Department of Mechanical Engineering

Curriculum for M. Tech. Programme in Thermal Sciences

Semester 1

Code	Title of Course	L	T	P/S	C
MA6001	Mathematical Methods	3	--	--	3
ME6201	Advanced Fluid Mechanics	3	--	--	3
ME6202	Advanced Chemical Thermodynamics	3	--	--	3
ME6203	Analytic Methods in Heat Transfer I	3	--	--	3
	Elective-I	3	--	--	3
	Elective- II	3	--	--	3
ME6291	Computational Laboratory	--	--	3	1
ME6292	Seminar	--	--	3	1
	Total	**20**			

Semester 2

Code	Title of Course	L	T	P/S	C
ME6211	Analytical Methods in Heat Transfer II	3	--	--	3
ME6212	Advanced Computational Methods in Fluid Flow and Heat Transfer	3	--	--	3
ME6213	Analysis of Thermal Power Plant Cycles and systems	3	--	--	3
ME6214	Cryogenic Engineering	3	--	--	3
	Elective-III	3	--	--	3
	Elective-IV	3	--	--	3
ME6293	Thermal Science Laboratory	--	--	3	1
ME6294	Term Paper/ Mini Project/Industrial Training	--	--	3	1
	Total	**20**			

Semester 3

Code	Title of Course	L	T	P/S	C
ME7295	Project work	--	--	-	8
	Total	**8**			

Semester 4

Code	Title of Course	L	T	P/S	C
ME7296	Project work	--	--	-	12
	Total	**12**			

Total Credits: 60

Stipulations:

1. A minimum of 60 credits have to be earned for the award of M. Tech. degree in this programme.
2. Students have to credit a minimum of eight core courses and four electives during the programme; however they have option to credit two electives in the Third Semester, drawing one each from First and Second Semesters.
3. Students may undergo Industrial Training during May-June.

List of Electives

Sl. No.	Code	Title	Credit
1	ME6221	Thermal Environmental Engineering	3
2	ME6222	Design of Heat Transfer Equipment	3
3	ME6223	Principle and Analysis of Turbo machines	3
4	ME6224	Aerodynamics	3
5	ME6225	Statistical Thermodynamics	3
6	ME6226	Theoretical Hydrodynamics	3
7	ME6227	I. C. Engine Systems, Combustion and Performance Analysis	3
8	ME6228	Multiphase Flow	3
9	ME6229	Industrial Food Preservation	3
10	ME6230	Introduction to Turbulence	3
11	ME6231	Postulational Thermodynamics	3
12	ME6232	Advanced Instrumentation Systems	3
13	ME6233	Theory and applications of heat pipes	3
14	ME6234	Thermodynamic property relations and exergy analysis	3
15	ME6235	Transport phenomena	3
16	ME6402	Renewable energy technology	3
17	ME6412	Design and analysis of energy systems	3
18	ME6413	Energy conservation in thermal systems	3
19	ME6414	Energy and Environment	3
20	ME6424	Fluidized bed systems	3
21	ME6425	Heat pump technology	3
22	ME6322	Computer Graphics	3

Note: Students may choose any course offered in the Institute with the approval from the Programme Coordinator.

DEPARTMENT OF MECHANICAL ENGINEERING

BRIEF SYLLABI

M. Tech. Programme in Thermal Sciences

Pre-requisite for courses: Nil
Total Hours for all courses except for Project: 42
Lecture hours for theory courses: 3
Hours for Practical/Seminar: 3
Credit for theory courses: 3
Credit for Practical/Seminar: 1

MA6001 MATHEMATICAL METHODS

Vector Spaces, Inner Product Spaces, Linear Transformations, Change of Bases, Power Series Solution about Ordinary Point and Singular Points, Sturm-Liouville Problem and Generalized Fourier Series, First Order Partial Differential Equations, Second Order Partial Differential Equations, Classification, Formilation and Method of Solutiions of Wave Equation, Heat equation and Laplace equation, Spaces of N-dimensions, Coordinate transformations, covariant, contravariant and mixed tensors, Fundamental Operation with tensors, Quotient Law, Christoffel's symbols, Covariant derivative.

ME6201 ADVANCED FLUID MECHANICS

Review of fundamental Concepts Eulerian and Lagrangian methods of description of fluid flow; Reynolds transport equation, Navier-Stokes equations and boundary conditions; Nondimensionalization of equations and order of magnitude analysis, Exact solution of incompressible Navier-Stokes equations, Low Rerynolds number flows. Boundary layer theory, Prandtl's boundary layer equations, Blasius solution and other similarity solutions Von Karman's momentum integral equations .Introduction to turbulent flow, Reynolds stresses.

ME6202 ADVANCED CHEMICAL THERMODYNAMICS

Thermodynamic potentials –Thermodynamic property relations – Maxwell relations, Joule-Thomson coefficient, Bridgman table, Clapeyron equation. Thermodynamic properties of real gases – ideal gas properties, departure functions and its evaluation, property table and diagrams; Multi-component mixtures – fugacity and fugacity coefficient, properties of real gas mixtures, fugacity of liquid, solid and component in a mixture. Stability and phase transitions – stability criteria, first order phase transition, single and multi-component systems, Gibbs phase rule, phase diagram of binary systems; Critical phenomena, Nerst postulate, introduction to irreversible thermodynamics, Onsager's reciprocity theorem, thermo-electric effects.Properties of solutions – Ideal solution, phase equilibrium and phase diagram of ideal solutions, Excess Gibbs free energy models, prediction of activity coefficients, Henry's law; chemical reaction equilibrium – Gibbs free energy change and equilibrium constant, effect of temperature, homogeneous gas phase reactions, degree of conversion, adiabatic reaction temperature, homogeneous and heterogeneous reactions.

ME6203 ANALYTICAL METHODS IN HEAT TRANSFER-I

Methods of formulation .Differential formulation of transient heat conduction problems with time-independent boundary conditions treatment of non homogeneity in differential equations and boundary conditions – method of superposition. Review of basic definitions in radiation heat transfer. Radiant energy exchange between two differential area element. Shape factor algebra. Radiant energy exchange between two surfaces, Radiant energy exchange in presence of absorbing and transmitting media.

ME6291 COMPUTATIONAL LABORATORY

Training on Commercial Software like I-DEAS, FLUENT, MATLAB etc., Programming practice on Roots of algebraic and transcendental equations, Solution of simultaneous algebraic equations, Numerical integration and differentiation, Numerical solution of ODEs: Initial and boundary value problems, Numerical solution of PDEs.

ME6211 ANALYTICAL METHODS IN HEAT TRANSFER-II

Conservation principles – continuity, momentum and energy equations, mass diffusion equation: simplified differential equations of the boundary layer; integral equations of the boundary layer; equations of the turbulent boundary layer; governing equations for mass transfer. Forced convection heat transfer – Flow over flat plates, similarity and integral solution of the thermal boundary layer, wedge flow; non-similar boundary layer, flow over bodies with boundary layer separation, boundary layer analogies, friction and heat transfer analogy, heat and mass transfer analogy; flow through circular tubes – fully developed velocity and temperature profiles, uniform wall temperature and heat flux cases; concentric circular tube annulus; non circular tubes; thermal entry length solutions – arbitrary variation of wall temperature and wall heat flux. Free convection: Boundary layer equations – vertical semi-infinite plate, constant and variable wall temperatures, effect of suction and blowing, variable fluid properties; integral solution of the free convection boundary layer; free convection flow regimes; free convection between heated plates; combined free and forced convection. Heat transfer in turbulent flow – internal and external flows, various turbulence models, fully developed velocity and temperature profiles, low and high Prandtl number flows; influence of temperature dependent fluid properties in liquids and gases; convective heat transfer at high velocities, compressibility effects, influence of Mach number, Reynolds analogy for turbulent heat transfer.

ME6212 ADVANCED COMPUTATIONAL METHODS IN FLUID FLOW AND HEAT TRANSFER
Experimental, theoretical and numerical methods of predictions; physical and mathematical classifications partial differential equations. Consistency, stability and convergence for marching problems; discrete perturbation stability analysis. Finite volume method for diffusion and convection–diffusion problems – steady one- dimensional convection and diffusion. Numerical marching techniques, two-dimensional parabolic flows with heat transfer.

