ACADEMIC REGULATIONS & COURSE STRUCTURE

For

THERMAL SCIENCES AND ENERGY SYSTEMS

(Applicable for batches admitted from 2016-2017)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
KAKINADA - 533 003, Andhra Pradesh, India

I Semester

S.No	Subject	L	P	C
1	Computational Methods in Engineering	4	0	3
2	Advanced Thermodynamics	4	0	3
3	Advanced Fluid Mechanics	4	0	3
4	Advanced Heat Transfer	4	0	3
5	**Elective – I** 1. Computational Fluid Dynamics 2. Refrigeration & Cryogenics 3. Thermal & Nuclear Power Plants 4. Gas Turbines & Jet Propulsion	4	0	3
6	**Elective –II** 1. Design of Heat Transfer Equipment 2. Combustion in IC engines 3. Nano Technology 4. Advanced Finite Element Methods	4	0	3
7	Simulation Laboratory	0	3	2
Total Credits				**20**

II Semester

S.No	Subject	L	P	C
1	Solar Thermal and Photovoltaic Systems	4	--	3
2	Hydrogen and Fuel Cells	4	--	3
3	Biomass, Wind and Ocean Energy	4	--	3
4	Energy Audit and Conservation	4	--	3
5	Elective – III 1. Energy Systems Modelling & Analysis 2. Energy Economics and Planning 3. Optimization Techniques & Applications	4	--	3
6	Elective – IV 1. Instrumentation & Controls 2. Waste Heat Recovery Systems 3. Green Energy Technologies	4	--	3
7	Thermal Systems Laboratory	--	3	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	**--**	**--**	2
2	Seminar – I	--	--	2
3	Project Work Part - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work Part - II	--	--	18
Total Credits				**20**

I Year I Semester	COMPUTATIONAL METHODS IN ENGINEERING	L	P	C
		4	0	3

Unit – I

Introduction to numerical methods applied to engineering problems: Examples, solving sets of equations – Matrix notation – Determinants and inversion – Iterative methods – Relaxation methods – System of non-linear equations. Least square approximation fitting of non-linear curves by least squares –regression analysis- multiple linear regression, non linear regression - computer programs.

Unit – II

Boundary value problems and characteristic value problems: Shooting method – Solution through a set of equations – Derivative boundary conditions – Rayleigh – Ritz method – Characteristic value problems.

Unit – III

Transformation Techniques: Continuous Fourier series, frequency and time domains, Laplace transform, Fourier integral and transform, discrete Fourier transform (DFT), Fast Fourier transform (FFT).

Unit – IV

Numerical solutions of partial differential equations: Laplace's equations –

Representations as a difference equation – Iterative methods for Laplace's equations – poisson's equation – Examples – Derivative boundary conditions – Irregular and non – rectangular grids – Matrix patterns, sparseness – ADI method – Finite element method.

Unit – V

Partial differential equations: Explicit method – Crank-Nickelson method – Derivative boundary condition – Stability and convergence criteria. Solving wave equation by finite differences-stability of numerical method –method of characteristics-wave equation in two space dimensions-computer programs.

TEXT BOOKS:

1. Steven C.Chapra, Raymond P.Canale “Numerical Methods for Engineers” Tata Mc-Graw Hill

2.Curtis F.Gerald, Partick.O.Wheatly,”Applied numerical analysis”Addison-Wesley,1989

3.Douglas J.Faires,Riched Burden”Numerical methods”, Brooks/Cole publishing company,1998.Second edition.

References:

1.Ward Cheney and David Kincaid “Numerical mathematics and computing” Brooks/Cole publishing company1999, Fourth edition.

2.Riley K.F,. M.P.Hobson and Bence S.J,”Mathematical methods for physics and engineering”, Cambridge University press,1999.

3. Kreysis, Advanced Mathematics

I Year I Semester	ADVANCED THERMODYNAMICS	L	P	C
		4	0	3

UNIT -I:

REVIEW OF THERMODYNAMIC LAWS AND COROLLARIES: Transient flow analysis, Second law of thermodynamics, Entropy, Exergy, Exergy of closed and study flow systems, irreversibility and Gouy-Stodola equation. Exergy balance and second law efficiency. Thermodynamic potential, Maxwell relations, Specific heat relations, Mayer's relation.

UNIT – II:

Thermodynamic Equilibrium: Clausius – Clapeyron equation. Evaluation of thermodynamic properties. Mixtures of variable composition. Conditions of equilibrium of heterogeneous systems. Gibbs phase rule. Types of equilibriums. Conditions of stability.

UNIT-III:

CHEMICAL REACTIONS: Degree of reaction, Reaction equilibrium, Heat of reaction, Gibbs function change, Fugacity and activity. Fuels and combustion, theoretical and actual combustion processes. Enthalpy of formation and enthalpy of combustion.

UNIT – IV:

COMBUSTION:

First – law analysis of reaction systems: steady flow and closed systems. Adiabatic flame temperature. Entropy change of reacting systems. Second – law analysis of reacting systems. Chemical exergy.

UNIT-V:

POWER CYCLES: Review binary vapour cycle, co generation and combined cycles, Second law analysts of cycles. Refrigeration cycles. Thermodynamics of irreversible processes. Introduction, Phenomenological laws, Onsaga Reciprocity relation, Applicability of the Phenomenological relations, Heat flux and entropy production, Thermodynamic phenomena, Thermo electric circuits.

TEXT BOOKS:

1. Engineering Thermodynamics, 5th Edition/ P.K.Nag/ McGraw Hill Education.
2. Thermodynamics/Holman/ Mc Graw Hill.

REFERENCES

1. Thermodynamics, an Engineering approch/Y.A. Cenegel & M.A.Boles / McGraw Hill Ed
2. Engineering Thermodynamics / G. Rogers and Y. Mayhew/ Pearson
3. Thermodynamics for Engineers/Doolittle-Messe / John Wiley & Sons
4. Thermal Engineering / Soman / PHI
5. Thermal Engineering / Rathore / TMH
6. Engineering Thermodynamics/J.B.Jones and R.E.Dugan/PHI

I Year I Semester	ADVANCED FLUID MECHANICS	L	P	C
		4	0	3

UNIT I:

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

Basic Laws of fluid Flow: Condition for irrotationality, circulation & vorticity Accelerations in Carte systems normal and tangential accelerations, Euler's, Bernouli equations in 3D– Continuity and Momentum Equations

UNIT II:

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

UNIT III:

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

UNIT IV:

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

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

UNIT V:

Compressible Fluid Flow – I: Thermodynamic basics – Equations of continuity, Momentum and Energy - Acoustic Velocity Derivation of Equation for Mach Number – Flow Regimes – Mach Angle

– Mach Cone – Stagnation State

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

TEXT BOOKS:

1. Fluid Mechanics / L.Victor Steeter / TMH
2. Fluid Mechanics / Frank M.White / MGH

REFERENCES:

1. Fluid Mechanics and Machines/Modi and Seth/Standard Book House
2. Fluid Mechanics/Cohen and Kundu/Elsevier/5th edition
3. Fluid Mechanics/Potter/Cengage Learning
4. Fluid Mechanics/William S Janna/CRC Press
5. Fluid Mechanics / Y.A Cengel and J.M Cimbala/MGH
6. Boundary Layer Theory/ Schlichting H /Springer Publications
7. Dynamics & Theory and Dynamics of Compressible Fluid Flow/ Shapiro.
8. Fluid Dynamics/ William F. Hughes & John A. Brighton/TMH

I Year I Semester	ADVANCED HEAT TRANSFER	L	P	C
		4	0	3

UNIT-I:

BRIEF INTRODUCTION TO DIFFERENT MODES OF HEAT TRANSFER: Conduction: General heat Conduction equation-initial and boundary conditions.

