Chemical Engineering

Curricula for M.Tech. in Renewable Energy
Offered by
Department of Chemical Engineering
June 2017

Semester 1

S. No	Code	Course Title	L	T	P	Total	Credit
01	REEN5101	Energy Resource	3	1	0	4	4
02	REEN5102	Renewable Energy I	3	1	0	4	4
03	REEN5103	Transport Processes	3	1	0	4	4
04	REEN5104	Materials for Energy conversion systems	3	1	0	4	4
05	REEN5141	Design of Heat Transfer Equipments	3	1	0	4	4
06	REEN5142	Research Methodology and Project Management	3	1	0	4	4
Total							**20**

LABORATORY

S. No	Code	Course Title	L	T	P	Total	Credit
01	REEN5111	Solar Laboratory	0	0	6	6	2
02	REEN5112	Energy Devices Laboratory	0	0	6	6	2
Total							**4**

SESSIONAL

S. No	Code	Course Title	L	T	P	Total	Credit
01	REEN5121	Seminar -I	0	0	3	3	1
Total							**1**
TOTAL CREDIT							**25**

Semester 2

S. No	Code	Course Title	L	T	P	H	Credit
01	REEN5201	Process Modelling and Simulation in Energy System	3	1	0	4	4
02	REEN5202	Advanced Engineering Thermodynamics	3	1	0	4	4
03	REEN5203	Renewable Energy II	3	1	0	4	4
	HMTS5201	Foundation Course on Finance, Economics & Marketing	3	1	0	4	4
	REEN5241	Measurement and Control for Energy System					
	REEN5242	Energy & Environmental Impact Analysis					
	REEN5243	Bio Energy					
05	REEN 5244	Electronics Instrumentation & Control for Energy System	3	1	0	4	4
Total							**20**

LABORATORY

S. No	Code	Course Title	L	T	P	H	Credit
01	REEN5211	Non solar laboratory	0	0	6	6	2
Total							**2**

SESSIONAL

S. No	Code	Course Title	L	T	P	H	Credit
01	REEN5221	Internship					
02	REEN5222	Seminar -II	0	0	3	3	3
Total							**3**
TOTAL CREDIT							**25**

Semester 3

S. No	Code	Course Title	L	T	P	H	Credit
01	REEN6101	Energy Management and Audit	3	1	0	4	4
02	REEN6102	Renewable Energy III	3	1	0	4	4
03	REEN6141	Energy Transmission Technology	3	1	0	4	4
	REEN6142	Energy Trading and Pricing					
	REEN6143	Energy Storage from Renewable Resources					
Total							**12**

LABORATORY

S. No	Code	Course Title	L	T	P	H	Credit
01	REEN6111	Renewable Energy Laboratory	0	0	6	6	2
Total							**2**

SESSIONAL

S. No	Code	Course Title	L	T	P	H	Credit
01	REEN6121	Thesis Part-I	0	0	14	14	6
Total							**6**
TOTAL CREDIT							**20**

Semester 4

S. No	Code	Course Title	L	T	P	H	Credit
01	REEN6221	Thesis Part-II	0	0	35	35	15
02	REEN6222	Comprehensive Viva-Voce					5
Total							**20**
TOTAL CREDIT							**20**

Chemical Engineering

M.TECH. PROGRAMME IN RENEWABLE ENERGY
OFFERED BY CHEMICAL ENGINEERING

SYLLABUS

June 2017

Semester I

THEORY

Subject Name: Energy Resources					
Paper Code: REEN5101					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Energy: Basic concepts and various forms; Fundamental of Renewable and Non-Renewable Energy Sources; Energy and Environment; Renewable Energy Resources and Present Energy Scenario in India; Sustainability of Development with Renewable Energy Resources; Basic Heat Transfer Mechanisms, Energy and Momentum Conservation Principles and Bernoulli's equation.
Inter-conversion of various forms of Energy and their utilisation in the appropriate perspective.

