces etc., - Energy conservation potential in different thermal processes - Types and applications of different energy recovery equipment's such as run-around coils, regenerators, recuperators, economizers, heat pipe heat exchangers, plate heat exchangers, heat pumps, steam accumulators, storage boilers, waste heat boilers, etc., - Sensible heat, latent heat and thermo-chemical energy storage systems - Thermal insulation and its role in energy conservation - Cogeneration - Case studies.

Reference books:

1. Handbook of Industrial Energy Conservation by S.David hu, Van Nostrand Reinhold Publ., 1983.
2. Handbook of Energy Engineering by D.Paul Mehta and Albert Thumann, The Fairmont Press Inc., 1989.
3. Design and Management for Energy Conservation by P.W.O'Callaghan, Rergamon Press, 1981.
4. Heat Pumps by K.Brodowicz and T. Dyakowski, Buttormorth-Heinemann Press., 1993.

(c) Introduction to Turbulence

Laminar Turbulent Transition, Experimental Evidence, Fundamentals of Stability theory, the Orr-Sommerfeld equation, Curves of neutral stability and the indifference Reynolds number, Plate boundary

layer, experimental confirmation, effects of pressure gradient, suction, compressibility and wall roughness, instability of the boundary layer for three dimensional perturbations.

Fundamental equations for mean motion, the k-equation, energy equation, boundary layer equations for plane flows; Internal flows, universal law of the wall, friction law, mixing length, fully developed internal flows, generalized law of the wall, pipe flow, slender channel theory.

Incompressible boundary layers, defect formulation, equilibrium boundary layers, boundary layer on a flat plate at zero incidence, boundary layers with separation, integral methods, field methods, thermal boundary layers; Compressible boundary layers, skin friction and Nusselt number, natural convection.

Free shear layers in turbulent flow, plane and axi-symmetric free jets, mixing layers, plane and axi-symmetric wakes, buoyant jets, plane wall jet; Turbulence modeling, zero equation, one equation and two equation models, derivation of the model equations, RNG model, DNS and large eddy simulation (LES).

Reference books:

1. Schlitching, H., Gersten, K., Boundary Layer Theory, Springer –Verlag, 2004.
2. Hinze, J. O., Turbulence, Second Edition, McGraw-Hill, 1975.
3. Biswas, G., Easwaran, V., (Eds.), Turbulent flows, Narosa Publishers, 2002.

II SEMESTER

HTES 2.1 Convection Heat Transfer

Derivation of equations of conservation of mass, momentum and energy, boundary layer approximations, similarity solutions for laminar boundary layer over flat plate, integral methods, forced convection in turbulent flows, eddy diffusivity, momentum and energy equation in turbulent shear layer, analogy between momentum and heat transfer, liquid metal heat transfer, natural convection from a vertical plate and cylinders, free convection in enclosed spaces, combined free and forced convection, heat transfer in MHD systems, transpiration cooling.

Reference books:

1. Analysis of heat and mass transfer by E.R.G. Eckert and Robert M. Drake, McGraw Hill
2. Boundary layer theory by Schlichting
3. Heat transfer by Gebhart
4. Natural convection heat and mass transfer by Y. Jaluria , Pergamon press
5. Convective heat and mass transfer by Kays, W.M., and Crawford, M.E., McGraw Hill

HTES 2.2 Thermal Environmental Engineering

Introduction: Thermodynamic consideration, Heat transfer considerations: Refrigeration. Vapour compression cycles, Refrigerants, Absorption refrigeration; Psychromatrices: Thermodynamic properties of moist air; Psychrometric charts, Cooling towers and evaporators - Condensers - Cooling and Dehumidifying coils, Air conditioning calculations.

References:

1. Thermal Environmental Engineering by Threkled, J.L.
2. Refrigeration and Air conditioning by Stoker, W.F.

HTES 2.3 Design of Thermal Equipment

Classification of heat exchangers; basic design methods for heat exchangers, double pipe heat exchangers, parallel and counter flow, design of shell and tube heat exchangers; TEMA codes; flow arrangements for increased heat recovery; condensation of single vapors, mixed vapors; design considerations for different plate type heat exchangers; regenerators, steam generators, condensers, radiators for space power plant, cooling towers, power plant heat exchangers, furnace calculations.

Reference books:

1. Process heat transfer by Donald Kern, Tata McGraw Hill Publishing Company Ltd.
2. Heat Exchanger Selection, Rating and Thermal Design by Sadic Kakac and Hongton Liu, CRC Press
3. Process Heat Transfer by Sarit Kumar Das, Narosa Publishing House Pvt.Ltd.
4. Heat exchanger design by Press and N. Ozisik
5. Standards of the Tubular Exchange Manufacturers Association, TMEA, New York
6. Heat Exchangers by Kakac, S., A.E. Bergles and F. Mayinger (Eds.) Hemisphere, 1981
7. Compact Heat exchangers by Kays, W.M., and A.L. London, McGraw Hill

HTES 2.4 Boiling and Two-Phase flow Heat Transfer

Definitions: Types of flow; volumetric concentration; void fraction; volumetric flux; relative velocity; drift velocity; flow regimes; flow maps; analytical models.

Homogeneous flow: One-dimensional steady homogeneous equilibrium flow; homogeneous friction factor; turbulent flow friction factor

Separated flow: Slip; Detailed discussion on bubbly, slug and annular flow; Lockhart-Martinelli method for pressure drop calculation; pressure drop for flow with boiling; flow with phase change.

Drift flow model: General theory; gravity flows with no wall shear; correlation to simple theory; Armond or Bankoff flow parameters.

Boiling: Regimes of boiling; nucleation; growth of bubbles; bubble motion at a heating surface; heat transfer rates in pool boiling; Rohsenow correlation for nucleate boiling. Zuber's theory for critical heat flux. Bromley theory for film boiling; forced convection boiling; Chen's correlation for flow boiling; maximum heat flux or burn out.

Condensation: Nusselt's theory; boundary layer treatment of laminar film condensation; experimental results for vertical and horizontal tubes; condensation inside a horizontal tube.

Reference books:

1. One-dimensional two-phase flow by Wallis, McGraw-Hill
2. Two-phase flow and heat transfer by Butterworth and Hewitt, Oxford
3. Convective boiling and condensation by J.G. Collier, McGraw-Hill
4. Boiling heat transfer and two phase flow by L.S. Tong, John Wiley
5. Transport processes in boiling and two-phase flow systems by Hsu and Graham, McGraw Hill

HTES 2.5 Elective – I

a) Advanced Finite Element Analysis

Introduction, Finite elements of an elastic continuum - displacement approach, generalization of the finite element concept - weighted residuals and variational approaches. Plane stress and plane strain, Axisymmetric stress analysis, 3-D stress analysis.