Transient heat conduction: Lumped system analysis-Heisler charts-semi infinite solid-use of shape factors in conduction-2D transient heat conduction-product solutions.

UNIT- II:

FINITE DIFFERENCE METHODS FOR CONDUCTION: One dimensional & two dimensional steady state and simple transient heat conduction problems-implicit and explicit methods.

Forced Convection: Equations of fluid flow-concepts of continuity, momentum equations-derivation of energy equation-methods to determine heat transfer coefficient: Analytical methods-dimensional analysis and concept of exact solution. Approximate method-integral analysis.

UNIT-III:

EXTERNAL FLOWS: Flow over a flat plate: integral method for laminar heat transfer coefficient for different velocity and temperature profiles. Application of empirical relations to variation geometries for laminar and turbulent flows.

Internal flows: Fully developed flow: integral analysis for laminar heat transfer coefficient-types of flow-constant wall temperature and constant heat flux boundary conditions-hydrodynamic & thermal entry lengths; use of empirical correlations.

UNIT-IV:

FREE CONVECTION: Approximate analysis on laminar free convective heat transfer-boussinesq approximation-different geometries-combined free and forced convection.

Boiling and condensation: Boiling curve-correlations-Nusselts theory of film condensation on a vertical plate-assumptions & correlations of film condensation for different geometries.

UNIT-V:

RADIATION HEAT TRANSFER: Radiant heat exchange in grey, non-grey bodies, with transmitting. Reflecting and absorbing media, specular surfaces, gas radiation-radiation from flames.

TEXT BOOKS:

1. Heat and Mass Transfer: Fundamentals and Applications/Yunus Cengel/ McGraw-Hill Science/Engineering/Math; 5 edition
2. Heat Transfer / Necati Ozisik / TMH
3. Fundamentals of Heat and Mass Transfer/Tirumaleshwar/Dorling Kindersley Pvt Ltd

REFERENCES:

1. Fundamentals of Heat and Mass Transfer-5th Ed. / Frank P. Incropera/John Wiley
2. Elements of Heat Transfer/E. Radha Krishna/CRC Press/2012
3. Introduction to Heat Transfer/SK Som/PHI
4. Heat Transfer / Nellis & Klein / Cambridge University Press / 2012.
5. Heat Transfer/ P.S. Ghoshdastidar/ Oxford Press
6. Engg. Heat & Mass Transfer/ Sarit K. Das/Dhanpat Rai
7. Heat Transfer/ P.K.Nag /TMH
8. Heat Transfer / J.P Holman/MGH

I Year I Semester		L	P	C
		4	0	3

COMPUTATIONAL FLUID DYNAMICS
(ELECTIVE-I)

UNIT – I

Introduction: Finite difference method, finite volume method, finite element method, governing equations and boundary conditions. Derivation of finite difference equations. **Solution methods**: Solution methods of elliptical equations – finite difference formulations, interactive solution methods, direct method with Gaussian elimination.

Parabolic equations-explicit schemes and Von Neumann stability analysis, implicit schemes, alternating direction implicit schemes, approximate factorization, fractional step methods, direct method with tridiagonal matrix algorithm.

UNIT – II

Hyperbolic equations: explicit schemes and Von Neumann stability analysis, implicit schemes, multi step methods, nonlinear problems, second order one-dimensional wave equations.
Burger's equations: Explicit and implicit schemes, Runge-Kutta method.

UNIT – III

Formulations of incompressible viscous flows: Formulations of incompressible viscous flows by finite difference methods, pressure correction methods, vortex methods.

Treatment of compressible flows: potential equation, Eluer equations, Navier-stokes system of equations, Flow-field-dependent variation methods, boundary conditions, example problems.

UNIT – IV

Finite volume method: Finite volume method via finite difference method, formulations for two and three-dimensional problems.

UNIT – V

Standard Variational Methods: Linear fluid flow problems, steady state problems, Transient problems.

TEXT BOOK:

1. Computational fluid dynamics, T. J.Chung, Cambridge University press,2002.
2. Computational Fluid Dynamics by John D. Anderson /TMH

REFERENCE:

1. Text book of fluid dynamics, Frank Chorlton, CBS Publishers &distributors, 1985.
2. Computational Techniques for Fluid Dynamics, Volume 1& 2 By C. A. J. Fletcher/ Springer

REFRIGERATION AND CRYOGENICS (ELECTIVE-I)

Unit-I: VAPOUR COMPRESSION REFRIGERATION SYSTEMS:
Analysis of vapour compression refrigeration cycle
COMPOUND VAPOUR COMPRESSION SYSTEM: Removing of flash gas – inter cooling – compound compression ultra water inter cooler -liquid flash cooler – flash inlet cooler, multiple evaporator and compression systems, one compressor system – individual compressors – compound compression – cascade systems.

Unit-II: ABSOPTION REFRIGERATION SYSTEM WITH MULTIPLE EVOPARATORS
Three fluid absorption systems-the Lithium Bromide water absorption system, Steam jet water vapour systems – thermoelectric refrigeration systems – vortex refrigeration system – pulse tube refrigeration.
Desirable properties of refrigerants – designation of refrigerants – inorganic, halo carbon refrigerants – inorganic halo carbon reactions- secondary refrigerants – reaction of refrigerants with moisture and oil – properties of mixtures of refrigerants – ozone depletion potential and global warming potential of CFC refrigerants – substitutes for CFC refrigerants

Unit-III : CRYOGENICS

Introduction necessity of low temperature - Multistage Refrigeration system -Cascade system - Manufacture of dry ice-Joule Thompson coefficient.

Liquification of air - Linde system- Analysis- Dual pressure cycle analysis-Liquefaction of Hydrogen and Helium-problems.

UNIT-IV: APPLICATION OF LOWER TEMPERATURES

Effects on the properties of metals-strength-Thermal properties-super conductivity-super fluidity. Applications like expansion fitting - cryobiology-cryosurgery - space research-computers under ground power lines.

UNIT- V: LOW TEMPERATURE INSULATION

Reflective insulation-Evacuated powders-Rigid foams-Super insulation. Cooling by adiabatic de-magnetization - Gas separation and cryogenic systems separation of gases- Rectifying columns-Air separating- single and double columns Air separation plant.

Storage and handling of cryogenic liquids - Dewars and other types of containers

TEXT BOOKS:

1. C.P. Arora*, Refrigeration & Air-Conditioning by* TMH
2. R.F Barron ,*Cryogenic Systems* , Oxford University Press .
REFERENCE BOOKS:

1. Stoecker W.F.*Refrigeration & Air-Conditioning, and Jones,* J.W., McGraw Hill
2. Manohar Prasad*, Refrigeration & Air-Conditioning ,* New Age .