Module 2: [10L]
Solar Energy: Solar Radiation and its viable Magnitude of Energy Harvesting. Solar Energy Conversion Techniques to Heat and Electricity; Solar Radiation: flat Plate Collector; Solar Air Collector Solar Concentrator; Evacuated Tube Collector; Solar Water Heating system Solar Distillation; Solar Cooker; Non-convective Solar Pond; Solar House;
Photo-Voltaic (PV) Systems: : Introduction; Intrinsic and Extrinsic semiconductors and their role in PV Solar Cell development; Photo-Voltaic Materials and Photo-Voltaic Modules and their Applications

Module 3: [10L]
Biomass; Biofuels and Biogas: Introduction; Renewability and Sustainability of Bio-Energy Resources; Origin of Biomass: The photosynthetic process; Biomass Resources; Direct Use as Energy Resources, Biofuel production Processes; Biogas Production Processes; Alcoholic Fermentation and Alcohol blending with Gasoline for saving fossil fuel; Biodiesel Production through Transesterification of Vegetable oils and Fats;Hydro Power generation: Introduction; Classification of Water Turbine; Theory of Turbo- Machineries; Jet Velocity. Angular Velocity; Hydroelectric Systems: Essential Components and their Overall efficiencies; Merits and Demerits of Hydroelectric Systems; Hydraulic Machines; Status of Hydro-Power in the Indian Scenario.

Wind Power: Introduction; Origin and Global Distribution of Wind; Turbine Types and Terminologies, Aerodynamic principles in Wind Power Generation; and Wind Turbine Generators and their Applications;

Module 4: [10L]

Geo-Thermal Energy: Introduction: Origin and Renewability of Geo-Thermal Energy; Dry Rock and Hot Aquifier Analysis; Geo-Thermal Exploration and Energy Recovery Process; Geo- Thermal Heat Pump and Geo-Thermal Energy Scenario in India;

Ocean Thermal, Tidal & Wave Energy, Human & Animal Power Conversion Systems
Environmental Impact of Renewable Energy Harvesting Processes and Natural Energy Cycle- Contradictions
Energy Analysis from different types of Energy Resources, both Renewable and Fossil
Economic Analysis: Introduction; Cost Analysis, ash Flow Analysis Diagram, Cost Comparison of different Renewable Energy Resources; Payback period, Cost-Benefit Analysis.

Text Books:

1. Renewable Energy Resources, Basic Principle and Applications by G. N. Tiwari, M. K. Ghosal; Narosa Publishing House, 2005.

Reference Books:

1. Solar Energy: Fundamentals, Design, Modelling & Applications, by G. N. Tiwari; 2002. Narosa Publishing House, New Delhi.
2. Solar Engineering of Thermal Processes, by Duffie , . A. and Beckman, D. A., (1991.); John Wiley and Sons. New York.
3. Hand Book of Solar Radiation Data for India; Manni, A., (1980). Allied Publisher Pvt. Ltd., India.
4. Biogas Systems; principles and Applications, by Mittal K. M. ; 1996. New Age International (p) Ltd. Publishers, New Delhi, India

Subject Name: Renewable Energy I					
Paper Code: REEN5102					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Introduction: Sources of renewable energy –solar Energy. Earth sun energy flux diagram, overview of renewable energy, energy conversion, energy resource assessment: solar, solar thermal collectors, low temperature systems, solar heat pumps & refrigeration, concentrating collectors, overview of solar thermal power systems, photovoltaic energy conversion.

Module 2: [10L]
Solar Energy Resources: Solar radiation: spectrum of electromagnetic radiation, solar radiation data requirements, sun structure and characteristics, solar constant, spectral distribution, sun earth geometric relationship, solar angles, sun's trajectories in different seasons, zenith solar time, air mass, beam, diffuse and total solar radiation, irradiance, solar radiation on different surfaces at different angles, extraterrestrial radiation. Attenuation of solar radiation by the atmosphere, beam and diffuse components of hourly and daily radiation, clearness index. Measurement of solar radiation: Instruments-sunshine recorder, pyranometer, pyrheliometer, albedometer. Radiation measurement stations in India, solar radiation data, graphs.

Module 3: [10L]
Prediction of available solar radiation: models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components, solar mapping using satellite data, TMY(Typical meteorological year) data. Solar PV power plant: Basic of Solar Cell, Solar Module manufacturing Engineering, Solar PV Systems, Design of Standalone and Grid connected solar PV power plant, solar PV applications, and International test procedures for Photovoltaic Modules, Solar Thermal Systems, and Environmental Impact.

Module 4: [10L]
Solar thermal applications: Temperature & choice of collectors, swimming pool heating, domestic and process heat, characteristic equation, mathematical modelling, simulation, storage tank; (pressurized vs. non pressurized), storage with stratification, storage tank with gas as auxiliary, heat exchangers, corrosion and antifreeze, dimensioning, connecting pipe circuit, expansion tank sizing, concentrating collectors, process heat, air heating collectors, solar drying, solar distillation.