ME6213 ANALYSIS OF THERMAL POWER PLANT CYCLES AND SYSTEMS
Energy sources - Fossil fuels, Nuclear fuels, Solar and Conventional energy sources - Fuel storage, Preparation, Handling and Combustion - Combustion calculations - General layout of Conventional Thermal power plants - Design and Operation- Superheat, Reheat and Regeneration - Other auxiliaries of thermal power plant - High-pressure boilers -Steam Generators control. Steam nozzles and Steam turbines - Working - Compounding - Governing of steam turbines - Condensers and Cooling towers - Cycles for Steam power plants - Rankine cycle and its analysis - Reheat cycle, Regenerative cycle and Binary power cycle - Steam piping - Waste heat management.Diesel electric power plant - working and fields of use - Different systems of diesel electric power plants and plant layout - Gas turbine and combined cycle analysis – Inter-cooling, reheating and regeneration - design for high temperature - Combined cycles with heat recovery boiler – Combined cycles with multi-pressure steam - STAG combined cycle power plant - Influence of component efficiencies on cycle performance - Energy transfer between a fluid and a rotor - Euler turbine equation - Pressure head and velocity head variations for forward, radial and backward curved vanes - Ideal and actual characteristics of Fluid machines.Nuclear power plants – Introduction - Nuclear fuels - Atomic number and mass number - Atomic mass unit - Nuclear energy conversion - Chemical and nuclear equations - Nuclear reactions -Fission and fusion - Energy from fission and fuel burn-up - Radioactivity - Neutron energies - Fission reactor types - Fast breeder reactor - Production of nuclear fuels - Fuel rod design - Steam cycles for nuclear power plants - reactor heat removal – Coolant channel orificing - Core thermal design - Thermal shields - Fins in nuclear plants – Core thermal hydraulics - Safety analysis - LOCA - Time scales of transient flow and heat transfer processes.

ME6214 CRYOGENIC ENGINEERING
Gas liquefaction systems, Joule Thomson effect. Gas separation and purification
Cryogenic refrigeration systems. Two-phase flow in cryogenics transfer systems, cool down process. Introduction to vacuum technology . Super-conductive devices, rocket and space simulation, cryogenics in biology and medicine, cryopumping.

MEB6293 THERMAL SCIENCES LABORATORY
Each student shall design his/her own experiment by suitably modifying one of the existing experimental set ups in any of the laboratories of Thermal Stream

ME6221 THERMAL ENVIRONMENTAL ENGINEERING
Thermal comfort, psychrometry, air conditioning processes. Estimation of air conditioning loads. Air distribution; Air handling equipments; air conditioning apparatus. Air conditioning systems, automatic valves piping design

ME6222 DESIGN OF HEAT TRANSFER EQUIPMENT
Thermal performance analysis of heat exchangers .Shell and tube heat exchangers .Direct contact heat Design and analysis of cooling towers, Heat pipes

ME6223 PRINCIPLES OF TURBOMACHINERY
Definition and classification of turbomachines; Flow mechanism through the impeller - Similarity. Steam turbines.

ME6224 AERODYNAMICS
Equations for incompressible inviscid flows,Flow past a cylinder,Aerofoils,, Prandtl-Lachester theory, Biot- Savarat law, Lineraised compressible flows in two dimensions, Flow past a wavy wall, Similarity rules, Aerofoil in compressible flows.

ME6225 STATISTICAL THERMOYDNAMICS
Thermodynamics and statistical mechanics. Transport phenomena. Application of Boltzmann statistics. Quantum statistics

ME6226 THEORETICAL HYDRODYNAMICS
Review of basic differential equations of motion .Complex potentials for simple flows, Schwarz – Christoffel transformation, .Three-dimensional irrotational flow

ME6227 I.C. ENGINE SYSTEMS, COMBUSTION AND PERFORMANCE ANALYSIS
Working principle - Constructional details - Classification and application of different types of I.C. engines - Two stroke engines . Mixture preparation systems for SI and CI engines Ignition. Engine testing
Review of basic thermodynamics and gaseous mixtures. General characteristics of combustion flame. Fuels and their properties .Normal combustion in SI Engines

ME6228 MULTI PHASE FLOW
Introduction Basic definitions; Basic flow models .Friction multiplier; separated flow model .Drift flux model. Profiles in multi phase flow. Boiling and condensation .Types of condensation, Nusselt theory.

ME6229 INDUSTRIAL FOOD PRESERVATION
Food and its preservation, nature of food hazards-causes of food spoilage, principles of fresh food storage, storage of grains; principles of refrigerated gas storage of food-Gas packed refrigerated dough, Principles of food freezing; Candy manufacture; Dehydration of fruits, Freeze drying. Principles of food concentrates. Food preservation, evaluation of packaging

MEB6230 INTRODUCTION TO TURBULENCE
Laminar Turbulent Transition, Fundamentals of Stability theory, Fundamental equations for mean motion, the k-equation, energy equation, boundary layer equations for plane flows; Internal flows, 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; Turbulence modeling, zero equation, one equation and two equation models, derivation of the model equations, RNG model, DNS and large eddy simulation (LES).

ME6231 POSTULATIONAL THERMODYNAMICS
General principles of classical thermodynamics, Gibbs- Duhem equation, Reversible processes, maximum work theorem, Energy minimum principle, Legendre transformations, Massieu functions. Maxwell relations and Jacobian methods, Gibbs phase rule, phase diagram for binary systems Critical Phenomena, Nernst postulate, introduction to irreversible thermodynamics, special topics on advanced thermodynamics.

ME6232 ADVANCED INSTRUMENTATION
Measurement of thermal and physical properties. Steady and unsteady states. Data acquisition and analog to digital conversion. Statistical analysis. Linear and non-linear regression. Error estimates in temperature measurements and effects of radiation. Fluid pressure measurement. LDA, PIV and hot wire anemometry. Thermal radiation measurements. Quasi-steady measurements. Temperature measurement in high temperature gases. Measurements in the micro scale.

ME6233 THEORY AND APPLICATION OF HEAT PIPES
Principle, working fluids and limits of heat pipe operation - Interfacial mass, momentum, energy, pressure balance – Capillary boiling – Sonic, entrainment, viscous and boiling limitations - Startup characteristics - Heat pipe design and manufacturing - wick structure and selection - heat pipe charging and testing - Numerical and analytical models for heat pipes - Heat pipe applications to energy systems - Special applications of heat pipes.

ME6234 THERMODYNAMIC PROPERTY RELATIONS AND EXERGY ANALYSIS
Review of 1st & 2nd law, entropy, availability and irreversibility, practical applications, introduction to exergy and second law efficiency-Maxwell's equations, T-ds equations, Difference in heat capacities, ratio of heat capacities, energy equation, Joule-Thomson effect. Clausius- Clapeyron equation, Evaluation of thermodynamic properties - Helmoltz and Gibbs functions- forms of exergy; the destruction of exergy. Exergy balance in thermodynamic systems, Exergic efficiency, exergy and irreversibility, Exergy analysis of thermodynamic systems, Applications of exergy analysis of thermodynamic operations and cycles- Staged heat recovery.

ME6235 TRANSPORT PHENOMENA
Viscosity and the mechanisms of momentum transfer - molecular theory of the viscosity of liquids- temperature and pressure dependence of thermal conductivity, and theory of thermal conductivity of gases at low density. Diffusivity and the mechanisms of mass transport- Shell momentum balances and velocity distributions in laminar flow- Shell energy balances and temperature distributions in solids and laminar flow- Concentration distributions in solids and laminar flow- The equations of change for isothermal systems- The equations of change for non- isothermal systems- equations of change for multi component systems.

DEPARTMENT OF MECHANICAL ENGINEERING

Detailed Syllabi for the M.Tech. Programme in THERMAL SCIENCES

MA6001 MATHEMATICAL METHODS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I   Linear Algebra (11 Hours)

Vector spaces, Basis, Dimension, Inner product spaces, Gram-Schmidth Process, Linear Transformations, Range and Kernel, Isomorphism, Matrix of transformations and Change of Basis.

Module II   Series Solutions of ODE and Sturm-Liouville (10 Hours)

Power series solutions about ordinary point, Legendre equation and Legendre polynomials, Solutions about singular points; The method of Frobenius, Bessel equation and Bessel Functions. Sturm-Liouville problem and Generalized Fourier series.

Module III Partial Differential Equations (11 Hours)

First order PDEs, Linear equations, Lagrange method, Cauchy method, Charpits method, Jacobi method. Second order PDEs, Classifications, Formulation and method of solutions of Wave equation, Heat equation and Laplace equation.

Module IV Tensor Calculus (10 Hours)

Line, area and volume integrals, Spaces of N-dimensions, coordinate transformations, covariant, contravariant and mixed tensors, fundamental operation with tensors, Quotient Law the line element and metric tensor, conjugate tensor, Christoffel's symbols , covariant derivative.