3. Domkunduwar, *Refrigeration & Air-Conditioning and Arora ,* Dhanpatrai & Sons

THERMAL & NUCLEAR POWER PLANTS
(ELECTIVE-I)

UNIT I

Energy scenario, overview of steam power plant, Analysis of steam cycles, Feed water heaters. De-aerator and drain cooler, optimization of cycle parameters, reheat and regeneration, Analysis of multi-fluid coupled cycles, Cogeneration of power and process heat, Combined cycle power generation.

UNIT II

Fuels, Combustion mechanisms, Draft systems, Combustion control, Furnaces for burning coal in fluidized beds and in pulverized form, Coal handling installation, Different types of boilers and their specific uses, Boiler mountings and accessories, Feed water treatment.

UNIT III

Boiler maintenance, Circulation theory, Downcomers and risers, Drum and its internals, Economiser, Convective and radiant super heaters, Superheat temperature control, Recuperative and regenerative air preheaters, Dust and ash removal systems, Environmental aspects of power generation

UNIT IV

Basic concepts of reactor physics, radioactivity, Neutron Scattering, Thermal and fast reactors, Nuclear cross-sections, Neutron flux and reaction rates, Moderator criteria, Reactor core design, Conversion and breeding, Types of reactors, Characteristics of boiling water, pressurized water, pressurized heavy water, gas cooled and liquid metal cooled reactors.

UNIT V

Future trends in reactor design and operation, Thermal-hydraulics of reactors, Heavy water management, Containment system for nuclear reactor, Reactor safety radiation shields, Waste management, Indian nuclear power programme.

TEXT BOOKS:

1. M.M.EI. Wakil., _*Nuclear Power Engineering'*, McGraw Hill Book Company, New York, 1987.
2. S. Glasstone and A. Setonske., _*Nuclear Reactors, Engineering*', 3rd Ed., CBS Publishers and Distributors, 1992.

REFERENCES:

1. Loftness, _*Nuclear Power Plants'*, D. Van Nostrand Company Inc, Princeton, 1964.

2. S. Sarg et al., _*Physics of Nuclear Reactors'*, Tata McGraw Hill Publishing Company Ltd., 1985.

3. T. J. Connoly., _*Fundamentals of Nuclear Energy'*, John Wiley, 1978

GAS TURBINES & JET PROPULSION
(ELECTIVE-I)

UNIT-I

Introduction to gas dynamics: control volume and system approaches acoustic waves and sonic velocity - mach number - classification of fluid flow based on mach number - mach cone-compressibility factor - general features of one dimensional flow of a compressible fluid - continuity and momentum equations for a control volume, Isentropic flow of an ideal gas: basic equation - stagnation enthalpy, temperature, pressure and density-stagnation, acoustic speed - critical speed of sound- dimensionless velocity-governing equations for isentropic flow of a perfect gas - critical flow area - stream thrust and impulse function.

UNIT-II

Steady one dimensional isentropic flow with area change-effect of area change on flow parameters-chocking- convergent nozzle - performance of a nozzle under decreasing back pressure -De lavel nozzle - optimum area ratio effect of back pressure - nozzle discharge coefficients - nozzle efficiencies, Simple frictional flow: adiabatic flow with friction in a constant area duct-governing equations - fanno line limiting conditions - effect of wall friction on flow properties in an Isothermal flow with friction in a constant area duct-governing equations - limiting conditions.

UNIT-III

Steady one dimensional flow with heat transfer in constant area ducts- governing equations - Rayleigh line entropy change caused by heat transfer - conditions of maximum enthalpy and entropy, Effect of heat transfer on flow parameters: Intersection of Fanno and Rayleigh lines. Shock waves in perfect gas- properties of flow across a normal shock - governing equations - Rankine Hugoniat equations - Prandtl's velocity relationship - converging diverging nozzle flow with shock thickness - shock strength.

UNIT- IV

Propulsion: Air craft propulsion: - types of jet engines - energy flow through jet engines, thrust, thrust power and propulsive efficiency turbojet components-diffuser, compressor, combustion chamber, turbines, exhaust systems.

UNIT-V

Performance of turbo propeller engines, ramjet and pulsejet, scramjet engines. Rocket propulsion - rocket engines, Basic theory of equations - thrust equation - effective jet velocity - specific impulse - rocket engine performance - solid and liquid propellant rockets - comparison of various propulsion systems.

TEXT BOOKS:

1. Compressible fluid flow - A. H. Shapiro
2. Fundamentals of compressible flow with aircraft and rocket propulsion- S. M. Yahya

REFERENCES

1. Elements of gas dynamics - Liepman & Roshko
2. Aircraft & Missile propulsion - Zucrow
3. Gas dynamics - M.J. Zucrow & Joe D.Holfman

I Year I Semester		L	P	C
		4	0	3

DESIGN OF HEAT TRANSFER EQUIPMENT
(ELECTIVE-II)

Unit-I

DESIGN OF HEAT EXCHANGERS & CONDENSERS

Heat Exchangers-mean temperature differences for parallel and counter flow effectiveness method (NTU), Overall heat transfer co-efficient –temperature distribution and heat flow in a condenser-pressure drop in a condenser-extended fin surfaces-consideration of fouling factors-LMTD correction factor.

Unit-II

DESIGN OF EVOPORATORS

Temperature distribution and heat flow in an evaporator – pressure drop-factor to be consider in the design of heat transfer equipment – types of heat consideration of fouling factor-correction factor.

Unit-III

DESIGN OF COMPRESSORS

Types – equivalent shaft work- volume metric efficiency- factors affection total volume metric efficiency – compound compression with inter cooling – rotary compressors surging.

Unit-IV

DESIGN OF COOLING TOWERS AND SPRAY PONDS & DUCTS

Classification-performance of cooling towers-analysis of counter flow cooling towers – enthalpy – temperature diagram of air and water- cooling ponds- types of cooling ponds-cross flow cooling towers – procedure for calculation of outlet conditions, Continuity equation – Bernoull's equation – pressure losses – frictional charts – co efficient of resistance for fillings – duct sizing methods.

Unit-V

DESIGN OF FANS & PIPING SYSTEM

Standard air –fan horse power – fan efficiency – similarity laws-fan laws – performance co efficient –theoretical expressions for total pressure drop by a fan, centrifugal fan, axial flow fan – system resistance, Requirements of a good piping system- pressure drop in pipe-Moody chart refrigerant piping – discharge line- liquid line-suction line – piping arrangement

TEXT BOOK

1. Heat and Mass Transfer by - Arora and Domkundwar.

REFERENCES

1. Cooling Tower, Fundamentals- John C. Hensley, SPX Cooling Technologies

2. Heat exchangers Selection, Rating and Thermal Design – Sadik Kakac,Hongtan Liu,Anchasa Pramunjanaroenkij, CRC Press

3. Process Heat Transfer – Donald Q. Kern, Tata McGraw-Hill
4. Process Heat Transfer – Hewitt ,Shires & Bott, CRC Press
5. Heat Pipes Theory, Design & Applications – D.A. Reay, P.D.Dunn, Pergamon

6. Cooling Techniques for Electronic Equipment– Dave S. Steinberg, Wiley-InterScience Publication

7. Fundamentals of Heat Exchanger Design -Ramesh K. Shah, Dusan P. Sekulic,Wiley-India

COMBUSTION IN IC ENGINES
(ELECTIVE – II)

UNIT I

COMBUSTION PRINCIPLES

Combustion – Combustion equations, heat of combustion - Theoretical flame temperature - chemical equilibrium and dissociation - Theories of Combustion - Pre-flame reactions - Reaction rates - Laminar and Turbulent Flame Propagation in Engines.