Text Books:

1. Renewable Energy Engineering and Technology – A Knowledge Compendium, ed. VVN Kishore (TERI Press*, 2008*).
2. CS Solanki: Solar Photovotaics – Fundamentals, Technologies and Applications, (PHI Learning)
3. D.Y. Goswami, F. Kreith and J.F. Kreider, Principles of solar Engineering, Tyalor and Francis, Philadelphia,2000.
4. A.Rabi, Active Solar Collectors and their applications, Oxford University Press, New York,1985

Reference Books:

1. JA Duffie and WA Beckman: Solar Engineering of Thermal Processes, Third Edition (John Wiley & Sons)
2. S Sukhatme and J Nayak: Solar Energy: Principles of Thermal Collection and Storage, Third Edition (Tata McGraw Hill, 2008)

Subject Name: Transport Processes					
Paper Code: REEN5103					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]

Review of vectors and tensors, Transport Theorem, introduction to momentum transfer, concept of continuum, viscosity and mechanisms of momentum transport, momentum flux, Newton's law of viscosity, shear stresses during laminar flow, Non-Newtonian fluids-Bingham model, Ostwald-de-Waele model, Eyring model, Reiner-Philippoff model, convective momentum transport, shell momentum balances and velocity profiles in laminar flow between flat plates, rectangular channels, circular tubes and pipes, annulus, flow around a sphere, continuity equation for both Newtonian and non-Newtonian fluids, flow of falling films with constant and variable viscosity, equations of continuity in Eulerian and Lagrangian form, equations of motion-Euler and Navier Stokes(rectangular, spherical and cylindrical coordinates), control volume approach, applications of these equations in steady and unsteady state problems, unsteady state laminar flow of Newtonian fluids in various geometries, concept of stream function and velocity potential, boundary layer theory (one and two-dimensional), velocity distributions in turbulent flow through ducts and circular tubes, momentum flux, application of Prandtl mixing length to turbulent flow, concept of Reynold's stresses, eddy viscosity, Reynold's averaged Navier Stokes equations, interphase transport, and concept of friction factor during flow through tubes, packed beds etc.

Module 2: [10L]

Modes of heat transfer, heat flux and Fourier's law of heat conduction, concept of thermal conductivity and diffusivity, shell energy balances and boundary conditions: heat sources: electrical, nuclear, viscous, chemical. Steady state heat conduction(one and two-dimensional) without heat generation for systems of different geometries e.g. composite walls, cylinders, spheres, having constant and variable thermal conductivities, conduction with generation: Poisson equation, conduction with temperature dependent generation, unsteady state heat conduction in finite and semi-infinite slabs (concept of distributed parameter and lumped parameter system)

Convection and Newton's law of cooling, heat transfer coefficient, different boundary conditions in the energy equations, cooling of a solid(lumped parameter system)forced and free convection, transpiration cooling, viscous flow and development of boundary layer, heat transfer in laminar flow through a tube, natural convection on a vertical plate , turbulent heat transfer in channels and pipe, temperature distributions in turbulent flow, temperature profiles near walls, turbulent heat flux, heat transfer through fins, countercurrent heat exchangers, boiling systems: Pool and nucleate boiling, condensation, phase change, Interphase energy transport, heat transfer coefficients, forced convection in tubes, around submerged objects and packed beds

Radiation Energy transfer: Properties of radiation, absorption, emission, and black body, properties of radiating surface, black body radiation: Plank's distribution law, Total emissive power: Stefan-Boltzman law, Wien's displacement law; Kirchoff's law; emissivity of black body, gray body and real body; radiation between surfaces: view factor, radiation heat exchange for three radiating surfaces; radiation heat transfer through absorbing emitting medium

Module 3: [10L]

Introduction to fundamentals of mass transfer, molecular mass transport, concept of diffusivity, Fick's law of diffusion, diffusion through stagnant gas film, falling film, diffusion with heterogeneous chemical reaction, equation of continuity for binary mixture, mass and molar transport by convection, concentration distributions in laminar flow, shell mass balances, boundary conditions, applications of diffusive transport with or without chemical reactions, absorption with or without chemical reaction, concentration distributions during unsteady state mass transport, steady state boundary layer theory for mass transport during flow through various geometries, concentration distributions in turbulent flow, interphase mass transport, concept of mass transfer coefficient, applications, mass transport in porous media and concept of Knudsen diffusion, mass transport across selectively permeable membranes, general advection- diffusion equations.