Element shape functions - Some general families of C continuity, curved, isoparametric elements and numerical integration. Some applications of isoparametric elements in two-and-three dimensional stress analysis.

Bending of thin plates - A C continuity problem. Non-conforming elements, substitute shape functions, reduced integration and similar useful tricks. Lagrangian constraints in energy principles of elasticity, complete field and interface variables (Hybrid method).

Shells as an assembly of elements, axisymmetric shells, semi-analytical finite element processes - Use of orthogonal functions, shells as a special case of 3-D analysis. Steady-state field problems - Heat conduction, electric and magnetic potentials, field flow.

The time domain, semi-discretization of field and dynamic problems and analytical solution procedures. Finite element approximation to initial value - Transient problems.

Reference books:

1. The Finite Element Method by Zienkiewicz, O.C.
2. The Finite Element Methods in Engineering by Rao, S.S.
3. Concepts and Applications of Finite Element Analysis by Cook, R.D.
4. Applied Finite Element Analysis by Segerland, L.J.

b) Turbo machines

Definition and classification of turbo machines; principles of operation; specific work and its representation on T-s and h-s diagrams; losses and efficiencies; energy transfer in turbo machines; Euler equation of turbo machinery.

Flow mechanism through the impeller – velocity triangles, ideal and actual flows, slip and its estimation; degree of reaction - impulse and reaction stages; significance of impeller vane angle.

Similarity; specific speed and shape number; cavitations in pumps and turbines; performance characteristics of pumps and blowers; surge and stall; thin aerofoil theory; cascade mechanics

Steam turbines - flow through nozzles, compounding, effect of wetness in steam turbines; gas turbines; hydraulic turbines – Pelton, Francis and Kaplan turbines, draft tube, performance and regulation of hydraulic turbines.

Reference books:

1. Yahya, S. M., Turbines, Compressors and Fans, Tata McGraw-Hill, 1983.
2. Gopalakrishnan, G. and Prithviraj, D., Treatise on Turbo machines, Schitech Publications, 2002
3. Shepherd, D. G., Principles of Turbomachinery, Macmillan Publishing Company, 1957
4. Csanady, G. T., Theory of Turbomachines, McGraw-Hill, 1964.
5. Dixon, S. L., Fluid Mechanics, Thermodynamics of Turbomachinery, Third Edition, Pergamon Press, 1978.

6.Nechleba, M., Hydraulic Turbine, Arita, 1957.

c) Hydel power and wind energy

Hydel Power: Stream flow data and water power estimates, use of hydrographs

Hydraulic turbine, characteristics and part load performance, design of wheels, draft tubes and penstocks, cavitation; plant layouts; costing of water power.

Wind Power and Engineering: Estimates of wind energy potential, wind maps; aerodynamic and mechanical aspects of wind machine design.

Wind tunnel simulations, conversion and storage methods; industrial applications. Instrumentation for wind velocity measurements

Reference books:

- i. Non-Conventional Energy Systems by K.Mittal, Wheeler
- ii. Non-Conventional Energy by Ashok V Desai, Wiley Eastern Publications
- iii. Non-Convectional Energy Sources by G.D.Rai
- iv. Renewable Energy Sources and Emerging Technologies by D.P.Kothari, K.C.Singal, Rakesh Ranjan, PHI Learning Pvt.Ltd
- v. Wind Energy Engineering by Pramod Jain, Mc Graw Hill
- vi. Wind Energy explained: Theory, Design and applications by James F Manwell, Jon G.Mc.Gowan and Anthony L Rogers, Wiley black well
- vii. Introduction to Hydro Energy Systems by Wagner, Herman –Josef, Mathur,Jyotirmoy, Springer Verlag, Berlin.
- viii. Hydro Electrical Energy, Tamra orr, Cherry lake Publishing.

HTES 2.6 Elective - IV

a) Energy Management

Periods per week : 4

Examination : 70 ; Sessionals : 30

Examination (Theory): 3hrs.

Credits : 4

Introduction: Energy Scenario – World and India, Energy Resource Availability in India, Energy Consumption, Energy intensive industries – an overview, Need for Energy Conservation, Role of Energy manager, Principles of Energy Management. Energy conservation Act 2003.

Instruments for Energy auditing: Instrument characteristics – sensitivity, readability, accuracy, precession, hystersis, Error and Calibration, Measurement of Flow, Velocity, Pressure, Temperature, Speed, Lux, Humidity, Analysis of stack, Water quality, Fuel quality and Power

Energy Audit: Definition and Concepts, Types of Energy Audits – Basic Energy Concepts – Energy audit questionnaire, Data Gathering – Analytical Techniques. Energy Consultant: Need of Energy Consultant – Consultant Selection Criteria

Energy Conservation: Technologies for Energy Conservation – energy flow networks – critical assesment of energy usage – Boilers, Thermic fluid heater, Furnaces, Waste heat recovery

systems, Thermal storage systems, Steam traps, Refractories, Insulation - Optimum thickness

Synthesis of alternative options and technical analysis of options, Process integration.

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

Methods of Evaluation of Projects: Payback – Annualized Costs – Investor's Rate of return – Present worth – Internal Rate of Return – Pros and Cons of the common methods of analysis – replacement analysis.

Text Books:

1. Energy Management Hand book by W.C. Turner (Ed)
2. Management by H.Koontz and Cyrill O Donnell
3. Financial Management by S.C. Kuchhal
4. Energy Management by W.R.Murthy and G.Mc Kay
5. Hamies, Energy Auditing and Conservation. Methods and Measurements, Management and Case study, Hemisphere, Washington, 1980
6. Energy Management by Trivedi, PR, Jolka KR, Commonwealth publication, New Delhi
7. Guide book for National Certificate Examination for Energy Managers and Energy Auditors (Could be downloaded from www.energymanagertraining.com)

REFERENCE:

1. Energy Management/W.R.Murphy, G.Mckay/Butterworths.
 2. Energy Management Principles/C.B.Smith/ Pergamon Press.
 3. Energy Economics/A.V.Desai/Wieley Eastern
- Industrial Energy Management and Utilization/L.C. Witte, P.S. Schmidt, D.R. Brown/
Hemisphere Publication/Washington

b) Computational Fluid Dynamics

Classification of partial differential equations - Discretization methods - finite difference and finite volume formulations –classification of PDES.

An overview of finite difference, finite element and finite volume methods. Numerical solution of parabolic partial differential equations using finite-difference and finite volume methods: explicit and implicit schemes, consistency, stability and convergence.

Numerical solution of systems of linear algebraic equations: general concepts of elimination and iterative methods, Gaussian elimination, Jacobi and Gauss-Seidel iterations, necessary and sufficient conditions for convergence of iterative schemes.

