

NIMS UNIVERSITY, JAIPUR



SYLLABUS

M. TECH.

(THERMAL POWER ENGINEERING)

SEMESTER - I

Teaching and Examination Scheme

Sr. NO.	Course No.	Title	L	T	P	CW *	Exam.	Total
1.	1MTTP1	Advanced Fluid Mechanics	3	1	0	25	100	125
2.	1MTTP2	Advanced Thermodynamics	3	1	0	25	100	125
3.	1MTTP3	Modelling, Simulation & Computer Applications	3	1	0	25	100	125
4.	1MTTP4	Analysis of Thermal Power Cycles	3	1	0	25	100	125
		Total	15	5	4	150	600	750

CW*->Course Work

SEMESTER-II

Sr. NO.	Course No.	Title	L	T	P	CW *	Exam.	Total
1.	2MTTP1	Computational Fluid Dynamics	3	1	0	25	100	125
2.	2MTTP2	Advanced Heat Transfer	3	1	0	25	100	125
3.	2MTTP3	Refrigeration & Cryogenic Systems	3	1	0	25	100	125
4.	2MTTP4	Elective I: 1. Advanced IC Engines 2. Boiler Auxiliaries And Performance Evaluation	3	1	0	25	100	125
		TOTAL	15	5	4	150	600	750

SEMESTER -III

Sr. NO.	Course No.	Title	L	T	P	CW*	Exam.	Total
1.	3MTTP1	Elective II: 1. Combustion 2. Alternative Fuels For I.C. Engines	3	1	0	25	100	125
2.	3MTTP2	Elective III:	3	1	0	25	100	125

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		1. Renewable energy source 2. Environmental Pollution And Control						
3.	3MTTP3	Major Project: Part I						
4.	3MTTP4	Project Planning & Review Seminar						
5.	3MTTP5	Course Work Viva Voice						

SEMESTER-IV

Sr. NO.	Course No.	Title
1	4MTTP1	Dissertation /Major Project Part-II
2.	4MTTP2	Seminar & Viva Voice

M. Tech. (Thermal Power Engineering)

SEMESTER I

1MTTP1. MATHEMATICAL METHODS IN THERMAL ENGINEERING

Linear Algebra:

Vector space, Norms of vectors and matrices, Condition number of matrices, Singular value decomposition, Backward error analysis, Concept of linear dependence and independence, Characteristics of linear systems, Eigen values and eigenvectors.

Calculus:

Functions of single variable, Limit, continuity and differentiability, Mean value theorems, Evaluation of definite and improper integrals, Differentiation under integral sign (Leibnitz rule), Partial derivatives, Total derivative, Maxima and minima, Vector operators and identities, Directional derivatives, Line, surface and volume integrals, Stokes, Gauss and Green's theorems, Introduction to calculus of variations, Transform calculus: Fourier and Laplace transforms

Differential equations:

Concept of order and degree of differential equations, First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Sturm-Liouville problems, Initial and boundary value problems, Concept of well-posed and ill-posed equations, Classification of PDEs and their characteristics, Parabolic, elliptic and hyperbolic prototype equations

Complex variables:

Analytic functions, Cauchy's integral theorem, Conformal mapping.

Probability and Statistics:

Fundamental definition, Conditional probability and Bayes theorem, Mean, median, mode and standard deviation, Random variables, Poisson, Normal and Binomial distributions, Regression analysis, Elements of sampling theory.

Numerical Methods:

Floating point operations and errors, Interpolation, Root finding of linear and non-linear algebraic equations, Numerical differentiation, Numerical integration, Numerical solution of ODEs: initial and boundary value problems; Numerical instability.

Introduction to Cartesian tensors.

REFERENCE BOOKS:

- *Desai C.S., and Abel, J. P.*, Introduction to Finite Element Method, *Van Nostrand Reinhold*.
- *Elsegolt, L.*, Differential Equations and the Calculus of Variations, *Mir Publishers*.
- *Grewal B.S.*, Higher Engineering Mathematics, *Khanna Publishers*.
- *Hildebrand P.B.*, Method of Applied Mathematics, *Prentice Hall*.
- *Venkataraman M. K.*, Higher Mathematics for Engineering and Science, *National Publishing Company*

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1MTTP2. ADVANCED FLUID MECHANICS

Basic Equations:

Deformation and the rate of strain, the deformation tensor, skew-symmetry of the deformation tensor, symmetry of the stress tensor, polar and non-polar fluids, stokesian and Newtonian fluids.