Module 4: [10L]

Analogies among momentum, heat and mass transfer, dimensional analysis, derivation of important dimensionless groups and significance of dimensionless groups in momentum, heat and mass transport, simultaneous mass, heat, momentum transfer and their industrial applications, e.g. applications of momentum heat and mass transport concepts for detailed design and analysis of cooling towers, distillation columns, absorbers, reactors, dryers, application of energy balance in solar cells, fuel cells, biogas generation etc, case studies of several plants e.g. thermal power plants, refineries, petrochemical industries, pharmaceutical industries, textile industries, desalination plants, effluent treatment units.

Text Books:

1. Transport Phenomena, 2nd ed., B.R. Bird, W. E. Stewart, and E. N. Lightfoot, John Wiley & Sons

Reference Book:

1. Analysis of transport phenomena, 2nd ed. , W.M. Deen, Oxford University Press
2. Fundamentals of Momentum, Heat and Mass Transfer, J. Welty, C.E.Wicks, G.L. Rorrer & R.E. Wilson
3. Fundamentals of Heat and Mass Transfer, 7th ed., T.L. Bergman, A.S. Lavine, F.P. Incropera, D.P.Dewitt, Wiley
4. Introduction to Transport Phenomena, S.C. Roy, C. Guha, Dhanpat Rai &Co.
5. Advanced Transport Phenomena, J.C. Slattery, The Press Syndicate of the University of Cambridge
6. Transport Phenomena Fundamentals, J.L. Plawsky, CRC Press

Subject Name: Materials for Energy Conversion Systems					
Paper Code: REEN5104					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Device fabrication technology: Diffusion, Ion Implantation, Etching, oxidation, photolithography, sputtering, physical vapour deposition (PVD), Chemical Vapor deposition(CVD), Plasma enhanced CVD (PECVD), Hot wire CVD (HWCVD), etc. Spectral response of solar cells, quantum efficiency analysis, dark conductivity, crystalline silicon deposition techniques, I-V characterization. Introduction to material characterization: Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), X-ray diffraction (XRD), Raman spectroscopy, Atomic force microscopy (AFM).

Module 2: [10L]
Introduction to physics of semiconductor devices and basics of solar cells, semiconductors as basis for solar cells materials and properties, P-N junction, sources of losses and prevention, Concepts on high efficiency solar cells, III-V high efficiency solar cells, tandem and multi-junction solar cells, Solar PV concentrator cells and systems, III-V, II-IV compound materials thin film solar cells, Nano, micro and poly-crystalline Si for solar cells, mono-micro silicon composite structure, material and solar cell characterization, PERL (passivated emitter with rear locally diffused) Si solar cell.

Module 3: [10L]
Advanced solar cell concepts and technologies (Porous Si layer transfer, metal induced crystallization etc.) Amorphous silicon thin film technologies, multi junction tandem solar cells, stacked solar cells. HIT Solar cells, 3rd Generation Solar cells based on Nano- materials.

Module 4: [10L]
Organic/ Inorganic / Plastic / Flexible solar cells, Polymer composites for solar cells. Dye sensitised solar cell. Perovskite and its application to the solar cell. Characterization of materials and devices for energy storage: Batteries, Carbon Nano Tubes (CNT), Ultra Capacitor for energy storage.

Text / Reference Books:

1. Solar cells: Operating principles, technology and system applications, by Martin A.Green, Prentice- Hall Inc, Englewood Cliffs, NJ, USA, 1981.
2. Semiconductor for solar cells, H.J. Moller, Artech House Inc, MA, USA, 1993.
3. Carbon nanotubes and related structures: New material for twenty-first century, P.J.F.Harris, Cambridge University Press, 1999.
4. Thin film crystalline silicon solar cells: Physics and technology, R.Brendel, Willy-VCH Weinheim 2003.
5. Clean electricity from photovoltaics, M.D.Archer, R. Hill, Imperial college press, 2001.
6. Organic photovoltaics: Concepts and realization, C. Barbec, V.Dyakonov, J.Parisi, N.S.Saricittci, Springer-Verlag 2003.
7. Battery technology handbook, edited by H.A. Kiehne, Marcel Dekker, New York, 1989.

Subject Name: Design of Heat Transfer Equipments					
Paper Code: REEN5141					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Fundamentals of heat transfer: steady state heat conduction through plane wall, composite wall, heat transfer resistance in series and parallel, conduction with heat generation, convective resistance, critical insulation thickness, steady state heat conduction through extended surface, fin efficiency, dimensionless number for convection, empirical correlation for free and forced convection. Correlation of heat transfer coefficient for condensation and boiling

Module 2: [10L]
Classifications of heat exchangers, overall heat transfer coefficient, LMTD and LMTD correction factor, fouling factors, Effectiveness and number of transfer unit of heat exchangers, sizing and rating problems of heat exchanger design. Flow and stress analysis: Effect of turbulence, friction factor, pressure loss, stress in tubes, header sheets and pressure vessels design, thermal stresses, shear stresses - types of failures.