The finite volume method of discretization for diffusion problems: one dimensional steady diffusion problems, specification of interface diffusivity, source-term linearization. Discretization of transient one-dimensional diffusion problems. Solution of discretized equations using point and line iterations, strongly implicit methods and pre-conditioned conjugate gradient methods.

Numerical solution of the Navier-Stokes system for incompressible flows: stream-function vorticity and artificial compressibility methods.

Basics of grid generation- Numerical solution of hyperbolic equations - Burgers equation generation.

Reference books:

1. Tannehill, J.c., Anderson, D.A., and Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, 2nd ed., Taylor & Francis, 1997.
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. Peyret, R. and Taylor, T. D., Computational Methods for Fluid Flow, Springer- Verlag, 1983.
5. Computational Fluid Dynamics – Hoffman and Chiang, Engg Education System
6. Computational Fluid Dynamics – Anderson (TMH)
7. Computational Methods for Fluid Dynamics – Ferziger, Peric (Springer)
8. Computational Fluid Dynamics, T.J. Chung, Cambridge University
9. Computational Fluid Dynamics – A Practical Approach – Tu, Yeoh, Liu (Elsevier)
Text Book of Fluid Dynamics, Frank Chorlton, CBS Publishers.

c) Thermal and Nuclear Power plants

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.

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.

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

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.

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.

Power Plant Instrumentation: Classification, Pressure measuring instruments, Temperature measurement and Flow measurement. Analysis of Combustion gases, Pollution – Types, Methods to Control.

Reference Books:

1. Power Plant Technology / El Wakil.

2. Power Plant Engineering / P.C.Sharma / Kotaria Publications.
3. Power Plant Engineering / P.K. Nag / TMH.

(HTES1.1)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
First Semester
MATHEMATICAL METHODS IN ENGINEERING
(Effective from the admitted batch of 2015-16)
Model question paper

TIME: 3 hours

Max. Marks: 70

Answer any FIVE Questions
All questions carry equal marks

1. (a) Test the consistency and then solve the following equations by Gauss elimination method.

$$\begin{aligned} 2x + y + 3z &= 1 \\ 4x + 4y + 7z &= 1 \\ 2x + 5y + 9z &= 3 \\ 6x - y + 4z &= 2 \end{aligned}$$

- (b) Find the largest eigen value and the corresponding eigen vector of the matrix A using Rayleigh's power method.

$$A = \begin{bmatrix} -2 & 2 & -3 \\ 2 & 1 & -6 \\ -1 & -2 & 0 \end{bmatrix}$$

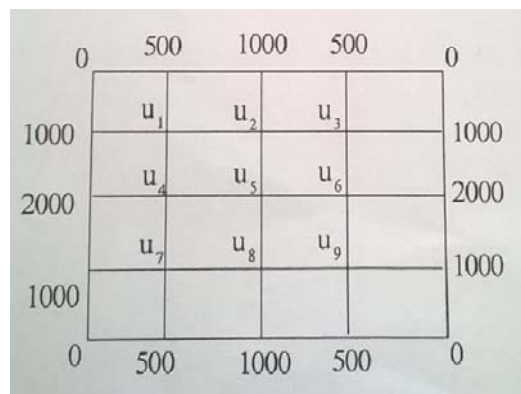
2. (a) Solve the following system of equations using Gauss-Seidel method.

$$\begin{aligned} 10x_1 - 2x_2 - x_3 - x_4 &= 3 \\ -2x_1 + 10x_2 - x_3 - x_4 &= 15 \\ x_1 + x_2 - 10x_3 + 2x_4 &= -27 \\ x_1 + x_2 + 2x_3 - 10x_4 &= 9 \end{aligned}$$

- (b) Show that the eigen values of a Hermitian matrix are real.

3. A tightly stretched string of length 'l' has its ends fastened at x=0 and x=l. The midpoint of the string is then taken to height 'h' and then released from rest in that position. Find the lateral displacement of a point of the string at time 't' from the instant of release.

4. (a) A rectangular plate has sides 'a' and 'b'. The sides $x = 0$, $x = a$ and $y = b$ are insulated and the edge $y = 0$ is kept at temperature $u_0 \cos \frac{\pi x}{a}$. Find the temperature $u(x,y)$ in the steady state.
- (b) Solve completely the two dimensional heat equation in steady state (Laplace's equation) in polar coordinates.
5. (a) Solve the differential equation $\frac{dy}{dx} = x^2 - y$, $y(0)=1$ by Picard's method to get the value of y at $x=1$. Compare it with the exact analytical solution
- (b) Find $y(0.4)$ and $y(0.5)$ by Milne's method if $y' + y = 2e^x$, $y_1 = 2.010$, $y_2 = 2.09$, $h=0.1$
6. (a) Evaluate y by Euler's method given $\frac{dy}{dx} = y - x$, $y(0) = 2$ at $x = 0.2, 0.4$ and 0.6
- (b) Apply Runge-Kutta method of order 4 to find an approximate value of y for $x = 0.2$ in steps of 0.1 if $\frac{dy}{dx} = x + y^2$ given that $y = 1$ where $x = 0$.
7. Solve the elliptical equation $u_{xx} + u_{yy} = 0$ for the square mesh with boundary values as shown below:



(use Gauss – Siedal iteration method accurate upto three decimals)

8. The transverse displacement 'u' of a point at a distance x from one end at any time t of a vibrating string satisfies the equation $\frac{\partial^2 u}{\partial t^2} = 4 \frac{\partial^2 u}{\partial x^2}$ with the boundary conditions $u = 0$ at $x = 0, t > 0$ and the initial conditions $u = x(4-x)$ and $\frac{\partial u}{\partial t} = 0$ at $t = 0$, $0 \leq x \leq 4$. Solve this equation numerically for $0 \leq t \leq 2$ taking $h=1$ and $k=0.5$.

(HTES1.2)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
First Semester
Conduction and Radiation Heat Transfer
(Effective from the admitted batch of 2013-14)
Model question paper

TIME: 3 hours

Max. Marks: 70

Answer any FIVE Questions
All questions carry equal marks

- (a) Derive an expression for the heat transfer rate from an infinitely long fin of uniform circular cross section.

(b) A solid sphere ($k=17\text{W/mK}$) of 10 mm radius has a uniform heat generation rate of 2MW/m^3 . Heat is conducted away at its outer surface to ambient air at 20°C with a convection heat transfer coefficient of $2000\text{ W/m}^2\text{K}$. Determine the steady temperatures at the centre and outside surface of the sphere.
- (a) A long hollow cylinder of inner and outer radii r_1 and r_2 respectively is heated such that its inner and outer surface are at uniform temperatures T_1 and T_2 . The thermal conductivity of the cylinder material varies with temperature as $k=k_0(1+bT)$. Find the rate of heat flow through the cylinder.

