Master of Technology in Mechanical Engineering
(With Specialisation in Thermal Engineering)

Submitted by

Department of Mechanical Engineering

MD University, Rohtak

Master of Technology in Mechanical Engineering
(With Specialisation in Thermal Engineering)

EFFECTIVE FROM THE SESSION 2012-13

Semester wise Course Scheme

FIRST SEMESTER

S. No.	Subject Code	Subject	L-T-P	Marks Weightage		Grand total
				Theory	Sessional	
1	MT-TH 501	Advanced Thermodynamics	3-0-0	100	50	150
2	MT-TH 503	Advanced Fluid Dynamics	3-0-0	100	50	150
3	MT-TH 505	Heat Transfer-I	3-0-0	100	50	150
4	MT-TH 507	Combustion Engineering	3-0-0	100	50	150
5	MT-TH 803A	Instrumentation & Measurements	3-0-0	100	50	150
6	MT-TH 509	Advanced Thermal Lab	0-0-4	5 0	50	100
7	MT-TH 813A	Instrumentation & Measurements Lab	0-0-2	25	25	50
			15-0-6	575	325	900

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SECOND SEMESTER

S. No.	Subject Code	Subject	L-T-P	Marks Weightage		Grand total
				Theory	Sessional	
1	MT-TH 502	Heat Transfer-II	3-0-0	100	50	150
2	MT-TH 508	Advanced Gas Dynamics	3-0-0	100	50	150
3	MT-TH 801A	Numerical Analysis and Optimization	3-0-0	100	50	150
4		General Elective	3-0-0	100	50	150
5		Programme Elective – I	3-0-0	100	50	150
6	MT-TH 504	Numerical Analysis and Optimization Lab	0-0-2	25	25	50
7	MT-TH 506	Heat and Mass Transfer Lab	0-0-2	25	25	50
			15-0-4	550	300	850

General Elective	**Program Elective – I**
MT-TH-510 – Design of Thermal Systems	MT-TH-516- Thermal and Nuclear Power Plant
MT-TH-512 – Heat Exchangers	MT-TH-518 – Steam Generator Technology
MT-TH-514 – Energy Management	MT-TH 520- Wind Energy Technology

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THIRD SEMESTER

S. No.	Subject Code	Subject	L-T-P	Marks Weightage		Grand total
				Theory	Sessional	
1	MT-TH 601	Minor Project	0-0-10	100	100	200
2	MT-TH 603	Turbo-machinery	3-0-0	100	50	150
3	MT-TH 605	Seminar	0-0-4	5 0	50	100
4		Programme Elective – II	3-0-0	100	50	150
5		Programme Elective – III	3-0-0	100	50	150
			9-0-14	450	300	750

Program Elective – II	**Program Elective – III**
MT-TH-607-Energy Conservation	MT-TH-613-Computational Fluid Dynamics
MT-TH-609-Solar Energy Systems	MT-TH 615-Non-Conventional Energy Resources
MT-TH-611-Cogeneration & Waste Heat Recovery Systems	MT-TH-617-Energy Economy & Environment Policy

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FOURTH SEMESTER

S. No.	Subject Code	Subject	L-T-P	Marks Weightage		Grand total
				Theory	Sessional	
1	MT-TH 602	Dissertation	0-0-24	400	200	600
			0-0-24	400	200	600

M.D. University, Rohtak
Scheme of Studies & Examinations for
Master of Technology Mechanical Engineering
(With Specialisation in Thermal Engineering)

The Performance of the student of M.Tech shall be graded on the basis of percentage of marks and corresponding grades as mentioned below :

A)

Marks		**Grades**		**Marks**
85	≤	A+	≤	100
75	≤	A	<	85
60	≤	B	<	75
50	≤	C	<	60
40	≤	D	<	50
00	≤	E	<	40

Letter Grades	**Performance**	**Division**
A+	Excellent	First
A	Very Good	First
B	Good	First
C	Fair	Second
D	Pass	Third
E	Repeat	Fail

Note : The Candidate who have passed all the semesters examination in the first attempt obtaining at the 75% marks in aggregate shall be declared to have passed in the first division with Distinction mentioned in the degree.

B)

Actual percentage of Marks Obtained and Corresponding grades should be mentioned on detailed marks certificate of student. To obtain 'D' grade a student must have secure at least 40% marks in each subject of the semester Examination.

C)

Student who earned an 'E' grade or less than 40% marks in any subject shall have to reappear in that subject.

MT-TH 501 Advanced Thermodynamics **L-T-P** 3-0-0

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Review of Thermo dynamic Laws and Corollaries – Recapitulation of zeroth, first, second laws of thermodynamics. First and second analysis of simple closed and open systems. Concepts of Entropy, irreversibility, availability, exergy. Evaluation of Thermodynamic properties of working substance. General conditions for thermodynamic equilibrium. Introduction to instability of thermodynamic equilibrium.

Single-component Pure Substances– Equations of state – Real Gas Behaviour – Vander Waal's equation - Generalised compressibility Factor – Energy properties of Real Gases – Vapour pressure – Clausius – Clapeyron Equation – Throttling – Joule – Thompson coefficient.

Multi-component Systems - Non-reactive Mixture of perfect Gases, Governing Laws, Evaluation of properties. Mixture of Real Gases. Psychrometry - Psychrometric chart. Applications to Air conditioning processes and Cooling Towers.

Thermodynamics of Reactive Mixtures. Combustion, Combustion Reactions, Enthalpy of Formation, Entropy of Formation – Reference Levels for Tables – Energy of formation – Heat of Reaction – Adiabatic flame Temperature General product – Enthalpies – Equilibrium.
Chemical Equilibrium of Ideal Gases – Effects of Non-reacting Gases Equilibrium in Multiple Reactions. The vant Hoff's Equation. The chemical potential and phase Equilibrium – The Gibbs phase Rule.

Mechanical Engineering Applications of Thermodynamics: Power Generation – Maximum Power Subject to Size Constraint, Maximum Power from Hot Stream, External Irreversibilities, Internal Irreversibilities, Advanced Steam-Turbine Power Plants, Advanced Gas-Turbine Power Plants, Combined Steam-Turbine and Gas-Turbine Power Plants, Supercritical power cycle. **Solar Power –** Thermodynamic Properties of Thermal Radiation, Reversible Processes, Irreversible Processes, The Ideal Conversion of Enclosed Blackbody Radiation, Maximization of Power Output per Unit Collector Area, Convectively Cooled Collectors, Extraterrestrial Solar Power Plant, Nonisothermal Collectors, Time-Varying Conditions, and Solar-Driven Refrigerators. **Referigeratiion –** Optimal Intermediate Cooling, Liquefaction, Refrigerator Models with Heat Transfer Irreversibilities, Magnetic Refrigeration. **Entropy Generation Minimisation –** Trade-off between Competing Irreversibilities, Balanced Counterflow Heat Exchangers, Heat Exchangers with Negligible Pressure-Drop Irreversibility, Storage Systems.