Module 3: [10L]
Kern method of Heat Exchanger Design: Double-pipe heat exchanger, shell and tube heat exchanger, condenser and boiler design. Details of shell and tube heat exchanger construction. Design and construction of furnace, recuperator, regenerator and economiser. Heat exchanger network and its optimization.

Module 4: [10L]
Types of Compact heat exchanger, merits and demerits, design of compact heat, exchangers, plate type heat exchangers, performance influencing parameters, limitations, Design of surface and evaporative condensers, cooling tower, performance characteristics.

Text/ Reference Book:
1. Process Heat transfer by D.Q. Kern Tata McGraw-Hill Education, 1997
2. Arthur. P Frass, Heat Exchanger Design, John Wiley & Sons, 1988
3. Taborek.T, Hewitt.G.F and Afgan.N, Heat Exchangers, Theory and Practice, McGraw-Hill Book Co. 1980.
4. Fundamentals of Heat Exchangers Design by Ramesh K. Shah and Dusˇan P. Sekulic John Wiley & Sons, Inc., 2003

Subject Name: Research Methodology and Project Management					
Paper Code: REEN5142					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Meaning of Research, Types of Research, process of Research, Formulation of Research Problem and Development of Research Hypotheses, Data Collection — Primary and Secondary Data, Types of Measurement Scale, Sample Designing, Sampling vs. Non sampling Error, Different types of Sample designing, Determination of Sample Size. Testing of Hypotheses, Null and Alternate hypothesis, One tailed and two –tailed test, Type I and Type II error, Steps in Testing Hypothesis, Level of Significance and Critical region, Z test, t Test, P Test, ANOVA, Correlation and Regression Analysis, Chi – Square test.

Module 2: [10L]
Concepts of a Project, Characteristics of a Project, Project Life Cycle Phases, Difference between Project Management and Functional Management, Roles and Responsibilities of a Project Manager, Matrix organization of a Project.

Module 3: [10L]
Project Appraisal: DPR - Technical, Marketing, Environment, Social, Financial Appraisal [Non Discounted Cash Flow Technique like Payback and Accounting Rate of return (ARR); Discounted Cash Flow technique like Profitability Index (P/I) or Benefit Cost ratio (BCR), Net Present Value (NPV), Internal Rate of return (IRR)]

Module 4: [10L]
Project Planning, Work Breakdown Structure (WBS), Networking Concepts, Network Analysis, Difference between PERT and CPM, Calculation of Floats, Concept of Crashing, Gantt Chart, LOB.
Case Study on Project Management

Text/ Reference Book:

1. Research Methodology Concepts and Cases by Chawla & Sondhi, Vikas Publishing House.
2. Project Management by S Choudhury, TMH Projects: Planning, Analysis, Selection, Implementation & Review by Prasanna Chandra, TIvll-l

LABORATORY

Subject Name: Solar Laboratory					
Paper Code: REEN5111					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**6**	**6**	**2**

Experiments:

At least any five experiments are to be carried out by students

1. Solar radiation measurement
2. Figure of Merit measurement of solar cell
3. Impact of Figure of Merit on energy output of solar cell
4. Characteristics of storage battery
5. Characteristics of power conditioning unit
6. Development of material for energy storage component
7. Development of black coating for solar thermal application

Subject Name: Energy Devices Laboratory					
Paper Code: REEN5112					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**6**	**6**	**2**

Experiments:

At least any five experiments are to be carried out by students

1. Introduction to material characterization: Scanning electron microscopy (SEM)
2. Transmission electron microscopy (TEM)
3. X-ray diffraction (XRD),
4. Chemical vapor deposition (CVD),
5. Fabrication of Solar cell in virtual wafer fabrication lab
6. Study of 100KW PV power plant, (Roof top of A & B Building)
7. Measurement of emissivity, reflectivity, transitivity of Solar irradiation.

Subject Name: Seminar -I					
Paper Code: REEN5121					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**3**	**3**	**2**

A Seminar topic will be allotted to individual student according to his/her subject of interest. A thorough report should be prepared based on which seminar presentation and question-answer session will be conducted. Assessment of the student would be done by the faculty members on the basis of presentation, performance in the question - answer session and the report submitted.