(b) A spherical vessel of 40 cm ID and 45 cm OD is covered with 5 cm thick plaster ($k=0.48\text{ W/mK}$). The thermal conductivity of the vessel material is 70 W/mK . If the inner surface of vessel is kept at 150°C while the outer surface is exposed to air at 30°C , determine the rate of heat loss from the vessel. Assume the convection heat transfer coefficient on the outside surface of the vessel is $5\text{W/m}^2\text{K}$.
- Consider a large uranium plate of thickness 5 cm and thermal conductivity $k = 28\text{ W/m}^\circ\text{C}$ in which heat is generated at a constant rate of $q_g = 6 \times 10^5$. One side of the plate is insulated and the other side is subjected to convection to an environment at 30°C with a heat transfer coefficient of $h = 60\text{W/m}^2^\circ\text{C}$. considering six equally spaced nodes with a nodal spacing of 1 cm, obtain

 - Finite difference formulation of this problem and determine
 - The nodal temperatures under steady conditions by solving these equations.

4. A long 35 cm diameter cylindrical shaft made of stainless steel 304 ($k = 14.9 \text{ W/m}^0\text{c}$, $\rho = 7900 \text{ kg/m}^3$, $c_p = 477 \text{ J/Kg}^0\text{c}$, and $\alpha = 3.95 \cdot 10^{-6} \text{ m}^2/\text{s}$) comes out of an oven at a uniform temperature of 400^0c . The shaft is then allowed to cool slowly in a chamber at 150^0c with an average convection heat transfer coefficient of $h = 60 \text{ W/m}^2\text{c}$. Determine the temperature at the center of the shaft 20 min after the start of the cooling process. Also, determine the heat transfer per unit length of the shaft during this time period. (Use one term approximate solution and also compare the result with that from charts).
5. (a) Determine the view factors associated with an enclosure formed by two spheres.
- (b) The surface of $5 \text{ m} \times 5 \text{ m} \times 5 \text{ m}$ cubical furnace are closely approximated as black surfaces. The base, top and side surfaces of the furnace are maintained at uniform temperatures of 800 K , 1500 K and 500 K respectively. Determine
- The net rate of heat transfer between the base and the side surfaces
 - The net rate of radiation heat transfer between the base and the side surfaces.
6. (a) Define the following
- Spectral transmissivity of a medium
 - Spectral absorptivity
 - Spectral emissivity
 - Beer's law
- (b) State Wein's displacement law and prove that the monochromatic emissive power of a black body is maximum when $\lambda_m T = 2900 \mu\text{mK}$.
7. (a) Explain the terms solid angle and intensity of radiation
- (b) Two large parallel planes having emissivities of 0.3 and 0.5 maintained at temperatures of 800^0c and 300^0c respectively. A radiation shield having an emissivity of 0.05 on both sides is placed between the two planes. Calculate
- Heat transfer per unit area without shield
 - The temperature of the shield and
 - Heat transfer per unit area with shield
8. Write short notes on the following:
- Electrical network method to determine radiant heat exchange between grey surfaces
 - Hottel's crossed strings method of finding view factor between two infinitely long surfaces
 - Lumped system analysis.

[HTES1.3]
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
I Semester
ADVANCED FLUID MECHANICS
Model question paper

Time: 3 hours

Max. Marks: 70

Answer any five questions

All questions carry equal marks

1. a) The following given stream function represents a two-dimensional steady state flow. $\Psi = 4(x^2 - y^2)$. Check whether the flow is irrotational or not? Find the corresponding velocity potential function.
b) Find the velocity potential function and the stream function of a doublet flow and show it diagrammatically
2. a) Prove that for a steady laminar flow between two fixed parallel plates, the velocity distribution across a section is parabolic and the average velocity is $2/3$ of the maximum velocity.
b) Oil of specific gravity 0.82 is pumped through a horizontal pipe line 15 cm in diameter and 3 km long at a rate of 900 litres per minute. The pump has an efficiency of 68% and requires 7.35 kW to pump the oil. Determine the dynamic viscosity of the oil and verify whether the oil is laminar.
3. a) Derive the Navier – Stokes equations. Also state its assumptions.
b) A pipe of 30 cm diameter inclined 30° to the horizontal is carrying gasoline (sp. gr. = 0.82). A venturimeter is fitted in the pipe to find out the flow rate whose throat diameter is 15cm. The throat is 1.2 m from the entrance along its length. The pressure gauge fitted to the venturimeter read 140 kN/m^2 and 80 kN/m^2 respectively. Find out the coefficient of discharge of venturimeter if the flow is $0.2 \text{ m}^3/\text{s}$. (b) Instead of fitting the pressure gauges, the venturimeter is connected to a U-tube containing mercury, find the reading in the mercury manometer in cm of Hg. The flow is towards the upwards direction.
4. a) Define the mixing length concept of Prandtl. How does the mixing length vary with the distance from the wall in turbulent flow?
b) A pipe 5 cm diameter is 5m long and carries a discharge of $0.005 \text{ m}^3/\text{s}$. Find the head loss due to friction. The central 2 m length of the pipe is next replaced by a pipe 7.5 cm diameter; the changes of the section being sudden. Determine the loss of head and the corresponding power due to adoption of this alternative. Take friction coefficient $f = 0.01$

for the pipe of both diameters and the contraction loss coefficient = 0.5.

5. a) Discuss the phenomenon of separation for flow over curved surface. What are the methods used to prevent the separation.
b) Water is flowing over a flat plate $2m \times 1.5m$ with a velocity of $0.2m/sec$. Find (a) thickness of boundary layer and shear stress at $1.4 m$ from the leading edge of the plate. The flow is parallel to $2 m$ side. Take $\rho = 1000kg/m^3$ and $\mu = 0.01$ poise for water. Also find the total drag force on one side of the plate.