BOOKS

1. A. Bejan, Advanced Engineering Thermodynamics, 3rd edition, John Wiley and sons, 2006.
2. F.W.Sears and G. L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Narosa Publishing House, New Delhi, 3rd edition, 1998.
3. M.J.Moran and H.N.Shapiro, Fundamentals Of Engineering Thermodynamics, John Wiley and Sons.
4. M. W. Zemansky and R. H. Dittman, Heat and Thermodynamics, McGraw Hill International Editions, 7th edition, 2007.
5. JP Holman, Thermo dynamics, McGraw Hill
6. *Desmond E. Winterbone:* Advanced Thermodynamics for Engineers, Elsevier, 1996

MT-TH 503 Advanced Fluid Dynamics **L-T-P 3-0-0**

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Recapitulation of basic laws of fluid flow in integral and differential form. Ideal and non-ideal flows, continuum view point and general equations of fluid motion, Newtonian fluids, Fluid statics, Fluid Kinematics. Reynolds transport theorem, Integral and differential forms of governing equations: mass, momentum and energy conservation equations.

Two dimensional flow – subsonic flow, physical significance of irrotational motion – Kelvin's theorem – Differential equation in terms of velocity Potential and stream function – Flow with small perturbation – flow past a wave shaped wall – Gothert's rule – Prandtl-Glanert rule – Hodograph method

Navier-Stokes Equations and their exact solutions. Couette flows, Poiseuille flows, Fully developed flows in non-circular cross-sections, Unsteady flows, Creeping flows. Turbulence, models, and flow equations: steady and unsteady turbulent boundary layers. Introduction to Computational Fluid Dynamics (CFD) Boundary conditions, Basic discretization – Finite difference method, Finite volume method and Finite element method.

Potential Flows; Recapitulation of fluid kinematics, Stream and Velocity potential function, Circulation, Irrotational vortex, Basic plane potential flows: Uniform stream; Source and Sink; Vortex flow, Doublet, Superposition of basic plane potential flows, Flow past a circular cylinder, Magnus effect; Kutta-Joukowski lift theorem; Concept of lift and drag.

Laminar Boundary Layers; Boundary layer equations, Boundary layer thickness, Boundary layer on a flat plate, similarity solutions, Integral form of boundary layer equations, Approximate Methods, Flow separation, Entry flow into a duct.
Turbulent Flow; Introduction, Fluctuations and time-averaging, General equations of turbulent flow, Turbulent boundary layer equation, Flat plate turbulent boundary layer, Turbulent pipe flow, Prandtl mixing hypothesis, Turbulence modeling, Free turbulent flows.

Books:

1. S M Yahya, Compressible Fluid Flow, Tata McGraw Hill, 2010
2. Fox W. Robert, McDonald T. Alan, Introduction to Fluid Mechanics, Fourth Edition, John Wiley & Sons, 1995.
3. Frank M. White, Fluid Mechanics, Tata McGraw-Hill, Singapore, Sixth Edition, 2008.
4. John D. Anderson Jr., Fundamentals of Aerodynamics, McGrawHill, 2005.
5. John D. Anderson Jr., Computational Fluid Dynamics: The Basics with Applications, McGraw-Hill Series of Mechanical Engineering, 1995.
6. Muralidhar K. and Biswas G., Advanced Engineering Fluid Mechanics, Second Edition, Narosa, 2005.
7. Panton R.L., Incompressible Flow, John Wiley and Sons, 2005.
8. Pijush K. Kundu and Ira M. Cohen, Fluid Mechanics, Fourth Edition, Academic Press (ELSEVIER), 2008.

MT-TH 505 Heat Transfer-1 **L-T-P** 3-0-0

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

INTRODUCTION AND BASIC CONCEPTS – Thermodynamics and Heat Transfer, Heat and other form of energy, Energy balance for steady- flow systems, Surface energy balance, Heat Transfer Mechanisms, Simultaneous heat transfer mechanism, Problem-solving Technique.

Heat Conduction Equation – Statement of Problem, Steady versus Transient Heat transfer, Multidimensional Heat Transfer, One- Dimensional Heat Conduction Equation in large plane wall, in long cylinder and in a sphere; Combined one dimensional Heat conduction Equation. General Heat conduction Equation in Rectangular, Cylindrical and Spherical coordinates. Boundary and initial condition – Specified Temperature Boundary condition, Specified heat flux Boundary condition, Convection Boundary condition, Radiation Boundary condition, Interface Boundary condition and Generalized Boundary condition. Solution of steady One-Dimensional Heat conduction Problems. Variable Thermal conductivity.

Steady Heat conduction – Steady Heat conduction in plane walls – Thermal Resistance concept, Thermal Resistance Network and Multi layer plane wall; Thermal contact resistance, Generalized Thermal Resistance Networks; Heat conduction in cylinders and spheres, critical radius of insulations; Heat transfer from finned surface – Fin Equation, Fin Efficiency, Fin Effectiveness, Proper Length of a fin. Heat Transfer of common configuration.

TRANSIENT HEAT CONDUCTION – Lumped System Analysis, Transient Heat conduction in large plane walls, Long cylinders, and sphere with spatial Effects, Transient Heat conduction in semi-infinite solids, Transient Heat conduction in Multidimensional systems

NUMERICAL METHODS IN HEAT CONDUCTION – Reasons for Numerical methods, Finite Difference Formulation of Differential Equations, One- Dimensional steady Heat conduction, Two- Dimensional steady Heat conduction, Transient Heat Conduction.

FUNDAMENTAL OF THERMAL RADIATION – Introduction, Thermal Radiation, Blackbody Radiation, Radiation Intensity, Radiative Properties, Atmospheric and solar Radiation.

RADIATION HEAT TRANSFER – The View factor, View factor relation, Radiation Heat transfer: Black surfaces, Radiation Heat transfer: Diffuse, gray surfaces; Radiation shied and Radiation effects, Radiation Exchange with emitting and absorbing gases.

Books:

1. Y A Cengel – Heat & Mass Transfer, 4th Edition, McGraw-Hill Publishers, 2010
2. Mills, A. F., *Heat and Mass Transfer*, Irwin, Chicago, Ill., 1995.
3. Incropera, F. P., and DeWitt, D. P., *Fundamentals of Heat and Mass transfer*, Wiley, New York, 1996.
4. White, F. M., *Viscous fluid flow*, McGraw-Hill, New York, 1991.
5. Vincenti, W. G., and Kruger, C. H., *Introduction to physical gas dynamics*, Wiley, New York, 1965.
6. Kays, W. M., and Crawford, M. E., *Convective heat and mass transfer*, McGraw-Hill, New York, 1993.
7. Bejan, A., *Convection heat transfer*, J. Wiley, New York, 1995.
8. Siegel, R., and Howell, J. R., *Thermal radiation heat transfer*, Hemisphere Pub. Corp., Washington, D.C., 1992.

MT-TH 507 Combustion Engineering L T P 3-0-0

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Basic Concepts – Scope and History of Combustion, Fuels– Gaseous, Liquid & Solid Fuels; Thermodynamics of Combustion – Review of first Law concepts,Properties of Mixtures, combustion Stoichiometry, Chemical Energy, Chemical Equilibrium, 1^{st} Law Combustion Calculations, 2^{nd} Law Analysis; Chemical Kinetics of Combustion – Elementary Reactions, Chain Reactions, Preignition kinetics, Global Reactions, Nitrogen Oxide Kinetics, Reactions at solid Surface, Soot kinetics.