Derivation of the general differential equations of continuity, momentum and energy in vector form; Euler and Navier-Stokes equations, integration of the momentum equation; the generalized Bernoulli's equation.

Two Dimensional Irrotational Flow:

Two dimensional flows in rectangular and polar coordinates; continuity equation and the stream function, irrotationality and the velocity potential function, vorticity and circulation, plane potential flow and the complex potential function. Sources, sinks, doublets and vortices; superposition of uniform stream with above; flow around corners; Rankine ovals, flow around circular cylinders with the without circulation, pressure distribution on the surface of these bodies. Elements of two dimensional aerofoils theory, symmetrical aerofoil theory; lift and moment.

Three-Dimensional Irrotational Flow:

Irrotationality and the velocity potential function; symmetric flows and the Stokes stream function; sources, sinks.

Vortex Motion:

Definitions, vortex lines, surfaces and tubes, vorticity, circulation; Kelvin's circulation theorem, Helmholtz's vorticity theorems; the convection and diffusion of vorticity.

Viscous Flow:

Exact solution, plane Poiseuille and Couette flows; Hagen Poiseuille flow through pipes. Flows with very small Reynolds number.

Flows with very large Reynolds number, elements of two dimensional boundary layer theory; displacement thickness and momentum thickness, skin friction, Blasius solution for boundary layer on a flat plate without pressure gradient; the Karman-Polhausen integral method for obtaining approximate solutions.

Drag on bodies; form drag and skin friction drag profile drag and its measurement.

REFERENCE BOOKS:

- *Fluid Mechanics and Its Applications*, Vijay Gupta & S.K. Gupta, *New Age International*
- *Fluid Mechanics and Machinery*, DR Durgaiiah, *New Age International*
- *Advanced Fluid Mechanics*, Raudkiri & Callander, *Edward Ronald*.
- *Fundamentals of Mechanics of Fluids*, Currie, *McGraw Hill*.
- *Fluid Mechanics*, Landau & Lifshitz, *Addition Wesley*.
- *The Phenomena of Fluid Motion*, Brodkey, *Addition Wesley*.
- *Foundation of Fluid Mechanics*, Yuan, *Prentice Hall Of India*.

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1MTTP3. ADVANCED THERMODYNAMICS

Review of basic thermodynamic principles; entropy; availability; irreversibility; first and second law analysis of steady and unsteady systems;

General thermodynamics relations; Fundamentals of partial derivatives; relations for specific heats; internal energy enthalpy and entropy; Joule - Thompson coefficient; Clapeyron equation.

Multi component systems; Review of equation of state for ideal and real gases; thermodynamic surfaces; gaseous mixtures; fugacity; ideal solutions; dilute solutions; activity; non ideal liquid solutions.

Multi component phase equilibrium ; Criteria of equilibrium; stability; heterogeneous equilibrium; binary vapour liquid systems; the nucleus of condensation and the behaviour of steam with formation of large and small drops; Gibbs Phase rule; higher order phase transitions.

Thermodynamics of chemical reaction (combustion); internal energy and enthalpy - first law analysis and second law analysis; basic relations involving partial pressures; third law of thermodynamics; chemical equilibrium and chemical potential equilibrium constants; thermodynamics of low temperature.

Statistical mechanics - Maxwell - Boltzmann statistics; microstate and macrostates; thermodynamic probability; entropy and probability Bose Einstein statistics; Fermi Dirac statistics.

Elementary concepts of irreversible thermodynamics

REFERENCE BOOKS:

- *Advanced Thermodynamics For Engineers,*
Wark, McGraw Hill
- *Advanced Engineering Thermodynamics,*
Bejan A., John Wiley & sons
- *Thermodynamics: Kinetic Theory of Gases
and Statistical Mechanics,* Sears, Addison Wesley
- *Advanced Engineering Thermodynamics,*
Benson, Pergamon Press
- *Introduction to Thermodynamics: Classical &
Statistical,* Sonntag & Van Wylen, John Wiley.
- *Thermal Physics,* Garg S C, Bansal R M,
Ghosh C K, Tata McGraw-Hill Publications.