References

1. D. C. Lay: Linear Algebra and its Applications, Addision Wesley, 2003.
2. F. G. Florey: Elementary Linear Algebra with Application, Prentice Englewood, 1979.
3. Stephen Andrilli & David Hecker: Elementary Linear Algebra, Third Edition, Academic Press, 2003.
4. W. W. Bell: Special Functions for Scientist's and Engineers, Dover Publications, 2004.
5. Sokolnikoff and Redheffer – Mathematics of Physics and Engineering. 2nd edition, McGraw Hill, 1967.
6. Ian Sneddon, Elements of Partial Differential Equations, McGraw Hill International, 1985.
7. Tychonov & Samarski: Partial Differential Equations of Mathematical Physics, Holden-Day, San Francisco , 1964.
8. B. Spain: Tensor Calculus, Oliver and Boyd, 1965.
9. J. Irving and N. Mullineux: Mathematics in Physics and Engineering, Academic Press, 1959.
10. Shepley L Ross, Differential Equations, JohnWiley & Sons, Third Edition, 2004.
11. L.A. Pipes and L.R. Harwill: Applied Mathematics for Engineers and Physicists, Mc Graw Hill, 1971.
12. M.A. Akivis and V.V Goldberg, An Introduction to Linear Algebra and Tensors, Dover Publications, 1997.

ME6201 ADVANCED FLUID MECHANICS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hours)

Review of fundamental concepts – continuum, control volume, Eulerian and Lagrangian methods of description of fluid flow; Reynolds transport equation – integral and differential forms of continuity, momentum, and energy equations, Navier-Stokes equations and boundary conditions; Nondimensionalization of equations and order of magnitude analysis, dimensionless parameters and their significance; classification of flows based on the characteristic Reynolds number; equations for low and high Reynolds number flows.

Module II (11 hours)

Exact solution of incompressible Navier-Stokes equations – Couette flow, flow between rotating cylinders, Stokes problems, stagnation point flow, flow near a rotating disk, fully developed flow through ducts; Low Rerynolds number flows, use of vorticity and stream function, creeping flow past a sphere, hydrodynamic theory of lubrication.

Module III (11 hours)

Boundary layer theory, D' Alemberts paradox, Prandtl's boundary layer equations, Blasius solution and other similarity solutions of the laminar boundary layer, flow in wakes and jets, Karman's momentum integral equations, prediction of boundary layer separations.

Module IV (9 hours)

Introduction to turbulent flow, stability of laminar flow, mean motion and fluctuation, time averaged turbulent flow equations, Reynolds stresses, boundary layer equations, boundary conditions, eddy viscosity, mixing length hypothesis, similarity hypothesis, universal velocity distribution laws, flow through pipes and ducts, turbulent jets and wakes.

References

1. White, F. M., Viscous Fluid Flow, Third Edition, McGraw-Hill, 2006
2. Schlitching, H., Boundary Layer Theory, Seventh Edition, McGraw-Hill, 1987.
3. Papanastasiou, T. C., Georgiou, G. C., and Alexandrou, A. N., Viscous Fluid Flow, CRC Press, 2000.
4. Muralidhar, K. and Biswas, G., Advanced Engineering Fluid Mechanics, Second Edition, Narosa Publishing House, 2005.
5. Schetz, J. A., Boundary Layer Analysis, Prentice Hall, 1994

ME6202 ADVANCED CHEMICAL THERMODYNAMICS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hrs)

Thermodynamic potentials – postulates, intensive properties equilibrium criteria, Euler and Gibbs-Duhem relations, Legendre transformation, extremum principles; Thermodynamic property relations – Maxwell relations, Joule-Thomson coefficient, Bridgman table, clapeyron equation.
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Module II (10 hrs)

Thermodynamic properties of real gases – ideal gas properties, departure functions and its evaluation, property table and diagrams; Multi-component mixtures – fugacity and fugacity coefficient, properties of real gas mixtures, fugacity of liquid, solid and component in a mixture.

Module III (11 hrs)

Stability and phase transitions – stability criteria, first order phase transition, single and multi-component systems, Gibbs phase rule, phase diagram of binary systems; Critical phenomena, Nerst postulate, introduction to irreversible thermodynamics, Onsager's reciprocity theorem, thermo-electric effects.

Module IV (11 hrs)

Properties of solutions – Ideal solution, phase equilibrium and phase diagram of ideal solutions, Excess Gibbs free energy models, prediction of activity coefficients, Henry's law; chemical reaction equilibrium – Gibbs free energy change and equilibrium constant, effect of temperature, homogeneous gas phase reactions, degree of conversion, adiabatic reaction temperature, homogeneous and heterogeneous reactions.

References

1. Rao, Y. V. C., Chemical Engg. Thermodynamic, Universities press, 1997.
2. Narayanan, K. V., A Text book of Chemical Engg. Thermodynamics, Prentice Hall of India.
3. Smith, J. M., Van Ness, H. C. and Abbott, M. M., Introduction to Chemical Engg. Thermodynamics, 6th Edition, Tata McGraw – Hill Publishing Co., 2001.
4. Kyle, B. G., Chemical and Process Thermodynamics, 3rd Edition, Pearson Prentice Hall, 1999.
5. Dodge, B. F., Chemical Engg. Thermodynamics, McGraw Hill Book Co., 1960.

PS: *This subject is to be handled by 50:50 sharing basis between MED & CHED*

ME6203 ANALYTICAL METHODS IN HEAT TRANSFER-I

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Methods of formulation – lumped, integral, and differential formulations; initial and boundary conditions, different kinds of boundary conditions, homogeneous boundary
conditions; transient response of thermocouples in the measurement of fluctuating gas temperature; integral formulation of heat conduction in a pin fin of uniform cross section and its approximate analytical solution; differential formulation of steady one-dimensional heat conduction problems and their analytical solution – heat transfer characteristics of straight, annular, and pin fins of uniform and non-uniform cross sections.

Module II (12 hours)

Differential formulation of transient heat conduction problems with time- independent boundary conditions in rectangular, cylindrical, and spherical geometries and their analytical solution - method of separation of variables, method of Laplace transforms; differential formulation of steady two-dimensional heat conduction problems in rectangular, cylindrical, and spherical geometries and their analytical solution - methods of separation of variables; treatment of nonhomogeneity in differential equations and boundary conditions – method of superposition.

Module III (9 hours)

Review of basic definitions – black, gray, opaque, transparent, and translucent bodies, transmissivity of a body, diffuse and specular surfaces; emissivity, absorptivity, and reflectivity of real surfaces; solid angle; radiation intensity, emissive power; irradiation, radiosity; radiant energy exchange between two differential area element; radiation shape factor, radiation shape factor between a differential element and a finite area and between two finite areas, crossed-string method, properties of shape factor – reciprocal, additive, and enclosure properties, shape factor algebra.

Module IV (12 hours)

Radiant energy exchange between two surfaces, reradiating surfaces, radiation shields; Radiant energy exchange in enclosures – enclosure composed of black surfaces, enclosure composed of diffuse-gray surfaces; electrical network analogy; radiant energy exchange in presence of absorbing and transmitting media, radiant energy exchange in presence of transmitting, reflecting and absorbing media; radiant energy exchange in the presence of conduction and convection.

References

1. Glen E. Myers, Analytical Methods in Conduction Heat Transfer, McGraw-Hill, 1971.
2. Modest, M. F., Radiative Heat transfer, Second Edition, Academic Press, 2003
3. Vedat S. A., Conduction Heat Transfer, Addison-Wesley, 1966.
4. Holman, J. P., Heat Transfer, Ninth Edition, Tata McGraw-Hill, 2002.
5. Janna, W. S., Engineering Heat Transfer, Second Edition, CRC Press, 2000.

ME6291 COMPUTATIONAL LABORATORY

L	T	P	C
0	0	3	1

I. Development of algorithms and computer programs using FORTRAN, C, C++, MATLAB.

II. Programming assignments on the following topics
- Roots of algebraic and transcendental equations
- Solution of simultaneous algebraic equations
- Curve fitting and optimization
- Numerical integration of ordinary differential equations: Initial value problems
- Numerical Solution of ordinary differential equations: Boundary value problems
- Numerical solution of partial differential equations

III. Hands-on Training on the following Softwares:

a. Design, modeling and analysis: using I-DEAS, ANSYS, PRO-E

b. Computational fluid dynamics and heat transfer: FLUENT

ME6292 SEMINAR

L	T	P	C
0	0	3	1

Each student shall prepare a seminar paper on any topic of his/her interest. However, the topic must be someway related to the core/elective courses being credited by him/her during the first or second semester. He/she shall get the paper approved by the Programme Coordinator/Faculty Advisor/any of the faculty members in the concerned area of specialization and present it in the class in the presence of Faculty in-charge, Seminar Class. Each student has submit a seminar report. Every student shall participate in the seminar. Grade will be awarded on the basis of the quality of the paper, his/her presentation and participation in the seminar.

ME6211 ANALYTICAL METHODS IN HEAT TRANSFER-II

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Conservation principles – continuity, momentum and energy equations, mass diffusion equation: simplified differential equations of the boundary layer; integral equations of the boundary layer; equations of the turbulent boundary layer; governing equations for mass transfer.