Combustion of Gaseous and Vaporized Fuels – Flames: Laminar Premixed Flames, Laminar Flame theory, Turbulent Premixed Flames, Explosion Limits,Flame Quenching, Ignition, Diffusion Flames; Gas-Fired furnace Combustion – Energy Balance and furnace Efficiency,Burner Types,Pulse Combustion Furnace,Fuel substitution,Emissions from Gas-Fired Furnaces; Premixed-Charge Engine Combustion – Introduction to Spark-Ignition Engine Combustion,Charge Preparation,Ignition and Burning Rate Analysis,Flame Structure and Correlations,Computational Fluid Dynamics Modeling,Chamber Design,Emissions Control,Engine Efficiency, Alternative Automobile Engines; Detonation of Gaseous mixtures – Transition to Detonation,Steady-State Detonation, One-Dimensional Model for Propagation Velocity andPressure and Temperature Rise across a Detonation,Maintained Detonations.

Combustion of Liquid Fuels – Spray Formation and Droplet Behavior : Spray Formation, Size Distributions,Fuel Injectors,Spray Dynamics,Vaporization of Single Droplets,Spray Models for CFD Programs; Oil-Fired Furnace Combustion: Oil-Fired Systems,Spray Combustion in Furnaces,Plug Flow Model of Distillate Spray Combustion,Emissions from Oil Furnaces; Gas Turbine Spray Combustion: Gas Turbine Operating Parameters,Combustor Design, Combustion Rate,Liner Heat Transfer,Low-Emissions Combustors; Direct-Injection Engine Combustion: Introduction to Diesel Engine Combustion,Fuel Injection,Ignition Delay,Combustion Rates, Chamber Geometry, Emissions, Diesel Design Improvements, CFD Modeling of Diesel Combustion; Detonation of Liquid-Gaseous Mixtures: Detonation of Liquid Fuel Sprays,Detonation of Liquid Fuel Films.

Combustion of Solid Fuels – Solid Fuel Combustion Mechanisms: Drying of Solid Fuels, Devolatilization of Solid Fuels, Char Combustion; Fixed-Bed Combustion: Wood Stoves and Dutch Ovens, Stoker-Fired Boilers,Emissions from Spreader Stokers, Modeling Fixed–Bed Combustion,Refuse-and Biomass-Fired Boilers, Downdraft Systems; Suspension Burning: Pulverized Coal-Burning systems,Location of Fuel and Air Nozzels/Furnace Design, Pulverrized Coal Combustion, Isothermal Plug Flow of pulverized Coal/Nonisothermal Plug Flow Of pulverized Char Suspension,Behavior of Ash,Emissions from Pulverized Coal Furnaces,Cyclone Combustors,Pulverized Biomass and refuse-Fired Boilers,Coal-Water Fuel; Fluidized-Bed Combustion: Fluidization Fundamentals, Combustion in a Bubbling Bed,Atmospheric fluidized-Bed Combustion Systems,Circulating Fluidized Beds,Pressurized Fluidized-Bed Combustion.
Environmental effects of Combustion.

Books:

1. G.L. Borman – Combustion Engineering, WCB, McGraw-Hill Publishers,
2. A.K.Agarwal, A.Kushari,S.k.Aggarwal,A.K.Runchal –Combustion Sci. & Tech., Narosa Publishing House
3. B.G.Miller-Coal Energy Systems, Elsevier

MT-TH 803A Instrumentation and Measurement L T P 3-0-0

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Introduction to Instrumentation.Major elements of a measurement system.Order, type of signals, response of instruments.Importance ofsensors in measuring system.Errors and response characteristics of sensors.Measurement error.Measurement Techniques

Signal conditioning: Amplification and noise filtering, impedance matching, Wheatstone Bridgetechnique.Digital signal processing: Sampling rate, aliasing, discretization, A/D and D/A converters, frequencycontent of a signal, concept of FFT. Common measuring instrument: Multimeters, oscilloscope, spectrumanalyzer, display and recorder, plotter. Statistical analysis of data: Concept of normal distribution, meanand variance (standard deviation).

Displacement and Motion Measurement: Potentiometer, linear variable differential transformer, strain gauge, proximity probe.

Angular velocity measurement: Mechanical and electric tachometer.
Seismic instrument: Accelerometer. Force, Torque & Power Measurement: Force measurement: elastic force transducer, piezoelectric force transducer, hydraulic and pneumatic method. Torque measurement: Using shaft deflection, using induced strain, torque reaction method.

Power measurement: Absorption dynamometer, mechanical & hydraulic method, transmission dynamometer, torque meter.

Temperature Measurement: Thermal expansion method: Liquid-in-glass thermometer, pressure thermometer, bimetal type thermometer. Resistance Thermometer: RTD, thermistor. Thermocouple, quartz thermometer, radiation thermometer.

Pressure Measurement: Measuring static pressure: Piezometer, manometer. Measuring dynamic & static pressure: Pressure transducer, bellow-type, diaphragm-type, piezoelectric. Bourdon tube pressure gauge. Flow Measurement

Obstruction meter: Venturi meter, nozzle, orifice meter, pitot tube. Positive displacement flowmeter: Rotary-vane meter, rotameter. Special methods: Turbine flow meter, ultrasonic flowmeter, magnetic flowmeter, hot wire anemometer, open channel flowmeter, laser Doppler flowmeter.

Examples of Instrumentation: Boiler power plant instrumentation, air conditioning plant control, industrial robotics system, etc.

Text Book(s):

1. Instrumentation and Measurement, by BC Nakra & KK Choudhry.
2. Instrumentation for Engineering Measurements, by JW Dally; John Wiley & Sons.

Reference Book(s):

1. Experimental Methods for Engineers, by JP Holman; McGraw Hill.
2. Mechanical Measurements, by Thomas Beckwith and Lewis Buck; Narosa Publishing House.

<u>MT-TH 509 Advanced Thermal Lab</u> **L-T-P 0-0-4**

Students shall perform any 8 of the following experiments:

1. Energy audit of steam generators
2. Performance study of cooling tower
3. Performance analysis of a two- pass condenser
4. Efficiency Measurement of Steam turbine
5. Measurement of combustion generated pollutants
6. Boiler Efficiency testing
7. Performance testing on S.I. Engine
8. Performance testing on C.I. Engine
9. Performance testing refrigeration systems
10 Performance study of heat exchangers
11 Performance study of Air conditioning system
12 Performance study of solar water heater
13 Comparative study of fuel oils
14 Study of Fuel cell system
15 To study the performance of steam turbines
16 To determine gas pollutants and smoke density of exhaust gases.

MT-TH 813A MECHANICAL MEASUREMENT LAB L T P 0 0 2

Experiments on measurement of linear displacement and motion by LVDT; temperature measurement by RTD Thermistor and Thermocouple; pressure and fluid flow.
Applications of plotters and recorders, Inductive Pick up Strain Gauge based cantilever, the load measurement by load cell and strain gauge based cantilever.

MT-TH 502 Heat Transfer-2 **L-T-P** 3-0-0

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Fundamentals of Convection – Physical Mechanism of Convection, Classification of Fluid Flows, Velocity Boundary Layer, Thermal Boundary Layer, laminar and Turbulent Flows, Heat and Momentum Transfer in Turbulent Flow, Differential Convection Equations and their Solutions, Analogies between Momentum and Heat Transfer.