1MTTP4. MODELLING, SIMULATION & COMPUTER APPLICATIONS

Physical Modelling

Concept of system and environment, Continuous and discrete system, linear and nonlinear systems, stochastic activities, static and dynamic models, principles used in modeling

System Simulation

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Technique of simulation, Monte Carlo method, experimental nature of simulation, numerical computation techniques, continuous system models, analog and hybrid simulation, feedback systems

System Dynamics

Growth and decay models, logistic curves, system dynamics diagrams.

Probability Concepts in Simulation

Stochastic variables, discrete and continuous probability functions, random numbers, rejection method.

Simulation of Flow and Thermal Systems

Laminar and turbulent flow modeling, simulation of conduction, convection and radiation problems

Simulation of Manufacturing Systems

Simulation of job shop model with material handling, flexible manufacturing system

REFERENCE BOOKS:

- *System Simulation*, Geoffrey Gordon, *Prentice-Hall*
- *System Modelling and Control*, J. Schwarzenbach and K. F. Gill, *Edward Arnold*
- *Modelling and Analysis of Dynamic Systems*, Charles M. Close & Dean K. Frederick, *Houghton Mifflin*

1MTTP5. ANALYSIS OF THERMAL POWER CYCLES

Steam power plant cycle - Rankine cycle - Reheat cycle - Regenerative cycle with one and more feed heaters - Types of feed heaters - Open and closed types - Steam traps types.

Cogeneration - Condensing turbines - Combined heat and power - Combined cycles – Brayton cycle, Rankine cycle, combinations - Binary vapour cycle.

Air standard cycles - Cycles with variable specific heat - fuel air cycle - Deviation from actual cycle.

Brayton cycle - Open cycle gas turbine - Closed cycle gas turbine - Regeneration - Inter cooling and reheating between stages.

Refrigeration Cycles - Vapour compression cycles - Cascade system - Vapour absorption cycles- GAX Cycle.

REFERENCE BOOKS:

- *Principles of Energy Conversion*, Culp, R., *McGraw-Hill*, 2000.
- *Power Plant Engineering*, 2nd ed., Nag. P.K., *Tata McGraw-Hill*, 2002.
- *Engineering Thermodynamics*, 3rd ed., Nag. P.K., *Tata McGraw-Hill*, 2005.
- *Refrigeration and Air Conditioning*, 2nd ed., Arora, C.P., *Tata McGraw-Hill*, 2004.

SEMESTER – II

2MTTP1. COMPUTATIONAL FLUID DYNAMICS

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

Numerical solution of elliptical equations - Linear system of algebraic equations – Iterative solution of system of linear equation.

Model Equations – Wave equations - Numerical solution of parabolic equations – Stability analysis – Advanced shock capturing schemes.

Solutions of convection - Diffusion equation – Conservative and non-conservative schemes – concept of artificial viscosity and Numerical Diffusion.

Navier-Stokes equations and algorithms; Basics of grid generation- Numerical solution of hyperbolic equations - Burgers equation generation.

REFERENCE BOOKS:

- *Computational Fluid Mechanics and Heat Transfer*, Tannehill, J.c., Anderson, D.A., and Pletcher, R.H., *Taylor & Francis*, 1997.
- *Computational Fluid Dynamics for Engineers*, Hoffmann, K.A. and Chiang, S.T., *Engineering Education Systems*, 2000.
- *Computational Methods for Fluid Flow*, Peyret, R. and Taylor, T. D., *Springer-Verlag*, 1983.

2MTTP2. ADVANCED HEAT TRANSFER

Review

Review of the basic laws of conduction, radiation and convection.

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Conduction

One dimensional steady state conduction with variable thermal conductivity and with internal distributed heat source; local heat source in non-adiabatic plate; Extended surfaces-review; optimum fin of rectangular profile; straight fins of triangular and parabolic profiles; optimum profile; circumferential fin of rectangular profile; spines; design considerations.

Two dimensional steady state conduction; semi-infinite and finite flat plates; temperature field in finite cylinders and in infinite semi-cylinders;

Unsteady state conduction; sudden changes in the surface temperatures of infinite plate, cylinders and spheres; solutions using Groeber's and Heisler's charts for plates, cylinders and spheres suddenly immersed in fluids.

Radiation

Review of radiation principles; diffuse surfaces and the Lambert's Cosine law.

Radiation through non-absorbing media; Hottel's method of successive reflections;

Radiation through absorbing media; logarithmic decrement of radiation; apparent absorptivity of simple shaped gas bodies; net heat exchange between surfaces separated by absorbing medium; radiation of luminous gas flames.