Module II (14 hours)

Forced convection heat transfer – Flow over flat plates, similarity and integral solution of the thermal boundary layer, wedge flow; non-similar boundary layer, flow over bodies with boundary layer separation, boundary layer analogies, friction and heat transfer analogy, heat and mass transfer analogy; flow through circular tubes – fully developed velocity and temperature profiles, uniform wall temperature and heat flux cases; concentric circular tube annulus; non circular tubes; thermal entry length solutions – arbitrary variation of wall temperature and wall heat flux.

Module III (9 hours)

Free convection: Boundary layer equations – vertical semi-infinite plate, constant and variable wall temperatures, effect of suction and blowing, variable fluid properties; integral solution of the free convection boundary layer; free convection flow regimes; free convection between heated plates; combined free and forced convection.

Module IV (10 hours)

Heat transfer in turbulent flow – internal and external flows, various turbulence models, fully developed velocity and temperature profiles, low and high Prandtl number flows; influence of temperature dependent fluid properties in liquids and gases; convective heat transfer at high velocities, compressibility effects, influence of Mach number, Reynolds analogy for turbulent heat transfer.

References

1. Kays, W. M. and Crawford, M. E., Convective Heat and Mass Transfer, Third Edition, McGraw Hill, 1993.
2. Gebhart, B., Heat Transfer, Second Edition, Tata McGraw Hill, 1971.
3. Schlichting, H., Boundary Layer Theory, Seventh Edition, McGraw Hill, 1987.
4. Jaluria, Y. Natural Convection Heat and Mass Transfer, Pergamon, 1980.
5. Ozisik, M. N., Heat Transfer, McGraw Hill, 1988.

ME6212 ADVANCED COMPUTATIONAL METHODS IN FLUID FLOW AND HEAT TRANSFER

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (9 hours)

Experimental, theoretical and numerical methods of predictions - physical and mathematical classifications - partial differential equations – simplification methods: proper choice of coordinate system, transformed coordinates, normalization – Physical domain and computational domain – discretization methods for converting partial derivatives to their discretised forms – Taylor series method, polynomial fitting method, integral method, control volume method – discretization error, first order, second order and higher order accuracy schemes – round off errors – grid optimization.

Module II (11 hours)

Steady one-dimensional conduction in Cartesian and cylindrical coordinates; handling of boundary conditions; two–dimensional steady state conduction problems in Cartesian and cylindrical co-ordinates– point-by-point and line-by-line method of solution, dealing of Dirichlet, Neumann, and Robins type boundary conditions; formation of discritized equations for uniform and non-uniform grids, formation of discretized equations for irregular boundaries and interfaces; grid generation methods; adaptive grids.

Module III (11 hours)

One, two, and three-dimensional transient heat conduction problems in Cartesian and cylindrical co-ordinates – explicit, implicit, Crank-Nicholson and ADI schemes; ADE schemes, Hopscotch scheme, Douglass schemes etc. stability criterion of these schemes; conservation form and conservative property of partial differential and finite difference equations; consistency, stability and convergence for marching problems; discrete perturbation stability analysis, Fourier or von Neumann stability analysis – discretization methods for Wave equations, Burger's equations – modified equations – error analysis.

Module IV (11 hours)

Finite volume method for diffusion and convection–diffusion problems – steady one-dimensional convection and diffusion; upwind, hybrid and power-law schemes, discretization of equation for two-dimension, false diffusion; computation of the flow field using stream function–vorticity formulation; SIMPLE, SIMPLER, SIMPLEC and QUICK schemes, solution algorithms for pressure–velocity coupling in steady flows; numerical marching techniques, two-dimensional parabolic flows with heat transfer.

References

1. Anderson, D. A, Tannehill, J. C., and R. H. Pletcher, R. H., Computational Fluid Mechanics and Heat Transfer, Second Edition, Taylor & Francis, 1995.
2. Muraleedhar, K. and T. Sundararaja, T. (eds.), Computational Fluid Flow and Heat Transfer, Second Edition, Narosa Publishing House, 2003.
3. Patankar, S. V., Numerical Heat Transfer and Fluid Flow, Hemisphere, 1980.
4. Hoffmann Klaus, A., Computational Fluid Dynamics for Engineers – Volume 1, Engineering Education Systems, Wiehita.
5. Versteeg, H. K. and W. Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Addison Wesley – Longman, 1995.
6. Hornbeck, R. W., Numerical Marching Techniques for Fluid Flows with Heat Transfer, NASA, SP-297, 1973.

ME6213 ANALYSIS OF THERMAL POWER PLANT CYCLES AND SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Energy sources - Fossil fuels, Nuclear fuels, Solar and Conventional energy sources - Fuel storage, Preparation, Handling and Combustion - Combustion calculations - General layout of Conventional Thermal power plants - Design and Operation- Superheat, Reheat and Regeneration - Other auxiliaries of thermal power plant - High-pressure boilers -Steam Generators control.

Module II (10 hours)

Steam nozzles and Steam turbines - Working - Compounding - Governing of steam turbines - Condensers and Cooling towers - Cycles for Steam power plants - Rankine cycle and its analysis - Reheat cycle, Regenerative cycle and Binary power cycle - Steam piping - Waste heat management.

Module III (10 hours)

Diesel electric power plant - working and fields of use - Different systems of diesel electric power plants and plant layout - Gas turbine and combined cycle analysis – Inter-cooling, reheating and regeneration - design for high temperature - Combined cycles with heat recovery boiler – Combined cycles with multi-pressure steam - STAG combined cycle power plant - Influence of component efficiencies on cycle performance - Energy transfer between a fluid and a rotor - Euler turbine equation - Pressure head and velocity head variations for forward, radial and backward curved vanes - Ideal and actual characteristics of Fluid machines.

Module IV (12 hours)

Nuclear power plants – Introduction - Nuclear fuels - Atomic number and mass number - Atomic mass unit - Nuclear energy conversion - Chemical and nuclear equations - Nuclear reactions -Fission and fusion - Energy from fission and fuel burn-up - Radioactivity - Neutron energies - Fission reactor types - Fast breeder reactor - Production of nuclear fuels - Fuel rod design - Steam cycles for nuclear power plants - reactor heat removal – Coolant channel orificing - Core thermal design - Thermal shields - Fins in nuclear plants – Core thermal hydraulics - Safety analysis - LOCA - Time scales of transient flow and heat transfer processes.

References

1. D.G. Shepherd: Principles of Turbo Machinery, The Macmillan Company, 1956.
2. M. M. El-Wakil: Power Plant Technology, McGraw Hill, 1985
3. A. W. Culp Jr: Principles of Energy Conversion, McGraw Hill, 2001
4. H. A. Sorensen: Energy Conversion Systems, J. Wiley, 1983
5. T. F. Morse: Power Plant Engineering, Affiliated East West Press, 1978
6. M. M. El-Wakil: Nuclear Power Engineering, McGraw Hill, 1962
7. R. H. S. Winterton: Thermal Design of Nuclear Reactors, Pergamon Press, 1981
8. R. L. Murray: Introduction to Nuclear Engineering, Prentice Hall, 1961

ME6214 CRYOGENIC ENGINEERING

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 hours)

Gas liquefaction systems, thermodynamically ideal systems, Joule Thomson effect, adiabatic expansion; liquefaction system for air, Neon, hydrogen and helium, effect of component efficiencies on system performance.

Module II (10 hours)

Gas separation and purification – principles, plant calculation, air, hydrogen, and helium separation systems.

Module 1II (11 hours)

Cryogenic refrigeration systems, ideal and practical systems, cryogenic temperature measurement; cryogenic fluid storage and transfer systems, storage vessels and insulation, two-phase flow in cryogenics transfer systems, cool down process.

Module 1V (11 hours)

Introduction to vacuum technology, low temperature properties of materials, pump down time, application of cryogenic systems, super-conductive devices, rocket and space simulation, cryogenics in biology and medicine, cryopumping.

References

1. Barron, R., Cryogenic Systems, McGraw-Hill, 1966.
2. Timmerhaus, K. D. and Flynn, T. M., Cryogenic Process Engineering, Plenum Press, 1989.
3. Scott, R. B., Cryogenic Engineering, D'Van-Nostrand, 1962.
4. Vance, R. W. and Duke, W. M., Applied Cryogenic Engineering, John Wiley, 1962.
5. Sitting, M., Cryogenics, D' Van-Nostrand, 1963.

ME6293 THERMAL SCIENCES LABORATORY

L	T	P	C
0	0	3	1

Each student shall design his/her own experiment by suitably modifying one of the existing experimental set ups in any of the laboratories of Thermal Stream under the supervision of Faculty-in-Charge of the Class and Staff-in-Charge, concerned Laboratory. He/she shall conduct the planned experiment and submit a detailed report on the experimental results obtained. The report shall also contain the detailed study carried out prior to designing the experiment. Grade will be awarded on the basis of the quality of the experiment conducted, the final report submitted, and oral examination conducted towards the end of the semester. Students also carried out experiments on following thermal systems.