UNIT II

COMBUSTION IN S.I. ENGINE

Initiation of combustion, stages of combustion, normal and abnormal combustion, knocking combustion, pre-ignition, knock and engine variables, features and design consideration of combustion chambers. Flame structure and speed, Cycle by cycle variations, Lean burn combustion, stratified charge combustion systems. Heat release correlations. After treatment devices for SI engines.

UNIT III

COMBUSTION IN C.I. ENGINE

Stages of combustion, vaporization of fuel droplets and spray formation, air motion, swirl measurement, knock and engine variables, features and design considerations of combustion chambers, delay period correlations, heat release correlations, Influence of the injection system on combustion, Direct and indirect injection systems, after treatment devices for diesel engines.

UNIT IV

COMBUSTION IN GAS TURBINES

Flame stability, re-circulation zone and requirements - Combustion chamber configuration, materials.

UNIT V

EMISSIONS

Main pollutants in engines, Kinetics of NO formation, NOx formation in SI and CI engines. Unburned hydrocarbons, sources, formation in SI and CI engines, Soot formation and oxidation, Particulates in diesel engines, Emission control measures for SI and CI engines, Effect of emissions on Environment and human beings.

TEXT BOOKS :

1. Ramalingam, K.K., Internal Combustion Engines, Scitech Publications (India) Pvt. Ltd., 2004.
2. Ganesan, V, Internal Combustion Engines, Tata McGraw Hill Book Co., 2003.
3. John B.Heywood, Internal Combustion Engine Fundamentals,McGraw Hill Book, 1998

REFERENCES :

1. Mathur,M.L., and Sharma,R.P., A Course in Internal Combustion Engines, Dhanpat Rai Publications Pvt. New Delhi-2, 1993.
2. Obert,E.F., Internal Combustion Engine and Air Pollution, International Text Book Publishers, 1983.
3. Cohen,H, Rogers,G,E.C, and Saravanamuttoo, H.I.H., Gas Turbine Theory, Longman Group Ltd., 1980.

NANO TECHNOLOGY
(ELECTIVE-II)

UNIT-I

Introduction,Size and shape dependence of material properties at the nanoscale, scaling relations, can nanorobots walk and nanoplanes fly, Nano scale elements in conventional technologies, Mechanics at nanoscale Enhancement of mechanical properties with decreasing size, Nanoelectromechanical systems, nano machines, Nano fluidics, filtration, sorting, Molecular motors, Application of Nano Technology.

UNIT-II

Nano material Synthesis Techniques: Top-down and bottom-up nanofabrication, Synthesis of nano composites, The Intel-IBM approach to nanotechnology: lithography, etching, ion implantation, thin film deposition, nano coatings and nano indentation, Electron beam lithography, Soft lithography: nanoimprinting and microcontact printing, Solution/plasma-phase nanofabrication, sol-gel methods, template techniques.

UNIT-III

Imaging/characterization of nanostructures General considerations for imaging, Scanning probe techniques: XRD, SEM, TEM, AFM and NSOM.

UNIT-IV

Metal and semiconductor nanoparticles Synthesis, stability, control of size, Optical and electronic properties, Ultra-sensitive imaging and detection with nano particles, bioengineering applications, Catalysis. Semiconductor and metal nanowires Vapor/liquid/solid growth and other synthesis techniques, Nanowire transistors and sensors.

UNIT-V

Carbon nanotubes

Structure and synthesis, Electronic, vibrational, and mechanical properties, How can C nanotubes enable faster computers, brighter TV screens, and stronger mechanical reinforcement?

TEXT BOOKS:

1. Nanoscale Science and Technology by Kelsall, Hamley, and Geoghegan, Wiley (2005)
2. Introduction to Nanoscale Science and Technology by Di Ventra, Evoy, and Heflin, Kluwer Academic Publishers (2004).

REFERENCES:

1. Introduction to Nanotechnology by Poole and Owens, Wiley (2003)
2. Nanochemistry: A Chemical Approach to Nanomaterials, Ozin and Arsenault, RSC Publishing (2006).

ADVANCED FINITE ELEMENT METHODS (ELECTIVE-II)

UNIT I

Formulation Techniques: Basic principles of theory of elasticity, finite elements, Raleigh Ritz and Galerkin Methods. Coordinates, boundary conditions, Element matrices, assembling of global stiffness matrix, Finite Element Solution methods.

UNIT II

Trusses, Beams & Frames: Element matrices, assembling of global stiffness matrix, solution for displacements, reaction, stresses, temperature effects.

UNIT III

Two dimensional problems: four noded and eight nodded rectangular elements, Lagrange basis for rectangles, serendipity interpolation functions. Axisymmetric Problems: Axisymmetric

formulations, Element matrices, boundary conditions. Heat Transfer problems: Conduction and convection, examples: - two dimensional fin.

UNIT IV

Isoparametric formulation: Concepts, sub parametric, super parametric elements, numerical integration. Applications of Isoparametric elements for structural and dynamic problems.

UNIT V

Convergence, Solution improvement methods, patch test, formulation methods of geometric and material non linear problems, case studies on coupled analysis problems. Implementation of FEA problems through MAT Lab.

REFERENCE BOOKS :

1. R.D.Cook, Introduction to Finite Element Analysis, John Wiley & sons
2. T.J.R Hughes, The Finite Element Method: Linear and Dynamic Finite Element Analysis, Dover Publications
3. J.N. Reddy, Finite element method in Heat transfer and fluid dynamics, CRC press
4. Zienckiwicz O.C. & R. L. Taylor, Finite Element Method, McGraw-Hill
5. J. N. Oden, Finite Element of Nonlinear continua, McGraw-Hill, New York
6. K. J. Bathe, Finite element procedures, Prentice-Hall

I Year I Semester	SIMULATION LABORATORY	L	P	C
		0	3	2

FEM/CFD Analysis for the following:

1. Evaluation of boundary layer lift on circular cylinder
2. Evaluation of mach angle and mach cone for compressible flow through convergent divergent nozzle
3. Evaluation of convective heat transfer coefficient for fully developed flow through pipe for laminar and turbulent conditions
4. Solution of parabolic, elliptical and hyperbolic equations using mathematica software
5. Evaluation of radio activity and design of reactor core design of a modern nuclear reactor
6. Evaluation of combustion parameters like flame speed, heat release rate for CI / SI Engines
7. Design of nano tubes
8. Heat transfer problems under steady state conduction.
9. Heat transfer problems under unsteady state conduction.
10. Analysis of heat transfer through convection.
11. Transient analysis of heat conduction.
12. Flow through a pipe bend.
13. Flow through a nozzle.
14. Performance evaluation of solar flat plate collector
15. Performance evaluation of shell & tube heat exchanger
16. Performance evaluation of wind mill
17. Performance evaluation of ocean wave energy conversion system
18. Performance evaluation of biomass gasifier

I Year II Semester	SOLAR THERMAL AND PHOTOVOLTAIC SYSTEMS	L	P	C
		4	0	3

Unit-I: Introduction

Solar energy option - Specialty and potential - Sun - Earth - Solar radiation - Beam and diffuse - Measurement - Estimation of average solar radiation on horizontal and tilted surfaces - Problems - Applications.