Convection

Heat transfer in laminar flow; free convection between parallel plates; forced internal flow through circular tubes; fully developed flow; velocity and thermal entry lengths; solutions with constant wall temperature and with constant heat flux; forced external flow over a flat plate; the two dimensional velocity and temperature boundary layer equations; Karman Pohlhausen approximate integral method.

Heat transfer in turbulent flow; eddy heat diffusivity; Reynold's analogy between skin friction and heat transfer; von Karman; turbulent flow through circular tubes.

REFERENCE BOOKS:

- *Analysis of Heat and Mass Transfer*, Eckert and Drake, *McGraw Hill*.
- *Fundamentals of Heat Transfer*, Grober, Erk and Grigull, *Mc Graw Hill*.
- *Conduction Heat Transfer*, Schneider, *Addison Wesley*.
- *Thermal Radiation*, Siegel and Howell, *McGraw Hill*.
- *Heat, Mass and Momentum transfer*, Rohsenow and Choi, *Prentice Hall*.

2MTTP3. TURBOMACHINES

Introduction and cascades - Two-dimensional cascades - Analysis of cascade forces – Energy losses – Cascade correlation – Off design performance.

Power generating machine I - Axial flow turbines- Stage losses and efficiency – Soderberg's correlation – Turbine flow characteristics

Power absorbing machine I - Axial flow compressors, pumps, and fans – Three dimensional flow in axial turbo machines – theory of radial equilibrium – actuator disc approach – Secondary flows

Power absorbing machine II - Centrifugal pumps, fans, and compressors – slip factor – optimum design of centrifugal compressor inlet choking in a compressor stage.

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Power generating machine II - Radial flow turbines, Loss coefficients – off design operating condition – clearance and windage losses 90 deg IFR turbines.

REFERENCE BOOKS:

- *Fluid Mechanics and Thermodynamics of Turbomachinery*, 5th ed., Dixon, S.L., Butterworths Heinemann, 2005.
- *Theory of Turbomachines*, Csanady, G.T., McGraw Hill, 1964.
- *A Treatise on Turbomachines*, Prithvi Raj, D. and Gopalakrishnan, G., Scitech Publication, 2003.

2MTTP4. REFRIGERATION & CRYOGENIC SYSTEMS

Review of Thermodynamic Principles of Refrigeration: Vapors compression cycle, actual vapor compression cycle, multistage, multi evaporator system, cascade system, gas cycle refrigeration, aircraft refrigeration.

Refrigeration Systems: Estimation of thermal load, selection and matching of components compressors, evaporators, condensers, expansion devices, cyclic controls requirements of refrigerants, lubricants in refrigeration, Secondary refrigerants, mixed refrigerants. Theory of mixtures ; enthalpy composition diagrams, absorption system calculation, aqua ammonia systems, LiBr water system, Three fluid absorption systems, solar refrigeration system.

Cryogenic Systems: Introduction: Insight on Cryogenics, Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve - Joule Thomson Effect. Liquefaction Cycles: Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claudes Cycle, Dual Cycle, Helium Refrigerated Hydrogen Liquefaction Systems. Critical components in Liquefaction Systems.

Cryogenic Refrigerators: J.T.Cryocoolers, Stirling Cycle Refrigerators, G.M.Cryocoolers, Pulse Tube Refrigerators, Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators

Applications: Applications of Cryogenics in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications.

REFERENCE BOOKS:

- *Refrigeration and Air-conditioning Data*, W.F Stocker and J.W. Jones, McGraw Hill, 1985.
- *Refrigeration and Air Conditioning*, M. Prasad., Willey Eastern Ltd., 1990.

2MTTP5. ELECTIVE 1

1. ADVANCED I.C. ENGINE

Engine design and operating parameters – Thermo chemistry of fuel air mixtures- properties of working fluids.

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Ideal model of engine cycles – cycle analysis with constant specific heats – Volumetric efficiency – Super charging and Turbo charging

Fuel intake systems and combustion in SI and CI engines – Carburetor and fuel injection systems – Squish prechamber engine flows.

Pollutant formation and control in IC engines - Types of diesel combustion system – Fuel spray behavior – Ignition delay.

Engine friction and lubrication – measurement of friction – fluid mechanics based multi dimensional models – Engine operating characteristics.