Semester II

THEORY

Subject Name: Process Modelling and Simulation in Energy System					
Paper Code: REEN5201					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Introduction to system. Deterministic process and stochastic process, Concept of Physical modeling and mathematical modeling. Uses of mathematical models in Chemical Engineering, Concept of simulation and process analysis.

Lumped and distributed parameters models. Modeling of simple hydraulic tank, enclosed vessel, mixing vessel, simultaneous mass and energy balance, Continuous heating in a stirred tank using jacket and using coil. Modeling of cone-shaped tank.

Module 2: [10L]
Transient Conduction. Modeling of Heat and Mass Transfer: Modeling of Forced Convection across flat plate, cylinder, sphere and tube bundles. Modeling of Free Convection. Modeling of Boiling and Condensation. Modeling of Radiation Systems.

Module 3: [10L]
Thermal modeling in CSTR – ordinary differential equations and boundary conditions, nonlinearity in models, Plug Flow Reactors – partial differential equations and boundary conditions. Modeling temperature profile in double tube Heat exchangers for concurrent and counter current flow . Modeling of Evaporators – mass and enthalpy balance in a single effect evaporator, heating area calculation, calculation of steam consumption and steam economy.

Module 4: [10L]
Basic Modeling of Alternate energy systems – Energy balance equations used in modeling Solar Thermal domestic hot water system and single Solar PV cell ; Mass transfer models used in fuel cell - Fickian, Stefan–Maxwell and Dusty Gas Model for porous media and in porosity free domain.

Text/ Reference Book/ Literature:

1. Heat Transfer – A Basic Approach, M. Necati Ozisik, McGraw-Hill.
2. Solar energy – S.P.Sukhatme – Tata McGraw Hill
3. Fuel Cells: From Fundamentals to Applications - Supramaniam Srinivasan –Springer

Subject Name: Advanced Engineering Thermodynamics					
Paper Code: REEN5202					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Concept of Macroscopic approach to thermodynamics, path and point functions. Intensive and extensive property, thermodynamic system and their types. Thermodynamic Equilibrium State. Quasi-static, reversible and irreversible processes. Heat and work transfer, definition and comparison, sign convention. Displacement work and other modes of work. p-v diagram. Application of First law of thermodynamics to closed and open systems – steady and unsteady flow processes. Steady flow energy equation applied to nozzle, diffuser, boiler, turbine, compressor, pump, heat exchanger.

Module 2: [10L]
Heat Reservoir, source and sink. Heat Engine, Refrigerator, Heat pump, Equivalence of second law statements and its corollaries. Concept of entropy from Carnot Cycle, Clausius inequality. T- s diagram, Tds Equations, entropy change for - pure substance, ideal gases - different processes, principle of increase in entropy. Applications of 2^{nd} Law of thermodynamics. High and low grade energy. Available and non-available energy of a source and finite body. Anergy and irreversibility. Expressions for the anergy of a closed system and open systems. Exergy destruction in heat transfer process, exergy of finite heat capacity body, exergy of closed and steady flow system; 1^{st} and 2^{nd} law Efficiency.

Module 3: [10L]
Properties of Ideal gas- Ideal and real gas comparison- Equations of state for ideal and real gases- Reduced properties-.Compressibility factor-.Principle of Corresponding states. - Generalised Compressibility Chart and its use-. Maxwell relations, Fundamental property relations, Throttling and Joule-Thomson Coefficient, Clausius Clapeyron equation. Formation of steam and its thermodynamic properties, p-v, p-T, T-v, T-s, h-s diagrams. p-v-T surface. Use of Steam Table and Mollier Chart. Determination of dryness fraction.

Thermochemistry: Enthalpy, Heat of reaction at constant pressure and volume, Hess's Law of constant heat summation , reaction equilibirum, temperature pressure effect on reaction equibrium, Heat of combustion, Adiabatic flame temperature, material and energy balance of combustion reaction.

Module 4: [10L]

Vapor Power cycles: Carnot vapor cycle, Rankine cycle, comparison of Carnot and Rankine cycle, calculation of cycle efficiencies, variables affecting efficiency of Rankine cycle, reheat cycle, regenerative cycle, reheat-regenerative cycle, Gas Power cycles: Otto and Diesel cycle, Dual cycle, Comparison of Otto, Diesel and Dual cycles, air standard efficiency, mean effective pressure, brake thermal efficiency, relative efficiency, Brayton cycle, effect of reheat, regeneration, intercooling and turbine and compressor efficiency on Brayton cycle, Vapor compression Refrigeration cycle, COP of refrigeration cycle

Text/ Reference Book:

1. Engineering Thermodynamics by P.K. Nag, McGraw-Hill Education
2. Fundamentals of Thermodynamics by Borgnakke & Sonntag, 7th Ed. Wiley India (P) Ltd.
3. Thermodynamics – An Engineering Approach by Yunus Cengel & Boles, McGraw-Hill Education
4. Engineering Thermodynamics by Gordon Rogers and Yon Mayhew, Pearson Education Ltd.
5. Thermodynamics by C.P Arora, Tata McGraw-Hill, New Delhi, 2003.