Capturing solar radiation - Physical principles of collection - Types - Liquid flat plate collectors - Construction details - Performance analysis - Concentrating collection - Flat plate collectors with plane reflectors - Cylindrical parabolic collectors - Orientation and tracking - Performance analysis.

Unit-II: Power generation from Solar Thermal

Power generation - Solar central receiver system - Heliostats and receiver - Heat transport system - Solar distributed receiver system - Power cycles - Working fluids and prime movers - Concentration ratio.

Unit-III: Thermal Energy Storage

Introduction - Need for - Methods of sensible heat storage using solids and liquids - Packed bed storage - Latent heat storage - Working principle - Construction - Application and limitations - Solar devices - Stills - Air heaters - Dryers - Solar Ponds & Solar Refrigeration - Active and passive heating systems.

Unit-IV: Energy Collection, Storage and applications

Flat plate and concentrating collectors - Classification of concentrating collectors - Orientation and thermal analysis - Advanced collectors - Different storage techniques - Sensible - Latent heat and stratified storage - Solar ponds - Solar applications - Solar heating/cooling techniques - Solar distillation and drying - Photovoltaic energy conversion.

Unit-V: PV System Design and Applications:

Standalone PV systems - Lighting - Water pumping - Hybrid PV Systems - PV wind and PV diesel - Grid connected PV Systems - PV power plants - Roof top and ground mounted small & large power plants.

Text Books/Reference Books:

1. Principles of solar engineering, Kreith and Kerider, Taylor and Franscis, 2nd edition .

2. Solar energy thermal processes, Duffie and Beckman, John Wiley & Sons.

3. Solar energy: Principles of Thermal Collection and Storage, Sukhatme, TMH, 2nd edition .

4. Solar energy, Garg & Prakash, H. P. Garg, Tata McGraw-Hill Education, 2000.

5. Solar energy, B.S. Magal, McGraw-Hill Education (India) Pvt Limited, 01-Nov-1999.

6. Solar Thermal Engineering Systems, Tiwari and Suneja, Narosa Publishing House, 1997.

7. Power plant Technology, M. M. El-Wakil, McGraw-Hill, 1984.

8. Solar Photovoltaics: Fundamentals, Technologies and Applications, Chetan Singh Solanki, PHI Learning Private Limited 2011 (or later edition).

I Year II Semester	HYDROGEN AND FUEL CELLS	L	P	C
		4	0	3

UNIT I

HYDROGEN – BASICS AND PRODUCTION TECHNIQUES

Hydrogen – physical and chemical properties, salient characteristics.Production of hydrogen – steam reforming – water electrolysis – gasification and woody biomass conversion – biological hydrogen production – photo dissociation – direct thermal or catalytic splitting of water.

UNIT II

HYDROGEN STORAGE AND APPLICATIONS

Hydrogen storage options – compressed gas – liquid hydrogen – Hydride – chemical Storage – comparisons- Hydrogen transmission system- Applications of Hydrogen.

UNIT III

FUEL CELLS

History – principle - working - thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell

UNIT IV

FUEL CELL - TYPES

Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – relative merits and demerits

UNIT V

APPLICATION OF FUEL CELL AND ECONOMICS

Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space-Economic and environmental analysis on usage of Hydrogen and Fuel cell- Future trends in fuel cells.

TEXT BOOKS:

1. Rebecca L. and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Corporation, Oklahoma (2005)
2. Bent Sorensen (Sørensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications, Elsevier, UK (2005)

REFERENCES:

1. Kordesch, K and G.Simader, Fuel Cell and Their Applications, Wiley-Vch, Germany (1996).
2. Hart, A.B and G.J.Womack, Fuel Cells: Theory and Application, Prentice Hall, NewYork Ltd., London (1989)
3. Jeremy Rifkin, The Hydrogen Economy, Penguin Group, USA (2002). Viswanathan, B and M Aulice Scibioh, Fuel Cells – Principles and Applications, Universities Press (2006)

I Year II Semester	BIOMASS, WIND AND OCEAN ENERGY	L	P	C
		4	0	3

Unit - I

Sources and classification - Chemical composition - Properties of biomass - Energy plantations - Size reduction - Briquetting - Drying - Storage and handling of biomass, Feedstock for biogas - Microbial and biochemical aspects - Operating parameters for biogas production

Unit - II:

Thermo chemical conversion of lignocelluloses biomass - Incineration - Processing for liquid fuel production - Pyrolysis - Effect of particle size -Temperature and products obtained.

Unit - III: Wind Energy: Wind Energy, Indian Wind Energy Potential, Atmospheric circulations, classification, factors influencing wind, wind shear, turbulence, wind speed monitoring, Wind Energy Conversion Systems : classification, characteristics, applications

Unit - IV: Wave Energy -Concepts & Resource:

Introduction - Terminology & concepts -Preliminary considerations - Oscillating water column - Sea states & their energy - Wave growth, travel & decay - Wave climate estimation - Numerical and experimental modeling of wave energy conversion systems - Wave tank and wave maker design - Laboratory testing of wave energy conversion systems - Case studies.

Unit - V: Wave Energy - Power take - off systems:

Air turbine design for OWCS - Design configurations - Direct drive -Linear generator systems - Principles and case studies - Full scale WECS - LIMPET - Archimedes wave swing (AWS) - Pelamis & wave dragon - Design & implementation - Environmental impact - Legislation &administrative issues.

Text Books:

1. "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Chakraverthy A, Oxford & IBH publishing Co, 1989
2. 'Ocean wave Energy –Current Status & Future Perspectives" by Crug Joao, springer, 2008.
3. "Renewable Energy, Power for a Sustainable Future", Edited by Godfrey Boyle Oxford University Press, Third Edition 2012.
4. Wind Energy Conversion Systems, Freris, L.L., Prentice Hall, 1990

Reference Books:

1. Solar Engineering of Thermal Processes, Duffie, A and Beckmann, W. A., John Wiley, 1991.
2. Renewable Energy Sources, Twidell, J.W. and Weir, A.,EFN Spon Ltd., 1983.
3. Magneto Hydrodynamics, Kuliovsky and Lyubimov, Addison.

I Year II Semester	ENERGY AUDIT AND CONSERVATION	L	P	C
		4	0	3

UNIT I

Energy Audit: Definition, Need and Objectives.

Types of Energy Audit: Internal Audit, External Audit, Walk through Energy Audit, Preliminary Energy Audit, Detailed Energy Audit, Investment Grade Energy Audit, Industrial Energy Audit, Utility (Services) Energy Audit, Commercial Energy Audit, Residential Energy Audit.

UNIT II

Energy Audit Strategies: Monitoring and Control, Questioning the Need, Minimizing the Need of End Use, Minimizing the Losses, Operating the Equipment at Optimum Efficiency, Operating the Most Efficient Equipments from Set of Equipments, Minimizing the Idle Redundant Running, Proper Maintenance of the Equipment, Substitution with Efficient Equipment, Substitution with more Efficient Equipment, Substitution with more Efficient Process, Energy Storage, Fuel Substitutions, Quality Control and Recycling.