External Forced Convection –Dragand Heat Transfer in External Flow, Parallel Flow over Flat Plates, Flow across Cylinders and Spheres, Flow over Tube Banks.

Internal Forced Convection –Introduction, Average velocity and temperature, The entrance Region, General Thermal Analysis, Laminar Flow in Tubes, Turbulent Flow in Tubes.

Natural Convection – Physical Mechanisms, Equation of Motion and the Grashov Number, Natural Convection over Surfaces, Natural Convection from Finned Surfaces and PCBs, Natural Convection inside Enclosures, Combined Natural and Forced Convection.

Boiling and Condensation – Boiling Heat Transfer, Pool Boiling, Condensation Heat Transfer, Film Condensation, Dropwise condensation.

Basics of Heat Exchangers – Types, Overall Heat Transfer Coefficient, Analysis of Heat Exchangers, The LMTD Method, The Effectiveness- NTU Method, Selection of Heat Exchangers.

Fundamentals of Mass Transfer –Introduction, Analogy between Heat and Mass Transfer, Mass Diffusion, Boundary Conditions, MassConvection,Simultaneous Heat and Mass Transfer.

Heat Pipe -Introduction, Working of Heat pipe, Different types of Heat Pipe, Detail of Heat Pipe components, Advantages of Heat Pipe, Application of Heat Pipe, Performance of Heat Pipe, Limitation of Heat Pipe, Analysis of Heat Pipe.

Books:

1. Y A Cengel – Heat & Mass Transfer, 4th Edition, McGraw-Hill Publishers, 2010
2. Mills, A. F., *Heat and Mass Transfer*, Irwin, Chicago, Ill., 1995.
3. Incropera, F. P., and DeWitt, D. P., *Fundamentals of Heat and Mass transfer*, Wiley, New York, 1996.
4. White, F. M., *Viscous fluid flow*, McGraw-Hill, New York, 1991.
5. Vincenti, W. G., and Kruger, C. H., *Introduction to physical gas dynamics*, Wiley, New York, 1965.
6. Kays, W. M., and Crawford, M. E., *Convective heat and mass transfer*, McGraw-Hill, New York, 1993.
7. Bejan, A., *Convection heat transfer*, J. Wiley, New York, 1995.
8. Siegel, R., and Howell, J. R., *Thermal radiation heat transfer*, Hemisphere Pub. Corp., Washington, D.C., 1992.

MT-TH 508 Advanced Gas Dynamics **LTP 3-0-0**

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks
Introduction to compressible viscous flow, governing equations.

Speed of sound and Mach number, Basic equations for one dimensional flows, Isentropic relations, flow though nozzle and diffusers. Flow with friction – Fanno flow, flow with heat transfer – Rayleigh flow.

Normal and oblique shocks,Mach waves. Prandtl–Meyer expansion, Rankine–Hugnoit relation, Application of method of characteristics applied to two dimensional cases – simple supersonic wind tunnel; Design of supersonic wind tunnel and nozzle. Off-0design performance of nozzles.
Quasi-one dimensional flows, Multi-dimensional flow. Compressible boundary layers.
Interaction and intersection of shocks, P-M expansions and boundary layers. Reflection of shocks and Prandtl–Meyer expansion from solid surfaces and fluid surfaces. Application to simple problems related to propulsion and flow through turbomachines.

Books:

1. SM Yahya – Fundamentals of Compressible Flow, New Age Publishers, 2011.
2. T Radhakrishnan – Gas Dynamics Prentice Hall, New Delhi
3. Mohanty A K – Fluid Mechanics, Prentice Hall of India, 1986
4. Shapiro A F – The Dynamics of Compressible flow Vd 1, The Ronald Press Company 1963
5. Shames – Mechanics of Fluids, MC grow Hill 1962 Book Company 1962
6. Schlichting H – Boundary layer theory MC Grow Hill Book company 1979

MT-TH 801A NUMERICAL ANALYSIS AND OPTIMIZATION   L T P 3 0 0

Maximum marks: 100   **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

System of linear algebraic equations and Eigen value problems: elimination method, Gauss method, Gauss-Jordan method; Eigen values and Eigen vectors, bounds on Eigen values, Jacobi methods for symmetric matrices, householder's method for symmetric matrices.
Interpolation and approximation: interpolation problem, linear interpolation, Lagrange interpolation, Newton interpolation, interpolation with equidistant points, spline interpolation, least square approximation
Numerical differentiation and integration: differentiation of continuous functions, forward difference quotient, central difference quotient, error analysis; derivatives from differences table, higher-order derivatives, Richardson extrapolation techniques, Newton-Cotes method, trapezoidal rule, Simpson's rule, higher order rules, Romberg integration. Numerical solution of ordinary differential equations: Taylor's series method, Euler and modified Euler method, Runge-Kutta methods, Milne's method, Adam-Bashforth-Moultan method.
Optimization: basic concept of optimization, classification of optimization, optimization techniques, engineering applications of optimization. Classical optimization techniques: unconstrained optimization single-variable optimization, multivariable optimization, multivariable optimization, multivariable optimization with equality constraints: solution by direct search method, solution by Lagrange-multipliers method, multivariable optimization with inequality constraints, Kuhn-Tucker conditions

Non-linear optimization: general non-linear programming problem, classification of non-linearprogramming problem, unconstrained optimization techniques: direct search method, gradient method.

Constrained optimization techniques: separable programming, quadratic programming
Dynamic programming: Multistage decision process: representation of a multistage decision process, coversion of nonserial system to a serial system, types of multistage decision problems, principle of optimality, computational procedure in dynamic programming, linear programming as a case of dynamic programming, application of dynamic programming.

Text Book(s):

1. Engineering Optimization, by SS Rao; New Age International Ltd.
2. Numerical Method, by E. Balaguruswamy; Tata McGraw Hill.
3. Numerical methods for Scientific & Engineering Computation, by MK Jain, SRK Iyengar and RKJain; New Age International Ltd.

Reference Book(s):

1. Operations Research, by Taha H Hamidi; Prentice Hall of India, New Delhi
2. Operations Research, by Philips, Revindran, Solgebery; Wiley ISE
3. Applied Numerical Analysis, by Curtis F Gerald & Patrick G Whealley; Pearson Education Ltd.
4. Introductory Methods of Numerical Analysis, by SS Sastry; Prentice Hall of India, New Delhi

MT-TH 504 Numerical Analysis and Computation Lab **LTP 0-0-2**

Introduction to MATLAB. Solution of Linear & Non-linear equation using MATLAB. Experiments based on syllabus of M 801A relevant to thermal engineering can be performed.

<u>MT-TH</u> <u>506 Heat & Mass transfer Lab</u> **L-T-P 0-0-2**

Experiments based on syllabus of MT 505 & MT 502 can be done:

1. Study of variation of emissivity of test plate with absolute temperature.

2. To demonstrate the super thermal conductivity of heat pipe.

3. To plot the temp. v/s time response of the three pipes(test pipe, copper pipe, stainless pipe).

4. To plot the temperature distribution along the length of test pipe ,copper pipe, stainless pipe).

5. Solar radiation.

6. To study and evaluate- performance of solar cell.

7. Study of pyranometer.

8. To determine natural convective heat transfer coefficient and to calculate and to plot variation of natural convective heat transfer coefficient along the vertical tube.