1. CI and SI engines test rigs
2. Fluid Machine test rigs
3. Heat transfer test rigs
4. Interferometer using Laser beams
5. Nano and Micro Heat Transfer test rigs
6. Heat pipe systems
7. Fluidized bed systems
8. Wind tunnels
9. Drag and Lift measurements and verification using softwares
10. Solar Energy systems

ME6294 TERM PAPER/ MINI PROJECT/INDUSTRIAL TRAINING

L	T	P	C
0	0	0	1

Students are free to select any one assignment from the following term paper/mini project/industrial training.

Term Paper: Prepare a review paper on any thermal science topic with the individual analysis and comments.

Mini project: Students can select any project work and work under the guidance of any teaching staff in the department. End of the semester, each student has submit a thesis report. Project work is evaluated by the department as per M. Tech. regulations.

Industrial Training: Who are opting for industrial training, as to undergo a minimum of four weeks training in well established industries during in the summer vacation after the first two semesters. He has to submit a report on his training to the department and the same is evaluated as per M. Tech. regulations.

ME7295 PROJECT WORK

L	T	P	C
0	0	0	8

The student will be encouraged to fix the area of the project work and conduct the literature review during the second semester itself. The project work starts in the third semester. The topic shall be research and development oriented. The project can be carried out at the institute or in an industry/research organization. They are supposed to complete a good quantum of the work in the third semester. There shall be evaluation of the work carried out in the third semester.

ME7296 PROJECT WORK

L	T	P	C
0	0	12	12

The project work started in the third semester will be extended to the end of the fourth semester. The project can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project in industry or other organization have to fulfill the requirements as specified in the "Ordinances and Regulations for M. Tech.". There shall be evaluations of the project work by a committee constituted by the department and by an external examiner.

Regulations for M. Tech. under the section - Project Work in Industry or Other Organization
At the end of the third semester, the students' thesis work shall be assessed by a committee and graded as specified in the "Ordinances and Regulations for M. Tech.". If the work has been graded as unsatisfactory, the committee may recommend a suitable period by which the project will have to be extended beyond the fourth semester. At the end of the fourth semester, the student shall present his/her thesis work before an evaluation committee, which will evaluate the work and decide whether the student may be allowed to submit the thesis or whether he/she needs to carry out additional work. The final viva-voce examination will be conducted as per the "Ordinances and Regulations for M. Tech."

ME6221 THERMAL ENVIRONMENTAL ENGINEERING

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9hours)

Thermal comfort, effective temperature, comfort chart – inside design condition, ventilation standards, applied psychrometry, summer air conditioning processes, winter air conditioning processes.

Module II (11 hours)

Estimation of air conditioning loads - heating and cooling; heat gain/loss through glass, heat gain/loss through structures, internal load, ventilation load, and infiltration load.

Module III (11 hours)

Air distribution: room air distribution, air diffusion equipments, friction losses and dynamic loss in ducts, air dust design; Air handling equipments: Fans – types, performance, and selection; air conditioning apparatus, cooling dehumidifying, humidifying heating and cleaning equipments.

Module IV (11 hours)

Air conditioning systems, DX system, all water system, all air system, air water system, central and unitary systems, fan coil system; automatic controls of air conditioning systems, thermostats, dampers, and damper motors; automatic valves piping design- water piping, refrigerant piping, steam piping. Refrigeration systems.

References

1. Threlkeld, J. L., Thermal Environmental Engineering, Second Edition, Prentice Hall, 1970.
2. Norman C. Harris, N. C., Modern Air Conditioning Practice, Third edition, McGraw- Hill, 1985.
3. Levenhagen, J. L., Spethmann, D. H., Heating Ventilating and Air conditioning Controls and Systems, McGraw Hill1993.

ME6222 DESIGN OF HEAT TRANSFER EQUIPMENT

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Thermal performance analysis of heat exchangers - compact, cross flow, liquid to gas, and double pipe heat exchangers, film coefficients for tubes and annuli, equivalent diameter of annuli, fouling factors, caloric or average fluid temperature, true temperature difference; Design calculation of double pipe heat exchanger, double pipe exchangers in series-parallel arrangements.

Module II (11 hours)

Shell and tube heat exchangers - tube layouts, baffle spacing, classification of shell and tube exchangers, Design calculation of shell and tube heat exchangers, shell-side film coefficients, shell-side equivalent diameter, true temperature difference in a 1-2 heat exchanger, influence of approach temperature on correction factor, shell and tube sides pressure drop; performance analysis of 1-2 heat exchangers, design calculation of shell and tube heat exchangers; flow arrangements for increased heat recovery.

Module III (11 hours)

Direct contact heat transfer - Classification of cooling towers, wet-bulb and dew point temperatures, Lewis number, cooling-tower internals, heat balance, heat transfer by simultaneous diffusion and convection; Design and analysis of cooling towers, determination of the number of diffusion units, performance evaluation of cooling towers, influence of process conditions and operating variables on their design

Module IV (11 hours)

Heat pipes - types and applications, operating principles, working fluids, wick structures, control techniques, pressure balance, maximum capillary pressure, liquid and vapor pressure drops, effective thermal conductivity of wick structures, capillary limitation on heat transport capability, sonic, entrainment, and boiling limitations, determination of operating conditions; Heat pipe design – fluid selection, wick selection, material selection, preliminary design considerations, heat pipe design procedure, determination of heat pipe diameter, design of heat pipe containers, wick design, entertainment and boiling limitations, design problems; Non conventional heat pipes – flat, rotating, reciprocating and disc shaped heat pipes, heat pipes in cooling microelectronics – micro and mini heat pipes.

References

1. Kern, D. Q., Process Heat Transfer, Tata McGraw-Hill, 2000.
2. Chi, S. W., Heat Pipe Theory and Practice- A Source Book, McGraw-Hill, 1976
3. Fraas, A. P., Heat Exchanger Design, Second Edition, John Wiley & Sons, 1989
4. Dunn, P. D. and Reay, D. A., Heat Pipes, Fourth Edition, Pergamon Press, 1994

ME6223 PRINCIPLES OF TURBOMACHINERY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hours)

Definition and classification of turbomachines; principles of operation; specific work and its representation on T-s and h-s diagrams; losses and efficiencies; energy transfer in turbomachines; Euler equation of turbomachinery. Variation of velocity head and pressure head for forward, radial, backward curved vanes. Performance characteristics of fluid machines.

Module II (11 hours)

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.

Module III (10 hours)

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

.

Module IV (9 hours)

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.

References

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.

ME6224 AERODYNAMICS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Equations for incompressible inviscid flows, Fluid circulation and rotation, Vorticity, Kelvin's theorem, Velocity potential, Stream function, Equation of a stream line, Complex potential, Elementary flow patterns and their superposition.

Module II (11 hours)

Flow past a cylinder, Magnus effect, Kutta condition, Vortex theory of lift, Conformal transformation, The Jowkowski transformation, Lift on arbitrary cylinder, Aerodynamic center, Pitching moment.

Module III (11 hours)

Aerofoils, Low speed flows over aerofoils-the vortex sheet, Thin aerofoil theory, Symmetric aerofoil, Tear drop theory, Camber line at zero angle of attack, Characteristics of thin aero foils, Motion in three dimensions, Flow past slender bodies.

Module IV (11 hours)

Finite wings, Downwash and induced drag, Prandtl-Lachester theory, Biot- Savarat law, General series solution, Glauret method, Multhop's method, Horseshoe effects, Ground effects, Lineraised compressible flows in two dimensions, Flow past a wavy wall, Similarity rules, Aerofoil in compressible flows.

References

1. Kuethe, A. M. and Chow, C., Foundations of Aerodynamics, Fourth Edition, Wiley Eastern, 1986
2. Katz, J. and Plotkin, A., Low Speed Aerodynamics, McGraw-Hill, 1991.
3. Milne-Thomson, L. M., Theoretical Hydrodynamics, Macmillan, 1958
4. Anderson Jr., J. D., Fundamentals of Aerodynamics, McGraw Hill, 1988.
5. Houghton, E. L. and Brock, A. E., Aerodynamics for Engineering Students, Second Edition, Edward Arnold, 1970.

ME6225 STATISTICAL THERMOYDNAMICS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hrs)

Thermodynamics and statistical mechanics, Maxwell's Deon, ensembles and statistics, distribution laws, partition function, Boltzman's distribution, thermodynamic quantities; kinetic theory of ideal gases, collisions with the walls, equation of state, distribution of molecular velocities, energy distribution function, verification of Maxwell's distribution, classical theory of specific heat capacity.