Assume the velocity distribution in the boundary is given by

$$\frac{u}{U} = \frac{3}{2} \left(\frac{y}{\delta} \right) - \frac{1}{2} \left(\frac{y}{\delta} \right)^3$$

6. a) What do you understand by transmission efficiency of a pipe? Obtain a condition for maximum efficiency and prove that it is 66.7%. Determine the diameter of the pipe required to supply water to a turbine developing 180kW under the following condition.
Head = 100 m, Pipe length = 1000 m, $\eta = 80\%$. Take $f = 0.005$.
(b) What would be the diameter of the pipe if it is to be designed for maximum power condition?
7. a) What do you understand by stagnation pressure and stagnation temperature? Derive from first principles the equations for them.
b) An aeroplane is flying at a speed of 1000 km/hr at a particular altitude where the pressure is 0.75 bar and temperature is 270 K. Find the pressure, temperature and density of air at the stagnation point on the nose of the plane. Take $\gamma = 1.4$ and $R = 287$ Nm/kg-K for air.
8. Write short notes on any three;
(i) flow net
(ii) TEL and HGL
(iii) Hydrodynamic lubrication
(iv) Flow meters

(HTES1.4)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
First semester
MEASUREMENTS IN HEAT TRANSFER
(Effective from the admitted batch of 2011-2012)
Model question paper

Time : 3 hours

Max marks : 70

Answer any FIVE questions and All questions carry equal marks

1(a) A resistance arrangement of 50Ω is desired. Two resistances of $100\pm 0.1\Omega$ and two resistances of $25\pm 0.02\Omega$ are available. Which should be used, a series arrangement with the 25Ω resistor or a parallel arrangement with 100Ω resistors? Calculate the uncertainty for each arrangement.

(b) Obtain Y as a linear function X from the following data using method of least square

| | | | | | | | | | | | |
|----|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|
| Y: | 2.0 | 2.8 | 3.2 | 3.8 | 4.1 | X: | 1.6 | 2.4 | 4.8 | 5.4 | 6.2 |
|----|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|

2(a) What are transducers, distinguish between active and passive transducers. Explain their importance in instrumentation process.

(b) Describe the working principle of piezoelectric transducer and explain why it is desirable that piezoelectric transducers should be used for measurement of dynamic quantities only.

3(a) Describe the principle of operation of LVDT. Why it is necessary to connect the secondary's in differential mode. Sketch the typical input and output graph

(b) Explain with a neat diagram, working of Ionization transducer with its applications.

4(a) Explain with a neat diagram, construction and working of McLeod gauge with their relative advantages and disadvantages

(b) Explain the construction of foil types bonded strain gauge and how strain gauges can be used for measurement of pressure

5(a) Why rotameter is called variable area flow meter, explain its working with a neat sketch.

(b) Explain with a neat diagram, working of a ultra sonic flow meter with its advantages and disadvantages.

6(a) Explain with a neat diagram, working of laser dopler anemometer.

(b) Explain the errors caused by changes in ambient temperature in filled systems used for temperature measurement in terms of case compensation and full compensation.

7(a) Explain with a simple sketch, working of an optical pyrometer

(b) Explain with a simple sketch, measurement of thermal conductivity of liquid and gases

8(a) Describe the working of a sling psychrometer with its limitation

(b) Explain with a simple sketch, measurement of reflectivity and transmissivity

(HTES1.5)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
First Semester
Advanced Optimization Techniques
(Effective from the admitted batch of 2013-14)
Elective - I
Model Question Paper

TIME: 3 hours

Max. Marks: 70

Answer any FIVE Questions
All questions carry equal marks

1. (a) State and prove the arithmetic-geometric inequality for any number of non-negative numbers.

(b) Minimize the following function using Geometric programming

$$f(X) = \frac{1}{2}x_1^2 + x_2 + \frac{3}{2}x_1^{-1}x_2^{-1}$$

2. Explain in brief the dynamic programming approach and pose the following problem as a dynamic programming problem and solve.

A dealer places an order with his wholesaler on the first each month and obtains delivery one month later. The cost of holding inventory is C_1 per unit per month and the cost of shortage is C_2 per unit per month, shortage being carried over from one month to the next. If the monthly demand is X is a random variable with density function $P(X)$, find the policy that minimize the long term average costs per month.

3. (a) In the solution of integer programming problem using branch and bound technique, during branching, a non-negative solution is obtained with objective value $Z=10$, whereas an all integer solution has already been obtained with objective value $Z=8$. Should this be further branched or pruned? Explain.

(b) Solve the following problem by cutting plane method:

$$\text{Minimize } 3x_1 - x_2$$

$$\text{Subject to } -10x_1 + x_2 \leq 15$$

$$14x_1 + 18x_2 \geq 63$$

x_1, x_2 are non-negative integers

4. (a) Differentiate between probability density and probability distribution functions.

(b) An automobile body is assembled using a large number of spot welds. The number of defective welds (X) closely follows the distribution

$$P(X = d) = \frac{e^{-2} 2^d}{d!}, d = 0, 1, 2, \dots$$

5. (a) How do you map from a binary coded string to a real value? Explain with an example.

(b)

[HTES1.6]
M.Tech DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
FIRST SEMESTER
Solar Energy Technology
Elective – II
(Effective from the admitted batch of 2015-16)
Model question paper

Time: 3 hours

Max. Marks: 70

Answer any Five questions

All questions carry equal marks

1. a) Explain the depletion process of solar radiation as it passes through the atmosphere to reach at the surface of the earth.
b) Calculate the number of daylight hours (sunshine hours) in Srinagar on January 1 and July 1. The latitude of Srinagar is $34^{\circ} 08' 3''$ N.
2. a) What are the basic features required in an ideal pyranometer?
b) Calculate the angle of incidence of beam radiation on a plain surface, tilted by 45° from horizontal plane and pointing 30° West of south located at 1.30 p.m. (IST) on 15th November. The longitude and latitude of Mumbai are $72^{\circ} 49'$ WE and $18^{\circ} 54'$ N respectively. The standard longitude for IST is $81^{\circ} 44'$ E.
3. a) What is meant by cylindrical parabolic Collector?
b) What are the main advantages and disadvantages of concentrator system versus flat plate systems?
4. a) What are the methods employed to improve the efficiency of a flat plate collector.
(b) Write notes on the materials used for the manufacture of the absorption surface of flat plate collector.
5. a) Write notes on solar receivers.
b) Explain the Brayton cycle for low-temperature solar Applications.
6. a) Give in detail the merits of various cycles for solar applications.
b) What are the conditions required while choosing a prime mover for solar power application? What is an Osmotic pressure engine?
7. a) Explain the three modes of heat storage. What are the advantages of sensible heat storage in solids?
b) Discuss about the different materials required in latent systems.

8. a) What is the working principle of a reverse absorber heater in the air solar heaters?
b) Describe the principle and applications of solar ponds.