Basic Components of Energy Audit

Preparing for Audit Visit, Instrumentation, Data Collection Techno-economic Analysis, Safety Considerations.

UNIT III

Methodologies of Conducting Energy Audit

Preliminary Questionnaire, Review of Previous Records, Introductory Meeting, Walk through Tour, Flow Chart Construction for Detail Energy Audit, Identification of Required Audit Instruments, Finalization of Audit Schedule with the Company, Getting Detailed Data.

Post Audit Analysis

Process Flow Diagram, Material and Energy Balance, Energy Use and Cost Profile of each Fuel Used, Energy Balance Diagram for each Energy Type Used, Identification and Techno-economic Analysis of Energy Conservation Measures, Classification of Energy Conservation Measures, Outlines of Energy Audit Report Format Energy Audit Subsidy Scheme of PCRA, IDBI and IREDA. Useful Forms for Data Collections. Useful Charts for Quick Estimations.

Checklists for each Devices and Distribution Lines. Thumb Rules and Specific Energy indices for Devices and Processes

UNIT IV

Boilers:

Types, Analysis of Losses, Performance Evaluation, Feed Water Treatment, Blow Down, Energy Conservation Opportunities, Case Studies.

FBC Boilers:

Introduction, Mechanism of Fluidized Bed Combustion, AFBC, CFBC, PFBC Boilers, Condensing Boilers, Saving Potential, Case Studies.

UNIT V

Steam System:

Properties of Steam, Assessment of Steam Distribution Losses, Steam Leakages, Steam Trapping, Condensate and Flash Steam Recovery System, Identifying Opportunities for Energy Saving, Case Studies.

Cogeneration

Need, Applications, Advantages, Topping Cycles, Bottoming Cycles, Combined Cycles, Steam Tracking Mode, Electricity Tracking Mode, Saving Potential, Case Studies.

Recommended Books

1. Instructions to Energy Auditors, Vol. - I & Vol. - II –
National Technical Information Services U. S. Deptt. Of Commerce Springfield, VA 22161.
2. Energy Auditing, The Fairmont Press Inc. Published by Atlanta, Georgia
3. Albert Thumann, P.E., C.E.M. , Plant engineers & Managers Guide To Energy Conservation 8th edition-2002, Published By The Fairmont Press , Inc 700 Indian Trail Liburn, GA30047
4. G. L. Witte, Phillips S.Scbmidt and Daid R. Brown, Industrial Energy Management and Utilization, Hemisphere Publishing Corporation, Washington.
5. Carig,B. Saith, Energy Management Principles, Applications, Bnefit and Saving, Per n Press, New York.

I Year II Semester		L	P	C
		4	0	3

ENERGY SYSTEMS MODELLING AND ANALYSIS
(ELECTIVE-III)

Unit-I

INTRODUCTION:

Overview of various technologies and conventional methods of energy conversion, Designing a Workable System: Workable and optimum systems, Steps in arriving a workable system, Creativity in concept selection, Workable Vs Optimum system, Mathematical modeling, Polynomial representation, Functions of two variables, Exponential forms, Best fit Method of least squares

Unit-II

MODELING OF THERMAL EQUIPMENT:

Counter flow heat exchanger, Evaporators and Condensers, Heat exchanger effectiveness, Effectiveness of a counter flow heat exchanger, NTU, Pressure drop and pumping power

SYSTEM SIMULATION:

Classes of simulation, Information flow diagrams, Sequential and simultaneous calculations, Successive substitution, Newton Raphson method

Unit-III

OPTIMIZATION TECHNIQUES:

Mathematical representation of optimization problems, A water chilling system, Optimization procedure, Setting up the mathematical statement of the optimization problem, Dynamic Programming: Characteristic of the Dynamic programming solution, Apparently constrained problem, Application of Dynamic programming to energy system problems, Geometric Programming: One independent variable unconstrained, Multivariable optimization, Constrained optimization with zero degree of difficulty ,Linear Programming: Simplex method, Big-M method, Application of LP to thermal systems

Unit-IV

LAGRANGE MULTIPLIER'S METHOD: The Lagrange multiplier equations, Unconstrained optimization, Constrained optimization, Sensitivity coefficients

SEARCH METHODS: Single variable – Exhaustive, Dichotomous and Fibonacci, Multivariable unconstrained - Lattice, Univariable and Steepest ascent

Unit-V

MATHEMATICAL MODELING:

Thermodynamic properties-Need for mathematical modeling, Criteria for fidelity of representation, Linear regression analysis, Internal energy and enthalpy, Pressure temperature relationship at saturated conditions, Specific heat, P-V-T equations

Tex Books / References :

1. W.F.Stoecker (1989), *"Design of Thermal Systems"* McGraw Hill, 3rd Ed.
2. B.K.Hodg(1990), *"Analysis and Design of Thermal Systems",* Prentice Hall Inc.,.
3. I.J.Nagrath & M.Gopal, *"Systems Modelling and Analysis",* Tata McGraw Hill.
4. D.J. Wide(1978), *"Globally Optimal Design",* Wiley- Interscience,

ENERGY ECONOMICS AND PLANNING
(ELECTIVE-III)

UNIT I: INTRODUCTION TO ENERGY ECONOMICS

Natural Resources – Classification – Importance – Role of Natural Resources in Economic Development – Energy Resources – Types and Classification – Properties of Energy – Forms of Energy – Emergence of Energy Economics – Its Scope and Nature – Energy Indicators - Energy Economics and its relations with other Branches.

UNIT II: ENERGY AND DEVELOPMENT

Role of Energy in Economic Development – Energy intensity and Energy Elasticity – National and International Comparison – Low, Middle, and High Income Economies – Role of International Institutions – OPEC, OAPEC, IEA, and World Bank.

UNIT III: ENERGY AND ENVIRONMENT

Energy Crisis – Causes and Consequences – Remedial Measures – Environmental Crisis – Causes and Consequences – Remedial Measures – Impact of Energy Consumption and Production on Environment with illustrations – Role of Energy and Environmental Economists in solving Energy the crises.

UNIT IV: ENERGY CONSERVATION AND ENERGY MANAGEMENT

Energy Planning and Energy Conservation – Meaning, Objectives and Importance – Energy Management – Meaning, Objectives and Importance – Recent Developments – Energy Auditing – Energy Accounting – Energy Pricing and Taxes – Role of Economists in Promoting Sustainable Energy Management.

UNIT V: INDIA'S ENERGY PROFILE

Indian Energy Sector – Organizational Structure – Energy Supply (Coal, Lignite, Oil, Gas and Powers – Hydro, Nuclear, Thermal) – Energy Demand (Agriculture, Industry, Transport, Domestic, etc) – Renewable Energy Sources and Technology (Solar, Wind, Biogas, Biomass, Geothermal, OTEC, Tidal, Wave Hydrogen, Fuel Cell, Bio-Diesel) – Renewable Energy Programmes – Energy Under Five Year Plans – Energy Issues and Policy Options for India.