REFERENCE BOOKS:

- *Internal Combustion Engine Fundamentals*, Heywood, J.B., McGraw-Hill, 1988.
- *The Internal Combustion Engines in Theory and Practice*, Vol-2, Taylor, C.P., MIT press, 1985.
- *Internal Combustion Engines*, 2nd ed., Ganesan V., Tata McGraw-Hill, 2003.
- *A course in Internal Combustion Engines*, Domkundwar V.M., Dhanpat Rai & Co.

2. BOILER AUXILIARIES AND PERFORMANCE EVALUATION

Boiler types - Efficiency calculation - Balance diagram – Boiler start up calculations –Boiler turbine- matching – Power Plant balance diagram

Fuel and Ash handling Equipment – Crushers and Mills - Drum internals - Specification and selection.

Feed pumps – Different types, Specifications, Operation and maintenance aspects - Fans, blowers – Applications – Performance requirements, Selection, Operation and maintenance. Dust cleaning equipment – Selection criteria – Design, operation and maintenance of electro static precipitators, Bag filters.

Soot blowers – Various types and their constructional features – Specifications – Selection – Operation and Maintenance.

REFERENCE BOOKS:

- *“Modern Power Station Practice”*, CEGB London, Pergamon Press, 1991.
- *“Fans”*, Eck B., Pergamon Press, 1973.
- *“Boilers, Types Characteristics and Functions”*, Shields, C.D., McGraw-Hill, 1961.

SEMESTER III

3MTTP1. ELECTIVE II:

1. COMBUSTION

Introduction

Importance of combustion, combustion equipment, hostile fire problems, pollution problems arising from combustion.

Thermodynamics of Combustion

Enthalpy of formation, enthalpy of reaction, heating values, first and second law analysis of reacting systems, chemical equilibrium, equilibrium composition, adiabatic and equilibrium flame temperature.

Kinetics of Combustion

Law of mass action, reaction rate, simple and complex reactions, reaction order and molecularity, Arrhenius Law, activation energy, Chain reaction steady state and partial equilibrium approximations. Chain explosion, Explosion limits and oxidation characteristics of hydrogen, carbon monoxide and hydrocarbons.

Flames

Premixed Flames structure and propagation of flames in homogeneous gas mixtures; simplified Rankine Hugoniot relations; properties of Hugoniot curve; analysis of deflagration and detonation branches, properties of Chapman Jouguet wave. Laminar flame structure; theories of flame propagation and calculation of flame speeds, flame speed measurements. Stability limits of laminar flames; flammability limits and quenching distance; burner design. Mechanisms of flame stabilization in laminar and turbulent flows; flame quenching. Diffusion flames; comparison of diffusion with premixed flame. Combustion of gaseous fuel jets Burke and Schumann development.

Burning of condensed phase

General mass burning considerations, combustion of fuel droplet in a quiescent and convective environment. Introduction to combustion of fuel sprays.

Ignition

Concepts of ignition, chain ignition, thermal spontaneous ignition, forced ignition.

Combustion Generated Pollution & its Control

Introduction, nitrogen oxides thermal fixation of atmospheric nitrogen prompt NO, thermal NO_x formation and control in combustors. Fuel NO_x and control, post – combustion destruction of NO_x, Nitrogen dioxide carbon monoxide oxidation – quenching, hydrocarbons, sulphur oxides.

REFERENCE BOOKS:

- *Combustion*, Glassman, Academic Press.

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- *Introduction to combustion Phenomenon 2nd Edn.*, Kanury Murty, *McGraw Hill Book Co.*, 1972
- *Combustion Fundamentals*, Strehlow, *Mc Graw Hill*
- *Combustion, Flames and Explosion of Gases*, Lewis & von Elbe, *Academic Press*
- *An Introduction to Combustion - Concepts and Applications*, 2nd ed., Turns, S.R., *McGraw Hill*, 2000.
- *Fuels and Combustion*, Sharma, S.P. and Mohan, C., *Tata McGraw-Hill*, 1987.
- *Fuels and Combustion*, Sarkar. S., *Orient Longman*, 2005.

2. ALTERNATIVE FUELS FOR I.C ENGINES

Availability and Suitability to Piston Engines, Concept of conventional fuels, potential alternative fuels-Alcohol, Methanol, DEE/DME-Hydrogen, LPG, Natural gas, Producer gas, Bio-gas and vegetable oils-Use in IC engines-Merits and demerits of various fuels.