Subject Name: Renewable Energy II					
Paper Code: REEN5203					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Wind Energy: Sources and potential; Wind turbines-Site location, aerodynamics, types and construction fundamentals; Wind Energy Conversion Systems; Wind-Diesel hybrid systems; Wind-energy storage; Environmental aspects
Geothermal Energy: Sources and potential; Origin and Distribution; Hydrothermal Resources-Vapour dominated System, Liquid dominated system, Geo-pressured resources, Hot Dry Rock Resources; Analysis of geothermal resources-Hot Dry Rock Resource, Hot Aquifer Resource; Exploration and development; Environmental aspects; Potential in India.

Module 2: [10L]
Tidal Energy-Origin and Nature; Limitations; Tidal Range Power; Conversion Schemes; Present status; Environmental impacts Wave Energy-Power in waves; Wave Energy Technology-Heaving Float type, Pitching type, Heaving and Pitching-float type; Present status and Environmental impacts Ocean Thermal Energy-Origin and characteristics; Ocean Thermal Energy Conversion technology; Present status and Environmental impacts

Module 3: [10L]
Macro Hydel Power - Characteristics of hydropower plants ; Demand profiles and System considerations; Mathematical modelling of hydropower systems; Theory of hydraulic design and hydraulic turbines ―Selection of turbine types , Francis turbines, Pelton turbines, Kaplan turbines; Efficiency measurements, Regulators and load control, Valves and gates, Auxiliary equipment; Design strategies for hydraulic structures― Headworks and intakes, Spillways and outlets, Penstocks and conduits
Mini Hydel Power - Advantages and disadvantages; Layout of a Micro-Hydro Scheme; Water turbines-classification, characteristics and selection; Generators; Present status and environmental impacts

Module 4: [10L]
Magneto-Hydrodynamic (MHD) Power Conversion-Basic principle; MHD generator; MHD systems; Present status and Potential
Thermo-electric and Thermionic Power Conversion Systems-Basic principle; Present status and Potential Fuel Cell (FC)-potential applications; Classification; Types-PAFC, AFC, PEMFC, MCFC, SOFC; Fuel Cell development stages and relative performance; Fuels for FC; Efficiency and VI characteristics; FC power plant; Present status and environmental Impacts
Hydrogen Energy-potential applications; Production methods: thermo-chemical, electrolysis, thermolysis, bio-photolysis; Storage and Delivery; Conversion; Safety Issues; Present status

Text Book:

1. Non-Conventional Energy Sources-G.D. Rai, Khanna Publishers
2. Renewable Energy Resources Twidell & Wier, CRC Press (Taylor & Francis)

Reference Book:

1. Renewable Energy Resources-Tiwari & Ghosal, Narosa Publishers
2. Renewable Energy Technologies-Ramesh & Kumar, Narosa Publishers
3. Non-Conventional Energy Systems-K Mittal, Wheeler
4. Renewable Energy Sources and Emerging Technologies-Kothari & Singhal, Prentice Hall of India
5. Non-Conventional Energy Resources-B.H. Khan, McGraw Hill Education (India) Private Limit
6. Hydro-electric and Pumped Storage Plants – M G Jog, New Age International Publishers Foundation Course on Finance, Economics and Marketing

Subject Name: Foundation Course on Finance, Economics & Marketing					
Paper Code: HMTS5201					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Introduction, Scope & Objectives of basic financial concepts – Interference of Finance Department with other areas of business; Time value of money and Cost of Capital; Project Appraisal - Pay-back period, Internal Rate of Return, Net Present Value, Cost-Benefit Analysis; Sources of Finance - Internal and External – Short Term & Long Term – Securities, Debentures/bonds & Shares; Financial Institutions & Markets – Primary & Secondary Market, Money and Capital Market

Module 2: [10L]
Accounting System - Financial Statements, Types – Ledger, Cash Flow Statement, Profit & Loss Account, Balance Sheet; Financial Statement Analysis – Liquidity, Leverage, Activity, Profitability and Ratio; Trend & Du Pont Analysis.