References

1. Agarwal, M.C. and Monga, J.R. (1992): **Economic and Commercial Geography**, National Publishing House, New Delhi.
2. Agarwal, S.K. (1985): **Environment and Natural Resources Economics**, Scott Foresman & Co., London.
3. Common, M. (1985) : **Environmental and Resource Economics**, Longman, London.
4. David Pearct et al., (1990) : **Sustainable Development – Economics and Environment in the Third World**, Earths Can Publications, London.
5. Deoffrey Kirk (1982) : **Schemacher on Energy**, Abacus, London.
6. Government of India (2002) : **Thenth Five Year Plan**, Planning Commission, New Delhi.
7. Hemalatha Rao (1990) : **Rural Energy Crises : A Diagnostic Analysis**, Ashish Publishing House, New Delhi.
8. Karpagam, M. (1991) : **Environmental Economics**, Sterling, New Delhi.
9. Kneese. A.V and Sweeny, J.L, : 1993) : **Handbook of Natural Resource and Energy Economics**, North Holland.
10. Munasinghe, M and Meier, P (1993) : **Energy Policy and Modeling**, Cambridge University Press, UK.

11.Paul Stevens (Ed) (2000) : **The Economics of Energy, Vol. I and II**, Edward Elgar.
12.Raikhy, P.S. and Parminder Singh, (1990) : **Energy Consumption in India – Pattern and Determinants**, Deep and Deep, New Delhi.
13.Richard Eden (1981) : **Energy Economics – Growth, Resources and Policies**, Cambridge University Press, London.
14.Sankar, U, (1992) : **Public Sector Pricing : Theory and Applications**, IEA Trust for Research and Development, Bombay.
15. TERI (2012) : **Teri Energy Data Directory and Year Book 2011-12**, The Energy Research Institute, New Delhi.
16.William Burch (Ed.) (1997) : **Readings in Ecology, Energy and Human Society : Contemporary Perspectives**, Harper and Row, New York.
17.World Bank (1992) : **World Development Report 1992**, Oxford University Press, China

OPTIMIZATION TECHNIQUES & APPLICATIONS
(ELECTIVE-III)

OPTMIZATION TECHNIQUES & APPLICATIONS

UNIT I:- Introduction

Optimization levels, mathematical representation, optimization procedures, search methods. Constrained and unconstrained optimization using lagrange multiplier equations. Sensitivity coefficients and inequality constraints and related exercises.

UNIT II:- Search methods

Overview: Single variable, constrained and unconstrained multi variable methods. Dichotomous search, Fibonacci search, Lattice search, univariate search, steepest – ascent method. Penalty functions. Hemstitching method and exercises.

UNIT III:- Dynamic and Geometric programming

Description characteristics, efficiency and solution pattern of dynamic programming

Objective function, constraints, solution mechanism for constrained and unconstrained single and multivariable optimization of geometric programming.

UNIT IV:- Mathematical modeling of thermal systems.

Need for mathematical modeling. Non linear regression analysis. Newton – Rapson technique, Quasi-Newton method and related exercises.

UNIT V:- Dynamic behavior of Thermal systems.

Scope and approach. Laplace Transforms. Stability analysis using frequency response and loop transfer function. Proportional control, P.I. control and P.I.D control

TEXT BOOK:

1. Design of Thermal Systems by W.F.Stoecker, 3rd ed, TMH.

REFERENCES:

1. Engineering Optimization: Theory and Practice by Singiresu S. Rao. New Age International.
2. Optimization Techniques / Belagundu & Chandraputala / Pearson Asia

I Year II Semester		L	P	C
		4	0	3

INSTRUMENTATION & CONTROLS
(ELECTIVE-IV)

Unit-I

Elements of a Measurement System; Basic Instrumentation system; Errors and Uncertainties; Mechanical Transducers: Temperature- Bimetallic Element and Fluid Expansion type Thermometers; Pressure- Manometers and Bourdon Gauges; Load Cells and Elastic Force Devices; Electrical transducers: Resistive Transducers; Inductive Transducers; Capacitive transducers; Thermoelectric Transducers and Photoelectric Transducers; Piezoelectric Transducers.

Unit-II

Basic Signal Conditioning Elements: DC Bridges, AC Bridges, Wheatstone Bridge, Balance & Deflection Measurements - Amplifiers- Non Electrical and Electrical types; Op Amps-Summing, Differential, and Charge Amplifiers; Differentiating and Integrating Elements; Filters; Data Transmission Elements- Electrical, Pneumatic, Position and Radio Frequency Transmission types, Basic display elements

Unit-III

Industrial Measurements Velocity Measurement – Contact type: AC-DC Tachometers Non contact type: Magnetic, Photoelectric & stroboscopic methods Acceleration measurement – Seismic Accelerometer & Piezoelectric Accelerometer Measurement of Force – Different methods; Strain gauge load cell method Measurement of torque – Strain gauge method Radiation Measurement – Radiation Fundamentals; Radiation detectors; Optical pyrometer

Unit-IV

Control Systems: Open & Closed loop systems, Linear Time-invariant systems, Transfer Function Analysis, Mason's Gain Formula, Transient response analysis, Stability Analysis, RH Criterion, Relative stability.

Unit-V

Frequency response analysis: Bode plots, Nyquist Stability Criterion, Gain Margin & Phase Margin (Simple problems only)-Introduction to State Space Analysis (Elementary treatment only – No numerical); Concept of state, state variables & state models; State transition matrix

Reference Books:

1. Albert D Helfrick and William D Cooper; Modern Electronic Instrumentation and Measurement Techniques; 2004, PHI
2. BC Nakra, and KK Chaudhry; Instrumentation, Measurement and Analysis; 2 ed, 2004, Tata McGraw-Hill
3. DVS Murthy; Transducers and Instrumentation; 2003, PHI
4. CS Rangan, GR Sarma, and VSV Mani; Instrumentation Devices and Systems; 2 ed, Tata McGraw-Hill
5. Doeblin and Ernest; Measurement Systems Application and Design; 5 ed, 2004, Tata McGraw-Hill.
6. Measurement Systems – Applications & design by Doeblin E.O. 4th ed. Mc. Graw Hill
7. Principles of Industrial Instrumentation by Patranabis D. TMH – 1997
8. Mechanical & Industrial Measurements by Jain R.K, Khanna Publishers – 1986
9. Process Instruments and control Hand book by Considine D.M, 4th ed, Mc.Graw Hill
10. Instrument Technology – Vol 1 by Jones E.B., Butterworths – 1981
11. Control Systems Engineering by Nagrath & M.Gopal, Wiley Eastern

12. Automatic Control Systems by B.C.Kuo, John Wiley, 2009
13. Modern Control Engineering by Katsuhiko Ogata, Prentice Hal

WASTE HEAT RECOVERY SYSTEMS
(ELECTIVE-IV)

Unit-I: Integrated Solid Waste Management:

Solid waste in history - Economics and solid waste - Legislation and regulations - Materials flow - Reduction - Reuse - Recycling-Recovery - Disposal of solid waste in landfills - Energy conversion - The need for integrated solid waste management - Special wastes.

Unit-II: Landfills:

Planning, siting, and permitting of landfills - Planning - Siting - Permitting - Landfill processes - Biological degradation - Leachate production - Gas production - Landfill design - Liners - Leachate collection - Treatment and disposal - Landfill gas collection and use - Geotechnical aspects of landfill design – Storm water management - Landfill cap - Landfill operations - Landfill equipment - Filling sequences - Daily cover - Monitoring - Post closure care and use of old landfills - Landfill mining.