MT-TH 601 Minor Project **L-T-P 0-0-10**

Identification of faculty supervisor(s), topic, objectives, deliverables and work plan (in the preceding semester); regular work during semester with weekly coordination meetings of about 1 hour duration with the faculty supervisor, and an end-semester demonstration to Project Evaluation Committee. Marks to be decided on the basis of a mid-term and an end-semester presentation following the demonstration vis-vis the approved work plan. The topic should be of advanced standing requiring use of knowledge from programme core courses and be preferably hardware oriented. Topic will have to be different from the major project.

MT-TH 603 Turbo-Machinery **L-T-P 3-0-0**

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Introduction to Turbo machines, Principles of operation, Energy transfer in turbomachines, Classification of turbo machines, Losses and efficiencies – performance characteristics.

Review of flow through nozzle and diffuser, flow over immersed bodies, pressure distribution over a symmetrical and inclined airfoil;

Blade technology – blade cascades and nomenclature, lift and drag coefficients; elementary concept of three dimensional flow; free and forced vortex

Cascade theory. Wind tunnel testing.

Axial flow steam and gas turbines. Recapitulation of thermal turbines, their types, compounding, Velocity triangles, degree of reaction etc. Configuration of modern steam and gas turbines. Design of flow path. Losses and efficiency issues. Special features of last stage and wet stages. Diagnostic monitoring. Basic concepts of Wind Turbines. Future trends in turbine practice.

Axial flow fans – construction and operation – types of stages – performance of fans – applications - Centrifugal fans and blowers – Construction and operation – types – fan stage parameters – drum type and partial flow fans – losses .Future trends.

Axial flow Compressor – Construction and operating principles – Stage Velocity triangles– Enthalpy Entropy diagram – stage losses and efficiency – Work done factor –Performance Characteristics.

Centrifugal Compressors – Construction and operation principle. – Stage Velocity triangles – Enthalpy Entropy diagram – stage losses and efficiency – Slip factor – Performance Characteristics. Future trends.

Books:

1. Turbines Compressors and Fans – S.M.Yahya – Tata McGraw-Hill company, 2002
2. Gas Turbine Theory – Cohen Rogers ,SaravanaMuttoo, Long man Publishing2004
3. Csanady, G.T., Theory of Turbomachines, McGraw-Hill, 1964, New York, NY.
4. Dixon, S.L., Fluid Mechanics, Thermodynamics of Turbomachinery, Pergamon Press,Oxford, UK.
5. Logan, E., Turbomachinery, Marcel Dekker, Inc., 1993, New York, NY.
6. Wilson, D.G. and Korakianitis, T., The Design of High-Efficiency Turbomachinery and Gas Turbines, Prentice Hall, 1998, Upper Saddle River, NJ.
7.White, F.M., Fluid Mechanics, McGraw-Hill, 2000, New York, NY.
8.Wright, T., Fluid Machinery, CRC Press, 1999, Boca Raton, FL.

MT-TH 605 Seminar **L-T-P 0-0-4**

Seminar on Advanced topics so as to provide a full exposure of the advanced topics of both currently running technologies and the ongoing research topics. This must give students complete room for discussion, gaining knowledge and further research.

MT-TH 602 Dissertation **L-T-P 0-0-24**

The students are required to undertake Analytical/Experimental investigations in fields of Thermal Engineering. They would be working under the supervision of one faculty member. The investigation they undertake should be innovative to the level of PG study.

General Electives

MT-TH 510 - Design of Thermal Systems **L-T-P 3-0-0**

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Fluid Mechanics Review. Primary energy analysis - dead states and energy components-energy balance for closed and control volume systems - applications of energy analysis for selected energy system design. Introduction to economics. Introduction to Thermal Systems Design. Principles of designing a workable engineering system, probabilistic approaches to design.
Modelling overview- levels and steps in model development - examples of models. Mathematical modeling.Equation/curve fitting, regression analysis, modeling systems, system simulations, lagrange multiplers, search methods, dynamic programming, geometric programming, calculus methods of optimization. System simulation. Optimization.
Modelling of energy systems – heat exchanger, solar collectors, distillation, rectifications, turbo machinery components, refrigeration systems - information flow diagram, solution of set of nonlinear algebraic equations, successive substitution, Newton Raphson - examples of energy systems simulation. Modeling of thermal properties, steady state simulation, dynamic behavior of thermal systems

Introduction to Piping Systems, Piping Systems, Economics Review, Optimum Economic Diameter, Parallel Piping Systems, Flow Rate Measurement, Pumps and Piping Systems, NPSH and Dimensional Analysis, Pumps in Series and Parallel

Introduction to Heat Transfer Fundamentals, Introduction to Heat Exchangers (LMTD), Double Pipe Heat Exchangers, Effectiveness-NTU, Intro to Shell and Tube Heat Exchangers, Shell and Tube Heat Exchangers, Plate and Frame Heat Exchangers, Cross Flow Heat Exchangers, Review of Radiation Heat Transfer, Introduction to Solar Radiation, Heat Gain Through Fenestrations, Solar Flat-Plate Heat Exchangers

Optimization of Thermal Systems. Objectives-constraints, problem formulation - unconstrained problems - necessary and sufficiency conditions - constrained optimisation- LaGrange multipliers, constrained variations, linear programming - simplex tableau, pivoting, sensitivity analysis.

Energy- Economy Models: Multiplier analysis - energy and environmental Input / Output analysis – energy aggregation – econometric energy demand modelling - overview of econometric methods - dynamic programming - search techniques - Univariate / Multivariate.

Books:

1. *Design of Thermal Systems by W F Stoecker, McGraw-Hill Companies, 1989*
2. *Analysis and Design of Energy Systems* by B. K. Hodge and R. P. Taylor
3. *Design of Fluid Thermal Systems* by W. S. Janna
4. *Elements of Thermal-Fluid System Design* by L. C. Burmeister
5. *Design and Optimization of Thermal Systems* by Y. Jaluria
6. *Design Analysis of Thermal Systems* by R. F. Boehm
7. *Design and Simulation of Thermal Systems* by N. V. Suryanarayana, O. Arici and N. Suryanarayana
8. *Thermal Design and Optimization* by A. Bejan, G. Tsatsaronis and M. Moran, , John Wiley and Sons, 1996.
9. *Applied Systems Analysis* by R. de Neufville, , McGraw Hill, International Edition, 1990.

MT-TH 512 Heat Exchangers **L-T-P 3-0-0**

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Classification of Heat Exchangers. Overview of Heat Exchanger Design Methodology – Process and Design Specifications, Thermal and Hydraulic Design, Mechanical Design, Manufacturing Considerations and Cost Estimates, Trade-off Factors, Optimum Design, Other Considerations, Interactions Among Design Considerations.

Basic Thermal Design Theory for Recuperators – Formal Analogy between Thermal and Electrical Entities, Heat Exchanger Variables and Thermal Circuit, The ε-NTU Method, Effectiveness – Number of Transfer Unit Relationships,The P-NTU Method, P–NTU Relationships,The Mean Temperature Difference Method, F Factors for Various Flow Arrangements, Comparison of the ε-NTU, P–NTU, and MTD Methods,The ψ-P and P1- P2 Methods, Solution Methods for Determining Exchanger Effectiveness, Heat Exchanger Design Problems.