(HTES2.1)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
Second Semester
Convection Heat Transfer
(Effective from the admitted batch of 2015-16)
Model question paper

TIME: 3 hours

Max. Marks: 70

Answer any FIVE Questions
All questions carry equal marks

- For flow over a flat plate of length, L maintained at a uniform temperature of T_w , obtain an expression for average heat transfer coefficient under the conditions: $u = u_\infty = \text{constant}$ and $\frac{T - T_w}{T_\infty - T_w} = \left(\frac{y}{\delta_t}\right)$ where δ_t is the thermal boundary layer thickness.
 - Air at 1 atm pressure and 30°C enters a tube of 25mm diameter with a velocity of 10 m/s. The tube is heated in a way that a constant heat flux of 2 kW/m^2 is maintained at the wall whose temperature is 20°C above the bulk mean air temperature throughout the length of the tube. Determine the exit bulk mean temperature of air and the average Nusselt number if the length of the tube is 2m. Take for air $\rho = 1.2 \text{ kg/m}^3$ and $C_p = 1000 \text{ J/kgK}$. Neglect axial conduction.
- Air at 1 bar and 20°C flows across a bank of tubes 10 rows high and 4 rows deep. The air velocity is 8 m/s measured at the entry to the tube bank. Diameter of the tubes is 25mm and surface temperature of the tubes is maintained at 80°C . Tubes are arranged in an in-line manner. Take $S_T = S_L = 37.5 \text{ mm}$. Calculate the total heat transfer per unit length of the tube bank, and also the exit air temperature. Also find out the pressure drop.
- Using the Prandtl's mixing length theory, obtain an expression for the turbulent shear stress in terms of eddy viscosity for forced convection over a flat plate.
 - Using the $1/7^{\text{th}}$ velocity profile, obtain an expression for the turbulent boundary layer thickness over a flat plate.
- Castro Oil at 38°C flows over a wide, 6 m long heated plate at 0.06 m/s. For a surface temperature of 93°C , determine :
 - The hydrodynamic boundary layer thickness at the trailing edge of the plate
 - The total drag force per unit width

- iii. The thermal boundary layer thickness
 - iv. The local heat transfer coefficient at the end of the plate
 - v. The total heat flux from the surface per unit width.
5. a. Air at 1 atmosphere pressure and 77°C enters a 5.0 mm ID tube with a mean velocity of 2.5 m/s. The velocity profile is developed and the temperature profile is developing. The tube length is 1.0 m and a constant heat flux condition is imposed on the tube surface over the entire length. For a given outlet temperature of 127°C , determine:
- i. The value of the local heat transfer coefficient at the exit of the tube
 - ii. The average heat transfer coefficient
 - iii. The heat flux
 - iv. The tube surface temperature T_{wo} at the exit of the tube.
- b. State the hydrodynamic and thermal conditions for fully developed flow in a tube. And show that the local heat transfer coefficient in a thermally fully developed internal flow does not change in the direction of flow.
6. (a) A vertical plate 20 cm X 20 cm is heated and maintained at 100°C . Calculate the average heat transfer coefficient if the plate is exposed to atmospheric air at 20°C . Also find the heat lost by the plate per hour.
- (b) Derive the integral momentum equation for the laminar boundary layer over a heated vertical plate under free convection conditions.
7. (a) Derive an expression for the maximum velocity in the free convection boundary layer over a vertical plate. At what position in the boundary layer does this maximum velocity occur?
- (b) A 10 cm horizontal platinum wire of 0.4 cm diameter is placed horizontally in a container of water at 38°C and is electrically heated so that the surface temperature is maintained at 93°C . Calculate the heat lost by the wire.
8. Write short notes on
- i. Flow across tube banks
 - ii. Hydrodynamic and thermal boundary layers in a tube flow
 - iii. Reynolds-Colburn analogy
 - iv. Mixed convection

(HTES2.2)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
Second Semester
Thermal Environmental Control
(Effective from the admitted batch of 2015-16)
Model question paper

TIME: 3 hours

Max. Marks: 70

Answer any FIVE Questions
All questions carry equal marks

1. (a) What is standard rating of refrigeration machine?
(b) A cold storage plant is required to store 20 tonnes of fish. The fish is supplied at a temperature of 30°C . The specific heat of fish above freezing point is 2.93 kJ/Kg-K . The specific heat of fish below freezing point is 1.26 kJ/Kg-K . The fish is stored in cold storage which is maintained at -8°C . The freezing point of fish is -4°C . The latent heat of fish is 235 kJ/Kg-K . If the plant requires 75 kW to drive it, find
 - i. The capacity of the plant
 - ii. Time taken to achieve the cooling.Assume actual COP of the plant as 0.3 of the Carnot COP.
2. (a) What are the merits and demerits of air refrigeration system?
(b) An air refrigerator works between the pressure limits of 1 bar and 5 bar. The temperature of the air entering the compressor and expansion cylinder are 10°C and 25°C respectively. The expansion and compression follow the law $pv^{1.3} = \text{constant}$. Find the following:
 - i. The theoretical COP of the refrigerating cycle
 - ii. If the load on the refrigerating machine is 10 TR, find the amount of air circulated per minute through the system assuming that the actual COP is 50% of the theoretical COP.
3. A vapor compression refrigerator uses R-12 as the refrigerant and the liquid evaporates in the evaporator at -15°C . The temperature of the refrigerant at the delivery from the compressor is 15°C when the vapour is condensed at 10°C . Find the coefficient of performance
 - i. When there is no under-cooling
 - ii. The liquid is cooled by 5°C before expansion by throttling.Take the specific heat at constant pressure for the superheated vapour as 0.94 kJ/Kg K and that for liquid as 0.94 kJ/Kg K . Indicate both the results with the help of a T-S and h – S diagrams.

4. (a) What is the basic function of a compressor in a vapour compression refrigeration system? How this function is achieved in vapour absorption system?
 (b) Draw a neat diagram of Electrolux refrigerator and explain its working principle. What is the important role of hydrogen in this refrigerator and explain its working principle. What is the important role of hydrogen in this refrigeration system?
5. (a) Discuss the physical and thermodynamic properties of the following refrigerators:
 i. R – 11
 ii. R – 22
 iii. R – 717
 (b) What is capillary tube and discuss its operation in a refrigeration system.
6. (a) Prove that the relation between degree of saturation and relative humidity is given by an expression $\phi = \frac{\mu p_t}{p_t - (1 - \mu)p_{vs}}$
 (b) The DBT and WBT of atmospheric air are 35°C and 23°C respectively when the barometer reads 75 cm of Hg. Determine
 i. Relative humidity
 ii. Humidity ratio
 iii. Dew point temperature
 iv. Density
 v. Enthalpy of atmosphere air.
7. (a) Define the human comfort and explain the factors which affect human comfort.
 (b) Draw the diagram of a summer air conditioning system and explain its functioning.
8. A big shop is are conditioned for sensible load of 58.15 kW and latent load of 14.55 kW. The inside design conditions are 25°C DBT and 50 % RH and outside design conditions are 40°C DBT and 27°C WBT. 70 m³/min fresh (ventilation) air is supplied to the shop. Determine:
 i. The ventilation load
 ii. Total load to be taken by the plant
 iii. Effective sensible heat factor
 iv. Apparatus dew point
 v. Dehumidified air Quantity.