Technical Background of Diesel/Bio-diesel fuels-Oil feed stocks- Transesterification-Bio-diesel production from Vegetable oils and waste cooking oil-High blend levels of bio-diesel-Testing, Bio diesel-Oxidation stability-Performance in Engines, Properties of bio-fuels and their importance in the context of IC Engines.

Initiation of combustion, flame velocities, Normal and abnormal combustion, Knocking combustion, pre-ignition-Knock and engine variables,-Features and design consideration of combustion chambers- stratified charge combustion- concepts of lean burn engines. Computation of heat release rates from cylinder pressure data. Spray formation and combustion in diesel engines. Heat release and heat transfer correlations for diesel engines.

Types-Air flow, Fluid flow, Temperature, Speed, Oxygen, Detonation, Position, Principle of operation, Arrangement and material. Cylinder pressure measurement.

Atmospheric pollution from piston engines, Global warming, Pollutant Formation in IC Engines- Emission measurement-control of Engine pollution-driving cycles and Emission standards. Emission measuring instrumentation including HC, CO, NOx, smoke and particulates.

REFERENCE BOOKS:

- *Internal Combustion Engine Fundamentals*, John B.Heywood, *McGraw Hill Book Company*, 1988
- *The Internal Combustion Engines in Theory and Practice Vol-2.*, Taylor, C.P., *MIT press*.
- *Automotive Fuels Guide Book*, RichardL.Bechtold, *SAE Publications*, 1997.
- *Energy today & tomorrow*, M. Dayal, *I & B Horishr India*, 1982.
- *Power Plant Engineering*, Nagpal, *Khanna Publishers*, 1991

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3MTTP2. ELECTIVE III

1. RENEWABLE ENERGY SYSTEMS

General

Energy and development; energy demand and availability; energy crisis; conventional and non-conventional, renewable and non-renewable energy resources; environmental impact of conventional energy usage; basic concepts of heat and fluid flow useful for energy systems.

Solar Energy Systems

Solar radiations data; solar energy collection, storage and utilization; solar water heating; air heating; power generation; refrigeration and air conditioning; solar energy system economics.

Micro and Small Hydro Energy Systems

Resource assessment of micro and small hydro power; micro, mini and small hydro power systems; economics; pump as turbine; special engines for low heads; velocity head turbines.

Biomass Energy Systems

Availability of biomass- agro, forest, animal, municipal and other residues; bioconversion technologies; cooking fuels, biogas, producer gas, power alcohol from biomass; power generation. ; internal engine modifications and performance; system economics.

Wind Energy Systems

Wind data; horizontal and vertical axis wind mills; wind farms; performance and economics of wind energy.

Integrated Energy Systems

Concept of integration of conventional and non-conventional energy resources and systems; integrated energy system design and economics.

REFERENCE BOOKS:

- *Solar Engineering of Thermal Processes*, Duffie & Beckman, John Wiley
- *Energy, the Biomass Option*, Bungay, John Wiley
- *Introduction to Wind Energy Technology*, Lysen, Georgia Inst.
- *Energy & Environment*, Fowler, McGraw Hill
- *Solar Energy*, S.P. Sukhatme, Tata McGraw Hill

2. ENVIRONMENTAL POLLUTION AND CONTROL

Air pollution - Classification and properties of Air pollutants - Sampling and analysis of air pollutants –Control of air pollution. Dispersion of air pollutants - Gaussian plume model- Control of gaseous pollutants – Volatile organic compounds - Control of gaseous emission - Air pollution laws and standards.

Water pollution - Sampling and analysis of waste treatment – Advanced waste water treatments by physical, chemical, biological and thermal methods - Effluent quality standards.

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Solid waste management - Classification and their sources - Health hazards - Handling of toxic and radioactive wastes - Incineration and verification.

Pollution control in process industries namely Cement, Paper, Petroleum and petrochemical, Fertilizers and distilleries, thermal power plants and automobiles.

REFERENCE BOOKS:

- *Introduction to Engineering and Science, 2nd ed.*, Manster G.M., *Pearson Publishers, 2004.*
- *Environmental Pollution Control Engineering*, Rao E.S., *Wiley Eastern Ltd., 1991.*
- *Pollution Control in Process Industries*, Mahajan S.P., *Tata McGraw-Hill, 1985.*
- *Air Pollution Control Theory*, Crawford M., *Tata Mc Graw Hill, 1976.*