Module II (9 hrs)

Transport phenomena, intermolecular forces, mean free path, law of mass action, transformation of equilibrium expressions, viscosity, thermal conductivity, diffusion, isotope effect.

Module III (9 hrs)

Application of Boltzmann statistics, thermodynamic probability, statistical interpretation of entropy, configurational entropy, thermal entropy, barometric equation, principle of equipartition of energy.

Module IV (12 hrs)

Quantum statistics, Bose – Einstein statistics, Fermi – Dirac statistics, velocity, speed and energy distribution function, specific heat of electron gas, thermionic emission, introduction to fluctuations, theory of Brownian motion, Johnson noise

References

1. Sears F.W., An Introduction to Thermodynamics, Second Edition, Addison Wesley, 1971
2. Saad, M. A., Thermodynamics for Engineers, Prentice hall of India, 1969
3. Gupta, M. C., Statistical Thermodynamics, Second Edition, New Age International Publisher, 1998
4. Rocard,Y. and Manders, C .R .S., Thermodynamics, Pitman, 1961
5. Richard E Sonntagand Gordon J. Van Wylen, Fundamentals of Statistical Thermodynamics, John Wiley, 1968

ME6226 THEORETICAL HYDRODYNAMICS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hrs)

Review of basic differential equations of motion - inviscid approximation, Euler’s equation, Bernoulli’s equation; fluid circulation, vorticity, vortex line, vortex tube and vortex filament; vorticity transport equation, Kelvin’s theorem, irrotational flow, velocity potential; two-dimensional incompressible flows, stream function, equation of a stream line, relationship between velocity potential and stream function, boundary conditions, complex potential, Blasius theorems.

Module II (11 hrs)

Complex potentials for simple flows, uniform flow, source, sink and vortex, combination of simple flows, Rankine half body, Rankine oval, doublet, flow past cylinder, calculation of lift, Magnus effect; Conformal transformation, transformations of the circle, Jowkowski transformation, flow over an ellipse, flow past a flat plate, aerofoils, lift calculation, Kutta condition.

Module III (9 hrs)

Schwarz – Christoffel transformation, simple closed polygons, flow into and from a channel, flow past a flat plate with and without separation; method of images.

Module IV (11 hrs)

Three-dimensional irrotational flow, Stokes stream function for axi-symmetric flows, irrotational flow equations, velocity potentials, standard patterns and their combinations, flow past a sphere, flow past a stream-lined body; Graphical plotting of flow nets, numerical methods, Panel methods.

References

1. Valentine, H. R., Applied Hydrodynamics, Butterworth, 1967.
2. Milne – Thomson, L. M., Theoretical Hydrodynamics, Macmillan, 1963.

ME6227 I. C. ENGINES SYSTEMS, COMBUSTION AND PERFORMANCE ANALYSIS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Working principle - Constructional details - Classification and application of different types of I.C. engines - Two stroke engines - Wankel and other rotary engines - Stirling engine. Mixture preparation systems for SI and CI engines – Carburettor – MPFI – Diesel fuel supply systems – fuel pumps - fuel injectors – unit injector - CRDI - Combustion chambers.

Module II (10 hours)

Ignition, lubrication and Cooling Systems - Speed Governing systems - Intake and exhaust systems - Supercharging methods - Turbocharger matching - Aero-thermodynamics of compressors and turbines. Engine testing and performance – Effects of engine design and operating parameters on performance and emissions; Pollution formation in SI and CI engines - Factors affecting emissions - Control measures for evaporative emissions - Thermal reactors and catalytic converters - Engine modifications to reduce emissions - Instrumentation to measure pollutants - Emission standards and testing.

Module III (10 hours)

Review of basic thermodynamics and gaseous mixtures- Reactant an product mixtures - Stoichiometry-Adiabatic flame temperature- First and Second Laws of Thermodynamics applied to combustion- Equilibrium products of combustion - Fundamentals of combustion kinetics – Elementary reaction rates. General characteristics of combustion flame – detonation - deflagration- Factors affecting flame velocity and thickness – Quenching- Flammability –Ignition - Flame stabilization Laminar premixed flames- Laminar diffusion flames - Turbulent premixed flames.

Module IV (13 hours)

Fuels and their properties - Equivalence ratio – Self ignition temperature – Ignition lag- Role of fuel in engine combustion –Fuels for SI & CI engines – Octane number – Cetane number- Combustion generated pollutants. Normal combustion in SI Engines – Normal Combustion: Thermodynamic Analysis, Flame structure and speed, cyclic variations in combustion. Factors affecting combustion in SI engines –Effect of engine variables on flame propagation and ignition lag- Knocking- Effect of variables on knock – Detection of knock –Control of Knock- Pre ignition- Normal combustion in CI Engines –Analysis of cylinder pressure data – Direct Injection and Indirect – Injection Engine, Fuel spray behaviour - Variables affecting delay period - Factors affecting combustion in CI engines -Engine knock – Combustion chambers.

References

1. Stephen R. T., An Introduction to Combustion, McGraw-Hill International Editions
2. Kuo, K. K., Principles of Combustion, John Willey & Sons, 1986.
3. Strehlow, R. A., Combustion Fundamentals, McGraw-Hill, 1985.
4. Mukunda, H. S., Understanding Combustion, Macmillan India Ltd., 1992.
5. Smith, M. L. and Stinson, K. W., Fuels and Combustion, McGraw-Hill, 1952.
6. Ashley S. C., Thermodynamic Analysis of Combustion Engines, John Wiley, 1979.
7. Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, 1989.
8. Maleev, M. L., Internal Combustion Engines, Second edition, McGraw-Hill, 1989.
9. Mathur, M. L. and Sharma, R. P., Internal Combustion Engines, Dhanpath Rai & Sons, 2005.
10. G. R. Pryling, "Combustion Engineering", Revised Edn., Combustion Engg. Inc., New York 1967.
11. A. C. Eckbreth, "Laser Diagnostics for Combustion Temperature and Species", Cambridge, Abacus Press, 1988.
12. Fristrom. R. M. and Westenberg, A. A., "Flame Structure", McGraw – Hill Book Co. New York, 1965.
13. M. W. Thring, "The Science of Flames and Furnace", Chapman & Hill Ltd., London, 1962.

ME6228 MULTI PHASE FLOW

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Introduction- multi phase and multi-component flow, practical examples; method of analysis of multi phase and multi-component flow problems; basic definitions; two phase, one-dimensional conservation equations; pressure gradient components; flow patterns, Two phase flow patterns in mini and micro-channels.

Module II (10 hours)

Basic flow models – homogeneous flow model, pressure gradient, two phase friction factor for laminar flow and turbulent flow, two phase viscosity, friction multiplier; separated flow model – pressure gradient, Lokhart Martinelli correlation; Multidimensional two fluid model.

Module III (10 hours)

Drift flux model – gravity dominated flow regime, corrections for void fraction and velocity distribution in different flow regimes, pressure loss due to multi phase flow in pipe fittings, velocity and concentration profiles in multi phase flow; one-dimensional waves in two component flow, void-quality correlations.

Module IV (13 hours)

Boiling and condensation – evaporation, nucleate boiling, convective boiling; bubble formation and limiting volume; boiling map; DNB; critical boiling conditions ; static and dynamic instabilities , condensation process – types of condensation, Nusselt theory, deviations from Nusselt theory, practical equations, condensation of flowing vapors; introduction to boiling and condensation in small passages.

References

1. Collier, J. G., Convective Boiling and Condensation, McGraw-Hill, 1981.
2. Wallis, G. W., One-dimensional Two Phase Flow, McGraw-Hill, 1969.
3. Stephen, K. Heat Transfer in Condensation and Boiling, Berlin Hiedelberg, 1992.
4. Hsu, Y. Y. and Graham, R. W., Transport Processes in Boiling and Two phase Systems, McGraw-Hill, 1976.
5. Ginoux, J. J., Two Phase Flows and Heat Transfer, McGraw-Hill, 1978.
6. Hewitt, G., Delhaye, J. M., and Zuber, N., Multiphase Science and Technology, Vol. I, McGraw-Hill, 1982.
7. Ghiaasiaan, S. M., Two-Phase Flow, Boiling and Condensation: In Conventional and Miniature Systems, Cambridge University Press, 2008.
8. Tong, L. S. and Tang, Y. S., Boiling Heat Transfer and Two-Phase Flow, second Edition, Taylor & Francis, 1997.

ME6229 INDUSTRIAL FOOD PRESERVATION

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Food and its preservation-source of food problems, food of plant and animal origin, needs and benefits of industrial food preservation; nature of food hazards-causes of food spoilage, mycotoxims, epidemiology of food hazards; principles of fresh food storage-nature of harvested crop, plant and animal product storage; effect of cold storage and quality, storage of grains; principles of refrigerated gas storage of food-Gas packed refrigerated dough, sub-atmospheric storage; gas atmospheric storage of meat, grains, seeds and flour.