(HTES2.3)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
Second Semester
Design of Thermal Equipment
(Effective from the admitted batch of 2015-16)
Model question paper

TIME: 3 hours

Max. Marks: 70

*Answer any FIVE Questions
All questions carry equal marks*

Answer any FIVE questions.
All questions carry equal marks.
Use of heat transfer data hand book,
TEMA codes, graphs, etc., are permitted .
Reasonable assumptions may be made wherever necessary.

1. (a) Derive the temperature distribution and heat flow in condenser.
(b) In a certain double pipe heat exchanger , hot water flows at a rate of 5000 kg/hr and gets cooled from 95°C to 65°C . At the same time 50000 kg/hr of cooling water at 30 °C enters the heat exchanger. The flow conditions are such that overall heat transfer coefficient remains constant at 2270 w/m² k. Determine the heat transfer area required and the effectiveness, assuming two streams are in parallel flow.
2. (a) Derive the expression for overall heat transfer coefficient of a double pipe heat exchanger .
(b) Water enters a counter flow double pipe heat exchanger at 38°C flowing at 0.076 kg/s. It is heated by oil (C_p = 1800 J/kg °C) flowing at the rate of 0.152 kg/s from an inlet temperature of 116°C. For an area of 1 m² and U = 340 w/m²°C, determine the total heat transfer rate.
3. (a) Discuss the basic design procedure of shell and tube heat exchanger .
(b) A shell and tube heat exchanger is to be designed to heat water from 27°C to 90°C. The water flow rate is 4 kg/s. The heating is to be effected by engine oil , which enters the shell at 22°C and leaves at 110°C . The heat transfer coefficient for oil is 950 w/ m²k. There are 2 shell and 4 tube passes . The diameter of the tube is 30 mm. Find the flow rate of oil and length of the tube .
4. (a) Classify surface condensers and discuss the working of a down flow condenser and central flow condenser.
(b) Explain the concept of dropwise and film wise condensation .
5. (a) Discuss the thermal performance of a plate type heat exchanger .
(b) With a neat sketch describe the functioning of a rotary regenerator.
6. (a) Discuss the essentials, selection and classification of steam boilers.
(b) Explain in detail the operation Lamont boiler .
7. (a) Write the arrangements of wet-dry cooling tower and dry-wet cooling tower.
(b) Briefly write the design methods for furnace calculations.
8. Write short notes on the following :
 - (a) Influence of radiation in space power plant
 - (b) Power plant heat exchangers
 - (c) Efficiency of 1-2 and 2-4 shell and tube heat exchangers

(HTES2.4)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANSFER IN ENERGY SYSTEMS
Second Semester
Boiling and Two Phase Flow Heat Transfer
Model Question Paper
(Effective from the admitted batch of 2013-14)

TIME: 3 hours
70

Max. Marks:

Answer any FIVE Questions
All questions carry equal marks

1. (a) Explain with a neat sketch, different flow regimes observed in vertical co-current gas-liquid flow in a tube.
(b) Water is to be boiled at atmospheric pressure in a polished stainless steel pan placed on top of a heating unit. The inner surface of the bottom of the pan is at 110°C . If the diameter of the pan is 25 cm, determine
 - i. The rate of heat transfer to the water and the
 - ii. Rate of evaporation of water
2. A two phase mixture of saturated liquid and vapor water at atmospheric flows through a round tube with a diameter of 1.2 cm. The flow rate is such that the mass flux is $4. \text{kg/m}^2 \text{ s}$. Estimate the value of quality at which transitions from bubbly to slug and churn to annular flow occurs.
3. Derive an expression for the condensate heat transfer coefficient for laminar film condensation on a vertical plate. State the assumptions made.
4. Saturated steam at 30°C condenses on the outside of a 47 cm outer diameter, 2 m long vertical tube. The temperature of the tube is maintained at 20°C by the cooling water. Determine the
 - i. Rate of heat transfer from the steam to the cooling water
 - ii. The rate of condensation of steam
 - iii. The thickness of the condensate film at the bottom of the tube
5. Define the following
 - i. Mass flux
 - ii. Liquid volume fraction
 - iii. Superficial gas and liquid flux
 - iv. Two-phase volume fraction of liquid
 - v. Martinelli parameter
 - vi. Void fraction

6. Derive an expression for the overall pressure gradient during gas-liquid flow in an inclined tube. Assume one dimensional flow.
7. Estimate the peak heat flux for boiling of water on a large flat heater at saturation temperatures of
 - i. 100°C
 - ii. 300 K
8. Write short notes on
 - i. Film condensation and drop wise condensation
 - ii. Critical heat flux
 - iii. Separated flow model

(HTES2.5)
M.TECH DEGREE EXAMINATION
MECHANICAL ENGINEERING
HEAT TRANFER IN ENERGY SYSTEMS
Second Semester
Advanced Finite Element Analysis
(Effective from the admitted batch of 2013-14)
Elective - I
Model Question Paper

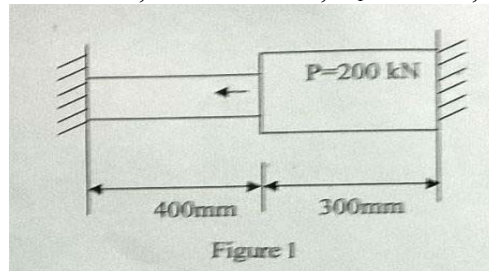
TIME: 3 hours

Max. Marks: 70

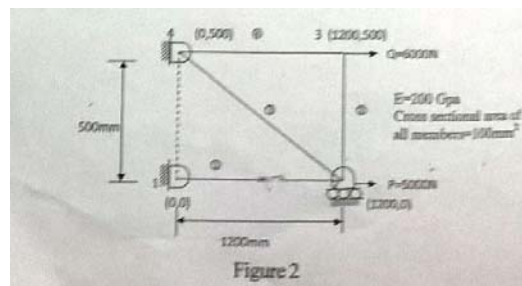
Answer any FIVE Questions
All questions carry equal marks

1. (a) Mention properties of shape functions.
(b) What are the properties of stiffness matrix?
(c) Give the list of thumb rules to be followed for discretization of elements and nodes.
(d) Discuss about FEM element formulation of plate and shell element.