Additional Considerations for Thermal Design of Recuperators – Longitudinal Wall Heat Conduction Effects, Non-uniform Overall Heat Transfer Coefficients, Additional Considerations for Extended Surface Exchangers, Additional Considerations for Shell-and-Tube Exchangers.

Thermal Design Theory for Regenerators – Heat Transfer Analysis, The ε-NTUo Method,
The Λ – Π Method, Influence of Longitudinal Wall Heat Conduction, Influence of Transverse Wall Heat Conduction, Influence of Pressure and Carryover Leakages, Influence of Matrix Material, Size, and Arrangement.

Heat Exchanger Pressure Drop Analysis – Introduction, Extended Surface Heat Exchanger Pressure Drop, Regenerator Pressure Drop, Tubular Heat Exchanger Pressure Drop, Plate Heat Exchanger Pressure Drop, Pressure Drop Associated with Fluid Distribution Elements, Pressure Drop Presentation, Pressure Drop Dependence on Geometry and Fluid Properties.

Surface Basic Heat Transfer and Flow Friction Characteristics – Basic Concepts, Dimensionless Groups, Experimental Techniques for Determining Surface Characteristics, Analytical and Semi-empirical Heat Transfer and Friction Factor Correlations for Simple Geometries, Experimental Heat Transfer and Friction Factor Correlations for Complex Geometries, Influence of Temperature-Dependent Fluid Properties, Correction Schemes for Temperature-Dependent Fluid Properties, Influence of Superimposed Free Convection, Influence of Superimposed Radiation.

Heat Exchanger Surface Geometrical Characteristics – Tubular Heat Exchangers, Tube-Fin Heat Exchangers, Plate-Fin Heat Exchangers, Regenerators with Continuous Cylindrical Passages, Shell-and-Tube Exchangers with Segmental Baffles, Gasketed Plate Heat Exchangers.

Heat Exchanger Design Procedures – Fluid Mean Temperatures, Plate-Fin Heat Exchangers, Tube-Fin Heat Exchangers, Plate Heat Exchangers, Shell-and-Tube Heat Exchangers, Heat Exchanger Optimization.

Selection of Heat Exchangers and Their Components - Selection Criteria Based on Operating Parameters, General Selection Guidelines for Major Exchanger Types, Quantitative Considerations.

Books:

1. Fundamentals of heat exchanger design by R.K. Shah & Dusˇan P. Sekulic, John Wiley & Sons, 2003.
2. Heat exchangers: Selection, Rating, and Thermal Design by SadikKakaç,Hongtan Liu, AnchasaPramuanjaroenkij, CRC Press, 2002.
3. Heat Exchangers - Basics Design Applications – EditorJovan Mitrovic, InTech 2012.
4. Heat Exchanger Design Handbook by T. Kuppan, CRC Press

MT-TH 514- ENERGY MANAGEMENT L-T-P 3-0-0

Maximum marks: 100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Introduction: Principles of Energy Management – Managerial Organization – Functional Areas for Manufacturing Industry, Process Industry, Commerce, Government. Role of Energy Manager in each of these organization. Initiating, Organising and Managing Energy Management Programs

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

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

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

Methods of Evaluation of Projects : Payback – Annualised Costs – Investor's Rate of return – Present worth – Internal Rate of Return – Pros and Cons of the common methods of analysis – replacement analysis. Energy Consultant: Need of Energy Consultant – Consultant Selection Criteria.

Alternative Energy Sources: Solar Energy – Types of devices for Solar Energy Collection – Thermal Storage System – Control Systems-Wind Energy – Availability – Wind Devices – Wind Characteristics – Performance of Turbines and systems.

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. Energy Management Principles by CB Smith.

Programme Electives - I

MT-TH 516 - THERMAL AND NUCLEAR POWER PLANTS L-T-P 3-0-0

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

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. Supercritical and Ultra-supercritical power plants.

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

Nuclear Power Plants: Recapitulation of relevant topics of Nuclear Physics. Nuclear Reactors, Classification – Types of Reactors, Site Selection. Methods of fuel enrichment – Uranium and thorium. Nuclear Power Plants Safety: By-Products of Nuclear Power Generation. Economics of Nuclear Power Plants, Nuclear Power Plants in India, Future of Nuclear Power. Nuclear waste disposal. Introduction to fusion.

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

BOOKS:

1. Black & Veatch – Power Plant Engineering, Springer, 2006.
2. CEGB Series (12 volumes)
3. A.K. Raja, A.P. Srivastava, M Dwivedi – Power Plant Engineering, New Age Publishers, 2006.
4. Power Plant Technology – M. M. El Wakil.

MT-TH 518 – STEAM GENERATOR TECHNOLOGY **L-T-P 3-0-0**

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

INTRODUCTION - Boilers – classification – basic design steps – fuel stoichiometry calculations – enthalpy calculation of air and combustion products, heat balance.

DESIGN OF COAL PREPARATION SYSTEM - Pulverizing properties of coal – air system for pulverization, size reducing machines – design of coal preparation system for pulverised coal boilers – fuel feeding arrangements.

DESIGN OF BURNERS - Tangential fired burners – basics and design methods - oil burners – design of supply system – oil atomiser – air register – design principles.

DESIGN OF BOILER FURNACE - General design principles – flame emissivity, heat transfer calculation for pulverised coal boiler furnace, water wall arrangement, furnace emissivity, distribution of heat load in furnace.

DESIGN OF CONVECTIVE HEAT TRANSFER SURFACE - Design of economizer, superheater, reheater, air preheater - temperature control insuperheater and reheater.

STEAM GENERATORS FOR SUPERCRITRICAL POWER PLANTS – Furnace sizing and layout, water wall circuitry, dry-out load, main steam and reheat temperature control, material issues.

Books:

1. Ganapathy, V. Industrial Boilers and Heat Recovery Steam Generators, Marcel Dekker Ink, 2003.
2. Prabir Basu, Cen Kefa et.al, Boilers and Burners – Design and Theory, Springer, 2000.
3. David Gunn, Robert Horton, Industrial Boilers, Longman Scientific and Technical Publication, 1986.
4. Carl Schields, Boilers – Type, Characteristics and Functions, McGraw Hill Publishers, 1982.
5. Donatello Annaratone-Steam Generators, Springer
6. B.Buecker-Steam Generation Chemistry, Pennwell

MT-TH 520- Wind Engineering & Technology **L-T-P 3-0-0**

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Introduction – History of wind energy, Current status and future prospects.

Basics of Wind Energy Conversion – Power available in the wind spectra, Wind turbine power and torque, Classification of Wind turbines, Characteristics of wind rotors, Aerodynamics of wind turbines, Rotor Design, Rotor Performance

Analysis of Wind regimes – The wind, Turbulence, Acceleration effect, Time variation; Measurement of Wind – Ecological indicators, Anemometers: Cup anemometer, Propeller anemometer, Pressure plate anemometer, Pressure tube anemometers, Sonic anemometer, Wind direction; Analysis of wind data – Average wind speed, Distribution of wind velocity, Statistical models for wind data analysis, Weibull distribution, Rayleigh distribution; Energy estimation of wind regimes – Weibull based approach, Reyleigh based approach.