Module II (11 Hours)

Principles of food freezing; development of frozen food industry; freezing point of foods; freezing of bakery products. Candy manufacture; food preservation by canning and drying- art of appetizing, spoilage of food caused by micro-organisms, categories of foods for canning, spoilage of canned foods; influence of canning on the quality of food; improvement in canning technology; drying- natural process-artificial drying, adiabatic driers, influence of drying on pigments and enzymes. Dehydration of fruits, vegetables, milk, animal products etc.-Freeze drying.

Module III (11 hours)

Principles of food concentrates-high solid-high acid foods; Pectin and gel formation; invert sugar, jelly making, other food products, concentrated moist foods; food preservation by fermentation-pickling and curing life with micro-organisms; sources of salts; fermented and pickled products; beverage processes; processing of meat, fish and poultry; principles of fish salting, meat curing and smoking, purpose of smoking; food preservation by chemicals-food additives, functional chemical additives applications; chemical preservatives and antibiotics.

Module 4: (11 Hours)

Food preservation by irradiation-technology aspects of radiations; pasteurization of foods, processing and storage of milk and diary products; public health aspects, micro-biology of irradiated foods; standards of processing of foods-milk and diary products, fish, meat, poultry, fruits and vegetables; food packaging-principle in development of protective packaging; deteriorative changes in food stuff and packaging methods for prevention; food containers-rigid containers and flexible packaging materials, and their properties; special problems in packaging perishables and processed food; evaluation of packaging, material and package performance, packaging equipment, package standards and regulation; bar coding; shrink packaging; biodegradable packaging; active packaging.

References

1. Heldman, J. C. and Lund, D.B., Handbook of Food Engineering, Marcel Dekker, 1992.
2. Lewis, M.J., Physical Properties of Food and Food Processing Systems, Woodhead, 1990.
3. Jelen, P., Introduction to Food Processing, Prentice Hall, 1985.
4. Painy, F.A. and Painy, H.Y., A Handbook of Food Packaging, Leonard Hill, 1983.
5. Considine, D.M., Foods and Food Production Encyclopaedia, VNR, 1982.
6. Furia, T.E., Regulatory Status of Direct Food Additives, CRC Press, 1980.
7. Florida, K., A. and Twig, B. A., Quality Control of Food Industry, AVI, 1970.
8. ASHRAE, Guide and Data Book, Applications for Heating, Refrigerating, Ventilating and Air Conditioning, 1962.

ME6230 INTRODUCTION TO TURBULENCE

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I. (9 hours)

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.

Module II (11 hours)

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.

Module III (11 hours)

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.

Module IV (11 hours)

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).

References

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.

ME6231 POSTULATIONAL THERMODYNAMICS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hours)

General principles of classical thermodynamics, postulational approach, basic postulates, conditions of equilibrium, fundamental equations, equations of state, Euler equation, Gibbs-Duhem equation, multi-component simple ideal gas systems.

Module II (9 hours)

Reversible processes, maximum work theorem, alternate formulation, energy minimum principle, Legendre transformations, extremum principles in the Legendre transformed representation, thermodynamic potentials and Massieu functions.

Module III (9 hours)

Maxwell relations and Jacobian methods, procedure to reduction of derivatives, applications, stability criteria of thermodynamic systems, first-order phase transition, single component and multi-component systems, Gibbs phase rule, phase diagram for binary systems.

Module IV (12 hours)

Critical Phenomena, liquid and solid Helium, Nernst postulate, introduction to irreversible thermodynamics, linearised relation, Onsager's reciprocity theorems, special topics on advanced thermodynamics.

References

1. Callen, H. B., Thermodynamics and an Introduction to Thermostatic, Second Edition, John Wiley and Sons, 1985.
2. Rao, Y. V. C., Postulational and Statistical Thermodynamics, Allied Publishers, 1994
3. Zemansky, M. W., Abbot, M. M., Van Ness, H. C., Basic Engineering Thermodynamics, McGraw-Hill, 1987
4. Saad, M. A., Thermodynamics for Engineers, Prentice Hall of India, 1987
5. Lee, J. F., Sears, F. W., Thermodynamics: An Introductory Text for Engineering Students, Addison Wesley, 1964
6. Wark Jr., K., Advance Thermodynamics for Engineers, McGraw-Hill, 1995.
7. M. M. Zemansky, Heat and Thermodynamics, 5^{th} Edition, McGraw Hill, 1968.
8. J. P. O. Connel and J. M.Haile, Thermodymamics – Fundamentals for Applications, Cambridge University Press, 2006.
9. V. V. Sychev, The Differential Equations of Thermodynamics, Mir Publishers, 1983.
10. C. Kalidas and M. V. Sangaranarayanan, Non-Equilibrium Thermodynamics Thermodynamics – Principles & Applications, Mac Millan India Ltd., 2002.

ME6232 ADVANCED INSTRUMENTATION

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (8 hours)

Measurements of thermal and physical properties - Viscosity - Use of poiseuille flow, Falling, Rotating and Oscillating bodies - Thermal conductivity of solids and liquids - Low conductivity and metallic - Steady and unsteady states - Measurement of specific heat of gases - Data acquisition - Analog and digital conversion - Post processing of data - Statistical analysis - Goodness of data - Correlating data - Linear and non-linear regression.

Module II (12 hours)

Error estimates in Temperature measurements - Solids and fluids - Steady state and unsteady measurements - Radiation effects - Platinum resistance thermometers - Construction and usage - Calibration - Bridges - Fluid pressure measurement - Capacitive probes - Piezoelectric pressure sensors - Anemometry.

Module III (11 hours)

Thermal radiation measurements - Radiometry - Surface radiation measurements – Gas radiation instruments - Errors in radiation measurements - Transient experimental techniques for surface heat flux rates - Negligible internal resistance - Negligible surface resistance - Rapid response measurements - Thick film and thin film gauges – Non uniform surface temperatures - Quasi steady measurements.

Module IV (11 hours)

Temperature Measurements in high temperature gases - Calorimetric, electrostatic, radiation, cyclic, transient pressure and heat flux probes - Spectroscopic methods - Cooled film sensors - Temperature measurement in cryogenics - Scales of measurement- Thermocouple, resistance and magnetic thermometry - Optical measurement of temperature - Schlieren shadow-graph and interferometer - Errors in optical measurements.

References

1. E.R.G. Eckert and R.J. Goldstein: Measurements in Heat Transfer, McGraw Hill, 1976
2. J.P. Holman: Experimental Methods for engineers, McGraw Hill, 1971
3. E.O. Doebelin: Measurements Systems: Application and Design.
4. T.G. Beekwith and L.M. Buck : Mechanical measurements, Adison-Wesley, 1965
5. Barney: Intelligent Instrumentation, Printice Hall, 1988

ME6233 THEORY AND APPLICATIONS OF HEAT PIPE

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hrs)

Operating principle, Working fluids and its temperature ranges, Heat transfer limits and Heat pipe characteristics, Various Applications
Interfacial heat and mass transfer, Physical surface phenomena, Capillary and disjoining forces – Interfacial resistance in vaporization and condensation process, Interfacial mass, Momentum, energy, pressure balance – Interfacial phenomena in grooved structures.

Module II (10 hrs)

Steady hydrodynamics – Thermal characteristics and heat transfer limitation, Thermal Fluid phenomena in capillary media, Vapor flow Analysis, Thermal characteristics including the wall effects and effect of vapor flow – Capillary boiling – Sonic, Entrainment, Viscous, condenser, Continuum, and Frozen startup Limitations.

Module III (10 hrs)

Area temperature relations, Pipe dimensions and structural considerations. Heat pipe heat exchanger, transient model calculations and procedures.

Module IV (10 hrs)

Heat pipe Behaviour – Transient response to sudden change in temperature heat input, Frozen startup and shut down of heat pipe – Numerical and Analytical model for Frozen start up. Two phase closed Thermosyphon – Reflux condensation heat transfer in Analysis, Evaporation heat transfer Analysis, Transient and oscillatory behavior of Thermosyphon. Minimum liquid fill requirement, Thermosyphon with capillary wicks.

References

1. S.W. Chi, 1976, Heat pipe Theory and practice, Hemisphere publishing corporation, Washington.
2. Dunn, P.D and Reay, D.A, 1982, “Heat Pipes”, Third Edition, Pergamon Press.
3. Amir Faghri, 1995 Heat pipe science and Technology, publisher: Taylor and Francis.
4. V.P. Carey, 1992, Liquid – Vapor phase – Change phenomena: An Introduction to the Thermophysics of vaporization and condensation Processes in Heat Transfer Equipment, Hemisphere Publishers, New York.
5. J.N. Israelachvili, 1985, Intermolecular and surface forces – Academic press, London.
6. I.B. Ivanov, 1988, Thin Liquid films: Fundamentals and Application – Marcel Dekkar, New York.
7. M.N. Ivanovskii, V.P. Sorokin and I.V. Yagodkin, 1982, The physical principles of Heat pipes, Clarendon press, Oxford.