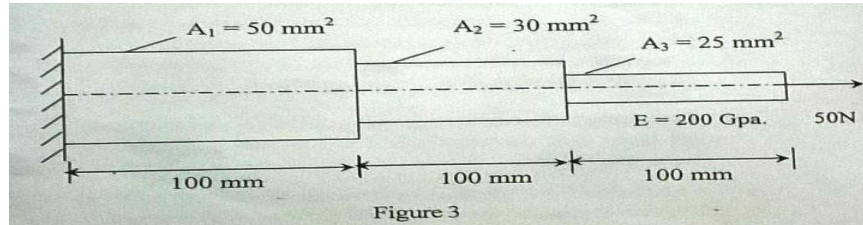
2. (a) Derive equations of equilibrium and strain displacement relations for 2D and 3D problems.
(b) Differentiate between plane stress and plain strain problems and derive the stress and strain relations.
(c) Consider the bar as shown in figure an axial load $P=200$ kN is applied as shown in figure 1. Determine the nodal displacements, stress in each material and reaction forces, $L_1=300$ mm, $L_2=400$ mm, $A_1=2400$ mm², $A_2=600$ mm², $E_1=70$ GPa, $E_2=200$ GPa.



3. (a) Write in detail about energy methods with an example and its role in solving FEA problems.
(b) Differentiate between bar and truss element in FEM formulation.
(c) For the truss shown in figure 2, an horizontal load of $P=5000$ N is applied at node 2 and $P=5000$ N at node 3. Obtain the global stiffness matrix, load vector and calculate the stresses in elements 2 and 3.



4. (a) Discuss in about the general procedure of FEM formulation with an example.
 (b) Derive the shape functions for linear and quadratic element using intrinsic and absolute co-ordinate system.
 (c) Use finite element method to calculate displacements and stresses of the bar as shown in figure 3.



5. (a) Discuss the formulation 2D heat transfer with 2 noded element including conduction and convection effects.
 (b) Determine shape functions for 4 noded tetrahedron elements in absolute and intrinsic co-ordinate system.
 (c) Evaluate the integral by using one and two point Gaussian quadrature and compare with the exact value.

$$I = \int_{-1}^{+1} \int_{-1}^{+1} (x^3 + x^2y + xy^2 + \sin 2x + \cos 2y) dx dy$$

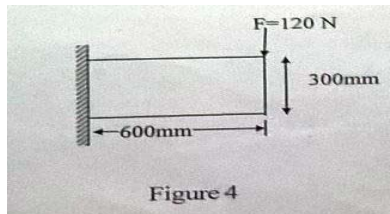
6. (a) Clearly explain the finite element formulation for an axisymmetric shell with an axisymmetric loading. Determine the matrix relating strains and nodal displacements for an axisymmetric triangular element. Also obtain D matrix for plane stress, plane strain and axisymmetric problems.

(b) A steel bush of 75mm is shrunk on a solid rigid shaft of 75.5mm diameter. The sleeve's axial length is 20mm. specify the boundary conditions to be used in the problem and show the finite element discretization.

(c) Derive the equilibrium equations, strain displacement relations and compatibility equations for 3D problems.

7. (a) Determine the matrix relating strains and nodal displacements for three and six triangular element and compare the behaviour.

(b) Determine the deflection and stresses at the point of load of application on a plate, by considering two triangular elements as shown in figure 4. Assume $t=4\text{mm}$, Poisson's ratio $=0.25$ and Young's modulus $E=210\text{GPa}$.



8. (a) For a beam and loading shown in figure 5, determine the slopes at 2 and 3 and the vertical deflection at the midpoint of distributed load.

(b) Determine the temperature distribution in a straight fin of circular cross section. Use three one dimensional linear elements and consider the tip is insulated. Diameter of fin is 1cm, length is 6cm, $h= 0.6\text{W/cm}^2\cdot\text{C}$, $\phi_\infty=25^\circ\text{C}$ and base temperature is $\phi_1=80^\circ\text{C}$.

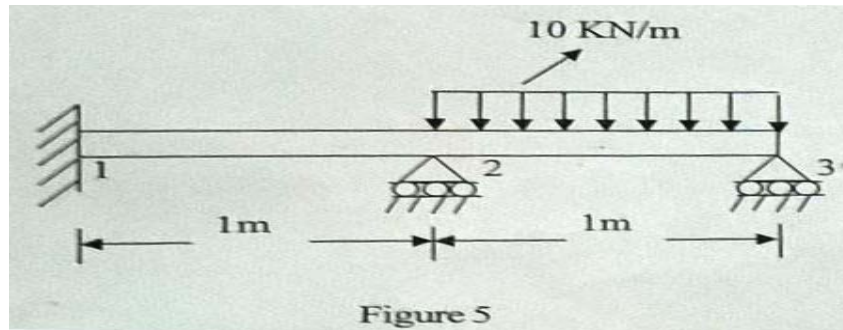


Figure 5

IE 2.6 Elective-III
M.Tech. DEGREE EXAMINATION
MECHANICAL ENGINEERING
INDUSTRIAL ENGINEERING
SECOND SEMESTER
ENERGY MANAGEMENT
(Effective from the Admitted Batch of 2015-2016)
MODEL PAPER

Time: 3 hours

Max. Marks: 70

Answer any **FIVE** questions
All Questions carry equal marks

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- 1 a) Briefly discuss the Indian energy scenario and what is the need to integrate renewable and non renewable energy sources.
b) What are energy intensive industries and why there is a need for energy conservation, Discuss in brief?
 - 2 a) Explain in detail, the desirable characteristics of any measuring instrument used in industry.
b) Define types of error and how error can influence the measured value in any measuring instrument
 - 3 a) What are different types of temperature measurement devices and what are their relative advantages and disadvantages
b) Describe the construction and working of stack analyser with a simple sketch and its limitations
 - 4 a) What are the methodologies adopted in energy auditing, explain them in detail
b) What is an energy cell and why there is a need for an energy consultant - justify
 - 5 a) A boiler is found to be inefficient and yielding only 60% efficiency, what are the avenues you will look into to improve its efficiency
b) What are thermal storage systems and how can they aid in energy conservation in an industry
 - 6 a) The surface of a furnace wall is found to be with a layer of 5 cm refractory brick ($k=2$ W/mK) and is to be placed between 4 mm thick steel ($k=40$ W/mK) plates. Both faces of the brick adjacent to the plates have rough solid to solid contact over 20% area, where the average height of asperities are 1mm. The outer surface temperature of steel plates are 400°C and 100°C respectively. Find the rate of heat flow per unit area and assume the cavity area is filled with air ($k=0.02$ W/mK)
b) furnace was found to be inefficient, What measures have to be taken to resolve the issue.
 - 7 a) What is the importance of NPV and how does it help in financial decision making.
b) What is pay back period and briefly explain importance of pay back period for any retrofitting
 - 8 Write short notes on
 - i. Energy conservation act 2003
 - ii. Process integration
 - iii. Consultant selection criteria
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