Wind Energy Conversion System – Wind electric generators: Tower, Rotor, Gear Box, Power regulation, Safety brakes, Generator, Induction generator, Synchronous generator, Fixed and variable speed operations, Grid integration. Wind Farms, Offshore wind farms. Wind pumps – Wind powered piston pumps, Limitations of wind driven piston pumps, The hysteresis effect, Mismatch between the rotor and pump characteristics, Dynamic loading of the pump's lift rod; Double acting pump, Wind driven roto-dynamic pumps, Wind electric pumps.

Performance of wind energy conversion systems – Power curve of the wind turbine, Energy generated by the wind turbine, Weibull based approach, Rayleigh based approach, Capacity factor, Matching the turbine with wind regime, Performance of wind powered pumping systems, Wind driven piston pumps, Wind driven roto-dynamic pumps, Wind electric pumping systems.

Wind energy and Environment – Environmental Benefits of wind energy, Life Cycle analysis, Net energy analysis, Life cycle emission, Environmental problems of wind energy, Avian issues, Noise emission, Visual impact

Economics of wind energy – Factors influencing the wind energy economics, Site specific factors, Machine parameters, Energy parameters, Incentives and exemptions, The 'present worth' approach, Cost of wind energy: Initial investment, Operation and maintenance costs, Present value of annual costs. Benefits of wind energy. Yardsticks of economic merits: Net present value, Benefit cost ratio, Pay back period, Internal rate of return. Tax deduction due to investment depreciation.

Books:

1. Sathyajith Mathew- Wind Energy, Springer
2. Brendan Fox, et al- Wind Power Integration, Instititution of Engg.& Tech.

Programme Elective - II

MT-TH 607 - Energy Conservation **L-T-P- 3-0-0**

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

INTRODUCTION- Energy scenario – India and world – energy resources availability in India – energy consumption – pattern, energy conservation potential – various industries and commercial, establishments, energy intensive industry – an overview - energy conservation and energy efficiency – needs and advantages, energy auditing – types, methodologies, barriers, role of energy manager – energy audit questionnaire – energy conservation act.

THERMAL ENERGY AUDITING-Energy audit – purpose, methodology with respect to process industries, power plants, boilers etc. – characteristic method employed in certain energy intensive industries –various energy conservation measures in steam systems – losses in boiler – methodology of upgrading boiler programme – energy conservation in refrigeration and airconditioning systems.

ELECTRICAL ENERGY SYSTEMS - Captive power generation systems – biomass, wind and diesel power generation – KVA demand estimation – wheeling and banking concept – EB bill detailing. basics of monitoring and targeting – elements of monitoring and targeting, data and information analysis techniques – energy consumption, production, Cumulative sum of differences (CUSUM).

PERFORMANCE EVALUATION AND OPTIMIZATION OF ELECTRICALUTILITIES -
Principle – types – performance evaluation of transformers, energy distribution - cable selection and cable losses, capacitors, electric motors, electrical heating and lighting systems.

ENERGY MANAGEMENT - Importance of energy management, energy economics – discount rate, payback period, internal rate of return, life cycle costing risk and sensitivity analysis, financing, energy performance contract and role of ETCOS.

Books :

1. Hamies, Energy Auditing and Conservation; Methods, Measurements, Management and Case Study, Hemisphere, Washington, 1980.
2. CB Smith, Energy Management Principles, Pergamon Press, New York, 1981.
3. Trivedi, P. R., and Jolka, K. R., Energy Management, Common Wealth Publication, New Delhi, 1997.
4. Handbook on Energy Efficiency, TERI, New Delhi, 2001.
5. Write, Larry C, Industrial Energy Management and Utilization, Hemisphere Publishers, Washington, 1998.

MT-TH 609- SOLAR ENERGY SYSTEMS **L-T-P 3-0-0**

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Introduction to Solar Energy – Renewable Energy Solutions, Global Solar Resource

Solar Resource – Introduction, Sun- Earth Geometric Relationship, Equation of Time, Structure of the Sun, Electromagnetic Radiation, Solar Spectral Distribution, Solar Constant, Extraterrestrial Solar Radiation, Terrestrial Solar Radiation, Measurement of Terrestrial Solar Radiation, Terrestrial Insolation on Titled Collectors.

Fundamentals of Engineering: Thermodynamics and Heat Transfer – Introduction, Conduction Heat Transfer, One- Dimensional Conduction heat Transfer in a Rectangular Coordinate, Thermal Resistance Circuits, One- Dimensional Conduction heat Transfer in a Cylindrical Coordinate, Convection Heat Transfer, Radiation Heat Transfer, Surface Property, Blackbody Radiation, Real Body Radiation. Introduction to Thermodynamics – The First Law of Thermodynamics, The Second Law of Thermodynamics, The Third Law of Thermodynamics.

Solar Thermal Systems and Applications – Introduction, Solar Collectors, Tracking Systems, Solar Thermal Systems.

Photovoltaic Cells – Introduction, Crystal Structure, Cell Physics, Energy Bands, Electrons and Their Energy, Electrons and Holes, Direct and Indirect Band-Gap Materials, Doping, Transport, Generation and Recombination, The p-n Junction, Solar Cell Equations, Characterizations, Efficiency, Current Research, Cell Applications.

Photovoltaic Conversion Systems – Solar Benefits, Basic Module Electrical Concepts, PV Arrays, PV Array Tilt, PV Balance of Systems, PV System Utility, PV System Safety, PV System Testing Rules.

Photovoltaic System Sizing and Design – Introduction, Solar Resource Sizing Considerations, Solar Trajectory, Solar Energy System Sizing Considerations, Solar Energy System Sizing, Solar Water Pumping System Sizing, Generic Water Pump Sizing Methodology, Electrical Codes for PV System Design, Stand –Alone PV Lighting Design Example.

Photovoltaic (PV) Applications – Introduction, Grid-Tied PV, Japanese PV Development and Applications, Future Japanese Trends, Stand-Alone PV Applications, PV for Schools, PV for Protected Areas, PV Water–Pumping: Static Head, Pumping Requirements, Dynamic Systems, Water Demand, Storage of Water versus Storage of energy in Batteries, Pumping Mechanisms Used for Solar Pumps, Types of Motors Used with Solar Pumps, Solar Pump Controllers, Pump Selection, Installation, Operation, and Maintenance, System Installation, Grounding and Lightning Protection for Solar Water Pumps, Solar Tracking for Solar Water Pumps, Operation and Maintenance of the Systems, The PV Array, PV Water-Pumping Results.

Economics – Cost of Solar Energy, Economic Feasibility, Economic Factors, Economic Analysis, Life Cycle Cost, Present Value and Levelized Costs, Annualized Cost of energy, Externalities, Solar Irrigation Case Study, Water Pumping Example.

Institutional Issues – Introduction, Sustainability, Institutional Considerations, Stakeholders, Program Implementation, Institutional Models for Solar Energy Dissemination, Cash Sales, Management and Ownership, Tariffs and Payment, Other Critical Issues.