ME6234 THERMODYNAMIC PROPERTY RELATIONS AND EXERGY ANALYSIS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 hrs)

Introduction to thermodynamics, review of 1st law, work and heat transfer, properties of pure substances, review of 2nd law, entropy, availability and irreversibility ,practical applications, introduction to exergy and second law efficiency

Module 2 (12 hrs)

Thermodynamic property relations: Maxwell's equations, T-ds equations, Difference in heat capacities, ratio of heat capacities, energy equation, Joule-Thomson effect. Clausius- Clapeyron equation, Bridgman Tables for Thermodynamic relations. Evaluation of thermodynamic properties from an equation of state. Helmoltz and Gibbs functions; Maxwell's relations; Enthalpy, entropy, internal energy, and specific heat relations; Applications to ideal and real gases. Joule-Thomson coefficient

Module 3 (10hrs)

Definition of exergy; forms of exergy; simple examples of calculation; the destruction of exergy. Exergy balance in thermodynamic systems, Exergic efficiency, exergy and irreversibility, Exergy analysis of thermodynamic systems, Heat exchange - Expansion Pressure let down - Mixing - Distillation - Combustion air pre-heating – Systematic design method, closed and open systems

Module 4 (10 hrs)

Applications of exergy analysis of thermodynamic operations and cycles, Air standard cycles; Carnot, Otto, Diesel, Dual and Stirling cycles, p-v and T -s diagrams, description, efficiencies and mean effective pressures. Gas turbine (Brayton) cycle; description and analysis. Performance improvement of gas turbines; Regeneration cycle – conventional, alternative, Staged heat recovery

References

1) Bejan. A, Advanced Engineering Thermodynamics, John Wily and Sons, 1998
2) Kennath Wack , Advanced Thermodynamics for Engineers, Mc Graw Hill Inc, 1995
3) M.W Zemanzky, R, R. Dittman, Heat and Thermodynamics, Mc Graw Hill, &th Edition, 1998
4) Rao Y.V.C, Postulations and Statistical Thermodynamics, Allied Publishers Ltd, New Delhi, 1994
5) Moran MJ , and Shaprio H N, Fundamentals of Engineering thermodynamics, Wiley, 2000
6) Holman, J.P., Thermodynamics, Fourth Edition, McGraw-Hill Inc.,1988.
7) Y.A. Cengal and M.A. Boles, Thermodynamics: an Engineering Approach, McGraw Hill (Fifth edition).

ME6235 TRANSPORT PHENOMENA

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hrs)

Viscosity and the mechanisms of momentum transfer: Newton's law of viscosity (molecular momentum transport), generalization of Newton's law of viscosity, pressure and temperature dependence of viscosity, molecular theory of the viscosity of gases at low density, molecular theory of the viscosity of liquids. Thermal conductivity and the mechanisms of energy transport: Fourier's law of heat conduction (molecular energy transport), temperature and pressure dependence of thermal conductivity, and theory of thermal conductivity of gases at low density.

Module II (10 hrs)

Diffusivity and the mechanisms of mass transport: Fick's law of binary diffusion (molecular mass transport), temperature and pressure dependence of diffusivities, theory of diffusion in gases at low density. Shell momentum balances and velocity distributions in laminar flow: shell momentum balances and boundary conditions, flow of a falling film, flow through a circular tube, flow through annulus, flow of two adjacent immiscible fluids, creeping flow
around a sphere.

Module III (10 hrs)

Shell energy balances and temperature distributions in solids and laminar flow: shell energy balances; boundary conditions, heat conduction with an electrical heat source, heat conduction with a nuclear heat source, heat conduction with a viscous heat source, heat conduction with a chemical heat source, heat conduction through composite walls, heat conduction in a cooling fin, forced convection, free convection. Concentration distributions in solids and laminar flow: shell mass balances; boundary conditions, diffusion through a stagnant gas film, diffusion with a heterogeneous chemical reaction, diffusion with a homogeneous chemical reaction, diffusion into a falling liquid film (gas absorption), diffusion into a falling liquid film (solid dissolution), diffusion and chemical
reaction inside a porous catalyst.

Module IV (12 hrs)

The equations of change for isothermal systems: the equation of continuity, the equation of motion, the equation of mechanical energy, the equation of angular momentum, the equations of change in terms of the substantial derivative, use of the equations of change to solve flow problems. Velocity distributions in turbulent flow: comparisons of laminar and turbulent flows, time- smoothed equations of change for incompressible fluids, the time- smoothed velocity profile near a wall. The equations of change for non- isothermal systems: the energy equation, special forms of the energy equation, the Boussenisq equation of motion for forced and free convection, use of the equations of change to solve steady state problems. The equations of change for multi component systems: the equations of continuity for a multi component mixture.

References

1. Transport phenomena by Bird R.B., Stewart W.C., Lightfoot F.N., 2nd ed. John Wiley & Sons Inc, U.S.A, 1960.
2. Transport phenomena for engineers by L. Theodore, International text book company,U.S.A.1971.
3. Transport processes and unit operations, 3rd, Geankoplis, PHI, 1997.
4. Fundamental of heat, momentum and mass transfer, Welty, Wicks, Wilson, John Wiley.

NS6102 MICROSCALE AND NANO SCALE HEAT TRANSFER

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (10 hours)

Introduction to microscale heat transfer - Observations on deviations from conventional theory – experimental and theoretical findings – Overview of studies and comparison of results – Introductory ideas about single phase, multiphase and gas flow in small channels – Contradictory observations and viewpoints in microchannel heat transfer- Applications of microscale heat transfer – basic ideas on micro heat exchangers and microscale heat sinks – applications in electronics cooling, biotechnology and MEMS.

Module II (8 hours)

Conduction in integrated circuits and their constituent films – current trends and future challenges – Microscale thermometry techniques – electrical and optical methods – thermorefectance thermometry – Thermal properties of amorphous dielectric films – Thermal characterization and heat transport in dielectric films – Heat conduction in crystalline silicon films – Phonon dispersion - heat conduction in semi-conductors at high temperatures – phonon transport equations – hot phonon effects.

Module III (12 hours)

Fundamentals of convective heat transfer in microtubes and channels – Thermodynamic concepts, general laws and particular laws - Governing equations and size effects. Single phase forced convection in microchannels – Flow structure – entrance length – experimental observations on flow and heat transfer characteristics – Theoretical investigations – Forced convection in mixtures - Gas flow in microchannels. Boiling and two- phase flow heat transfer in small channels – Boiling curve and critical heat flux - flow patterns – Bubble dynamics and thermodynamic aspects – Mathematical modeling and measurement of microscale convective boiling; Applications of microchannel heat transfer – microchannel heat sinks – micro heat pipes and micro heat spreaders – integration of microchannel heat sinks and heat spreaders to silicon structures – experimental and theoretical investigations.

Module IV (12 hours)

Fundamentals of heat transport at the nanoscale – characteristic lengths and heat transfer regimes – Nanoscale heat transfer phenomena – Conduction, radiation and convection in the nanoscale – Applications of nanoscale heat transfer in microelectronics, energy, nanomaterial synthesis, nano fabrication and biotechnology – Experimental methods in nanoscale heat transfer – thermophysical property measurement – heating and sensing based on microheaters and microsensors – Photothermal methods – Mixed optical and electrical heating methods – Nanowires and carbon nanotubes – Thermal imaging – Analytical methods – Boltzmann equation approach and Monte Carlo Simulation for Boltzmann transport equation – The wave mechanisms - quantized incoherent transport, molecular dynamics simulation and the fluctuation-dissipation theorem approach – Multicarrier and Multidimensional Transport – coupled electron-phonon transport, multi length-scale and multidimensional transport – Challenges and Future applications.

References

1. Ju, Y.S., and Goodson, K. , Microscale Heat Conduction in Integrated Circuits and their Constituent Films, Kluwer Academic Publishers, Boston, 1999. 2. Satish, K., Srinivas, G., Dongqing, L., Stephane, C., and Michael R. K., Heat Transfer and Fluid Flow in Minichannels and Microchannels, First Edition, Elsevier, 2005.
3. Garimella, S. V. and C. B. Sobhan, C. B., Transport in Microchannels – A Critical Review, in Annual Review of Heat Transfer, Begell House, NY, 2004.
4. Chen, G., Nanoscale Energy Transport and Conversion, Oxford University Press, 2005.
5. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2005.