Unit-III: Sources of Effluent from the Process of Industries:

Manufacturing process and sources of effluent from the process of industries like chemical - Fertilizer - Petroleum - Petrochemical - Paper - Sugar - Distillery - Textile - Tannery - Food processing - Dairy and steel manufacturing - Characteristics and composition of effluent and different methods of treatment & disposal of effluent for the following industries steel - Petroleum refineries - Textiles - Tanneries - Atomic energy plants and other mineral processing industries.

Unit-IV: Waste Water Treatment Methods:

Nitrification and de-nitrification - Phosphorous removal - Heavy metal removal - Membrane separation process - Air stripping and absorption processes - Special treatment methods - Disposal of treated waste.

Unit -V: Environmental Issues in Agriculture:

Types of farming systems - Agro meteorology - Water and nutrients requirement - Fertilizers: Types of fertilizers - Pesticides and other agrochemicals - Soil and water conservation practices.

Text Books:

1. Hand book of solid waste management and Waste Minimization Technologies. Nicholas P. Chermissionoff. An imprint of Elsevier, New Delhi (2003).
2. Solid Waste Engineering, P. AarneVesilind, William A. Worrell and Debra R. Reinhart. Thomason Asia Pte Ltd. Singapore (2002).
3. Industrial Solid Waste Management and Landfilling practice, M. Dutta, B. P. Parida, B. K. Guha and T. R. Surkrishnan.Narosa Publishing House, New Delhi(1999).
4. Design, Construction and Monitoring of Landfills, AmalenduBagchi.John Wiley and Sons. New York. (1994).
5. Environmental Pollution Control Engineering, C. S. Rao Wiley Eastern Ltd. New Delhi (1995).

Reference Books:

1. Industrial Waste Water Pollution Control, W. Wesley Eckenfelder Jr., McGraw-Hill, 2000.
2. Wastewater Treatment for Pollution Control, McGraw-Hill, Arceivala, S.J.,1998. .M.N.Rao & Datta, Waste Water Treatment, 3rd Edition, Oxford &IBH publishing Company Pvt Ltd.
3. Treatment of Industrial Effluent, Callegly, Forster and Stafferd, Hodder and Stonghton, 1988

GREEN ENERGY TECHNOLOGIES
(ELECTIVE-IV)

UNIT-I

INTRODUCTION:

SOLAR RADIATION: Role and potential of new and renewable sources, the solar energy option, Environmental impact of solar power, structure of the sun, the solar constant, sun-earth relationships, coordinate systems and coordinates of the sun, extraterrestrial and terrestrial solar radiation, solar radiation on titled surface, instruments for measuring solar radiation and sun shine, solar radiation data, numerical problems. Photo voltaic energy conversion – types of PV cells, I-V characteristics **SOLAR ENERGY COLLECTION**: Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis, advanced collectors.

UNIT – II

SOLAR ENERGY STORAGE AND APPLICATIONS: Different methods, sensible, latent heat and stratified storage, solar ponds, solar applications- solar heating/cooling technique, solar distillation and drying, solar cookers, central power tower concept and solar chimney.

WIND ENERGY: Sources and potentials, horizontal and vertical axis windmills, performance characteristics, betz criteria, types of winds, wind data measurement.

UNIT – III

BIO-MASS: Principles of bio-conversion, anaerobic/aerobic digestion, types of bio-gas digesters, gas yield, combustion characteristics of bio-gas, utilization for cooking, bio fuels, I.C. engine operation and economic aspects.

GEOTHERMAL ENERGY: Resources, types of wells, methods of harnessing the energy, potential in India.

OCEAN ENERGY: OTEC, Principles of utilization, setting of OTEC plants, thermodynamic cycles. Tidal and wave energy: Potential and conversion techniques, mini-hydel power plants, and their economics.

UNIT –IV

ENERGY EFFICIENT SYSTEMS:

ELECTRICAL SYSTEMS: Energy efficient motors, energy efficient lighting and control, selection of luminaire, variable voltage variable frequency drives (adjustable speed drives), controls for HVAC (heating, ventilation and air conditioning), demand site management.

MECHANICAL SYSTEMS: Fuel cells- principle, thermodynamic aspects, selection of fuels & working of various types of fuel cells, Environmental friendly and Energy efficient compressors and pumps**.**

UNIT-V

ENERGY EFFICIENT PROCESSES: Environmental impact of the current manufacturing practices and systems, benefits of green manufacturing systems, selection of recyclable and environment friendly materials in manufacturing, design and implementation of efficient and sustainable green production systems with examples like environmental friendly machining, vegetable based cutting fluids, alternate casting and joining techniques, zero waste manufacturing.

UNIT – VI

GREEN BUILDINGS: Definition, features and benefits. Sustainable site selection and planning of buildings for maximum comfort. Environmental friendly building materials like bamboo, timber, rammed earth, hollow blocks, lime & lime pozzolana cement, agro materials and industrial waste, Ferro cement and Ferro-concrete, alternate roofing systems, paints to reduce heat gain of the buildings. Energy management.

TEXT BOOKS:

1. Solar Energy – Principles of Thermal Collection and Storage/Sukhatme S.P. and J.K.Nayak/ TMH
2. Non-Conventional Energy Resources/ Khan B.H/ Tata McGraw Hill, New Delhi, 2006
3. Green Manufacturing Processes and Systems, Edited / J. Paulo Davim/Springer 2013

REFERENCES:

1. Alternative Building Materials and Technologies / K.S Jagadeesh, B.V Venkata Rama Reddy and K.S Nanjunda Rao/New age international
2. Principles of Solar Engineering / D.Yogi Goswami, Frank Krieth & John F Kreider / Taylor & Francis
3. Non-Conventional Energy / Ashok V Desai /New Age International (P) Ltd
4. Renewable Energy Technologies /Ramesh & Kumar /Narosa
5. Non conventional Energy Source/ G.D Roy/Standard Publishers
6. Renewable Energy Resources-2nd Edition/ J.Twidell and T. Weir/ BSP Books Pvt.Ltd
7. Fuel Cell Technology –Hand Book / Gregor Hoogers / BSP Books Pvt. Ltd.

I Year II Semester	THERMAL SYSTEMS LABORATORY	L	P	C
		0	3	2

List of Experiments:

1. Estimating the effect of sun tracking on the energy generation by PV modules.
2. a) Estimation of the average wind speed over a protracted period of with the help of an anemometer and data logger.

   b) Construction of a wind rose.

3. Measurement of lift and drag for Aerofoil's using wind tunnel
4. Evaluation of performance for multi pass shell and tube heat exchanger
5. Evaluation of performance of convergent divergent nozzle
6. Energy analysis of a boiler
7. Evaluation of HC, CO and NO_X emissions for a CI Engine
8. Energy auditing of steam power plant.
9. Performance evaluation of solar flat plate collector
10. Flow visualization study over objects in water flow channel
11. Generation of potential flow pattern over objects using Hele-Shaw Apparatus
12. Flow visualization in smoke tunnel
13. Studies on over expanded, correctly expanded and under expanded flows
14. Yaw effect on Pitot probe and Pitot-Static probe in compressible flows
15. Subsonic Jet Characteristics