Energy Storage – Introduction, Batteries in PV Systems, Lead–Acid Battery Construction, Plate Grids, Lead–Acid Battery Operation, Lead-Acid Battery Characteristics, Battery Problem Areas, Battery Maintenance, Battery Safety Precautions, Determination of Battery Failure, Battery Selection Criteria, Charge Controller Terminology, Charge Controller Algorithms, Charge Controller Selection Criteria.

Books:

1. R Foster, M Ghassemi, A Cota – Solar Energy: Renewable Energy and the Environment, CRC Press,
2. Principles of solar engineering – Kreith and Kerider
3. Solar energy thermal processes – Duffie and Beckman
4. Solar energy – Sukhatme
5. Solar energy – RD Garg
6. Solar energy – Magal
7. Solar energy – Tiwari and Suneja
8. Power plant technology – M.M. El Wakil

MT-TH 611- COGENERATION AND WASTE HEAT RECOVERY SYSTEMS L-T-P 3-0-0

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

INTRODUCTION-Introduction - principles of thermodynamics - cycles-topping, bottoming, combined cycle, organic Rankine cycle – performance indices of cogeneration systems – waste heat recovery – sources and types – concept of regeneration.

COGENERATION TECHNOLOGIES- Configuration and thermodynamic performance – steam turbine cogeneration systems, gas turbine cogeneration systems, reciprocating IC engines cogeneration systems, combined cycles cogeneration systems – advanced cogeneration systems, fuel cell, Stirling engines.

ISSUES AND APPLICATIONS OF COGENERATION TECHNOLOGIES- Cogeneration plants-electrical interconnection issues – applications of cogeneration inutility sector, Industrial sector, building sector, rural sector, impacts of cogeneration plants – fuel, electricity and environment.

WASTE HEAT RECOVERY SYSTEMS- Selection criteria for waste heat recovery technologies – recuperators, regenerators, economizers, plate heat exchangers, thermic fluid heaters - waste heat boilers classification, location, service conditions, design considerations - fluidized bed heat exchangers, heat pipe exchangers, heat pumps, absorption systems.

ECONOMIC ANALYSIS- Investment cost – economic concepts, measures of economic performance, procedure for economic analysis, examples, procedure for optimized system selection and design – load curves - sensitivity analysis, regulatory and financial frame work for cogeneration andwaste heat recovery systems.

Books :

1. Charles H. Butler, Cogeneration, McGraw Hill Book Co., 1984.
2. EDUCOGEN – The European Educational tool for cogeneration, Second Edition, 2001.
3. Horlock, JH, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford, 1987.
4. Institute of Fuel, London, Waste Heat Recovery, Chapman and Hall Publishers, London, 1963.
5. Sengupta Subrata, Lee SS EDS, Waste Heat Utilization and Management, Hemisphere, Washington, 1983.
6. De Nevers, Noel., Air Polllution Control Engineering, McGrawHill, New York, 1995.

<u>Prgramme Elective- III</u>

<u>MT-TH 613 – COMPUTATIONAL FLUID DYNAMICS</u> **L-T-P 3-0-0**

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

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

Finite difference methods: Taylor's series – FDE formulation for 1D and 2D steady state heat transfer problems – Cartesian, cylindrical and spherical co-ordinate systems – boundary conditions – Un steady state heat conduction – Errors associated with FDE - Explicit Method – Stability criteria – Implicit Method – Crank Nickolson method – 2-D FDE formulation – ADI – ADE

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

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

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

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

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

<u>BOOKS:</u>

1. Computational Fluid Flow and Heat Transfer – Muralidharan&Sundarajan (Narosa Pub)
2. Numerical heat transfer and fluid flow – S.V. Patankar (Hemisphere Pub. House)
3. An Introduction to Computational Fluid Dynamics – FVM Method – H.K. Versteeg, W. Malalasekhara (PHI)
4. Computational Fluid Dynamics – Anderson (TMH)
5. Computational Methods for Fluid Dynamics – Ferziger, Peric (Springer)
6. Computational Fluid Dynamics, T.J. Chung, Cambridge University
7. Computaional Fluid Dynamics – A Practical Approach – Tu, Yeoh, Liu (Elsevier)
8. Text Book of Fluid Dynamics, Frank Chorlton, CBS Publishers

MT-TH 615- NON-CONVENTIONAL ENERGY RESOURCES L-T-P 3-0-0

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

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

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

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

Direct Energy Conversion: Fuel cells, MHD power generation, Thermo electric and Thermionic Power Generation

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

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

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

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

Energy from Oceans -Tidal Energy; Tides – Diurnal and Semi – Diurnal Nature – Power from Tides. Wave Energy ; Waves – Theoretical Energy Available – Calculation of period and phase velocity of waves – wave power systems – submerged devices. Ocean Thermal Energy : principles – Heat Exchangers – Pumping requirements – Practical Considerations.

BOOKS:

1. Renewable Energy Resources – Basic Principles and Applications – G.N.Tiwari and M.K.Ghosal, Narosa Pub
2. Renewable Energy Resources / John Twidell & Tony Weir
3. Biological Energy Resources / Malcolm Flescher & Chrris Lawis
4. Kenneth-Weston, Fundamentals of Energy Conversion

MT-TH 617 - ENERGY ECONOMICS AND ENVIRONMENT POLICY **L-T-P 3-0-0**

Maximum marks:100 **Time:** 3 hrs

Note : In the Semester Examinations the examiner will set 8 questions in all, covering the entire syllabus and the student will be required to attempt only 5 questions. Each Question carry equal marks

Energy and Environment Basic Issues- Overview of Global and Local Energy and Environment Scenario and Policy Issues; Concepts of Energy Economics; Concepts of Environment Economics; Criteria for Economic Growth; Energy-Economy-Environment Linkages; Emissions Inventories: Assessment and Policy Relevance.
Issues for Developing Countries-Sustainable Development; Rural Energy Issues; Energy Security and Regional Cooperation; Indian Power Sector: Status, Reforms and Long-term Trends; Energy and Environment Policies from Urban and Rural perspectives.
Analysis Methodologies-Energy and Environment Scenarios and Models: Structures and Classifications; Integrated Assessment of Energy and Environment: Framework and Models; Top-Down Energy-Economy Models and Applications; Bottom-up Energy System Models and Applications.

Global and Local Environmental Issues-Overview of Global Climate Change; Climate Change Negotiations: Perspectives, Issues, Positions and Status; Climate Change: Assessment of and Vulnerability, Impacts and Adaptation measures for Energy Systems; Incentives for Developing Country Participation, Clean Development Mechanism; Local Environmental Concerns; Environmental Externalities

Technological Options-Technology, Policies and Measures for Long-term Energy and Environment Issues; Energy-Efficiency and New Energy Technologies; Renewable Energy: Issues, Prospects and Policies

Books:

1. Energy for a sustainable world: Jose Goldenberg, Thomas Johansson, A.K.N.Reddy, Robert Williams (Wiley Eastern).
2. Modeling approach to long term demand and energy implication : J.K.Parikh.
3. Energy Policy and Planning : B.Bukhootsow.
4. TEDDY Year Book Published by Tata Energy Research Institute (TERI),
5. World Energy Resources : Charles E. Brown, Springer2002.
6. ‘International Energy Outlook’ -EIA annual Publication
7. Principles of Energy Conversion: A.W. Culp (McGraw Hill International edition.)
8.BEE Reference book: no.1/2/3/4.