Module 3: [10L]
Concepts and its evolution, Marketing Mix; Market Analysis and Selection: Marketing Environment-impact on marketing decisions, Market Segmentation and Product Positioning; Distribution Channels and Physical Distribution Decisions: Nature, Functions and Types of Distribution Channels, Channels Management Decisions; Promotion Decisions: Communication Process, Promotion Mix- Advertising, Personal Selling , Publicity and Public Relations.

Module 4: [10L]
Introduction, Demand & Supply Analysis, Determinants of Demand, Laws of Demand, Elasticity of Demand, Demand Forecasting, Laws of Supply, Elasticity of Supply, Cost Concepts, Cost Curves, short run and long run, Break Even Analysis, Pricing Concepts, Price Determination. National Income, Concepts & Measurement, GDP, GNP, Methods of measuring national income, Inflation & Deflation, Unemployment.

Text/ Reference Book:

1. Financial Management: Theory and Practice; Prasanna Chandra, McGraw Hill.
2. Financial Management: I.M. Pandey; Vikas Publishing House Pvt. Ltd.
3. Managerial Economics by Suma Damodaran; Oxford University Press.
4. Marketing Management: Analysis, Planning, Implementation, and Control by PhilipKotler; Prentice Hall.
5. Marketing Management by Rajan Saxena; Tata McGraw Hill.

Subject Name: Measurement and Control for Energy System					
Paper Code: REEN5241					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Introduction to measurements, Errors in measurements, Statistical analysis of data, Regression analysis, correlation, estimation of uncertainty and presentation of data, design of experiments – Experimental design factors and protocols

Module 2: [10L]
Basic Electrical measurements, Transducers and its types, Signal conditioning and processing - Measurement of temperature, pressure, velocity, flow rate, thermo-physical and transport properties of solids liquids and gases, radiation properties of surfaces, vibration and noise - Computer assisted data acquisition, data manipulation and data presentation

Module 3: [10L]
Introduction, Open and closed loop control systems, Transfer function. Types of feedback and feedback control system characteristics – Effect of disturbances – dynamic characteristics Designing of temperature, pressure, flow and liquid level measurement and control system – Performance – Steady state accuracy – Transient response – Frequency response – Fault finding– Computer based controls

Module 4: [10L]
Process characteristics, Control system parameters – DC and AC servomotors, servo amplifier, potentiometer, synchro transmitters, synchro receivers, synchro control transformer, stepper motors - Continuous, Discontinuous and Composite control modes – Analog and Digital controllers

Text/ Reference Book:

1. Holman, J.P. Experimental methods for Engineers, McGraw – Hill, 2008
2. W. Bolten, Industrial Control and Instrumentation, University Press, 2004
3. Alan S Morris, Reza Langari, Measurements and Instrumentation – Theory and Application, Elsevier Inc, 2012.
4. S.P. Venkateshan, Mechanical Measurements, Ane Books Pvt Ltd, 2010
5. Curtis D Johnson, Process Control Instrumentation Technology, PHI Learning Private Limited,2011.

Subject Name: Energy & Environmental Impact Analysis					
Paper Code: REEN5242					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Basics of environmental problems associated with Renewable Energy Engineering. Sustainable technology and Renewable Energy Engineering, Genesis of environmental statutory body in India (Water act 1974). Legislative aspects, Environmental clearance for Renewable Energy Industries—Consent to Establish, Consent to Operate. Environmental standards and Threshold limits, EPA 1986
Air pollution aspects from conventional power plants, Sampling and analysis of air pollutants, Green house effect and global warming, Carbon foot print, general discussion on its reduction by the use of renewable energy devices.

Module 2: [10L]
Problems of water pollution in renewable energy industries. Effluent treatment plant, trickling filter, RBDC and RBRC, oxidation ditches, WSP, Root zone and Reed bed treatments. Combined Sewage & Effluent treatment plant along with canteen waste for bio-gas generation.

Module 3: [10L]
Solid waste & E-waste management in Renewable Energy Industries**:** Sources and classification,
public health aspects, Methods of collection and disposal methods. Recycling and reuse of components of renewable energy devices. Hazardous aspects associated with solar PV, Solar thermal, Hydro-power, Nuclear Power, Wind mill, OTEC, Geothermal energy, Bio-energy –case studies.

Module 4: [10L]
Environmental Impact Assessment for renewable energy industries– Rain water harvesting, structural hazards.hazards associated with illumination engineering – CFL versus LED lights. Energy analysis and energy efficiency compliances.
Case studies on use of renewable energy devices for reducing carbon foot print- Analysis of energy saving using solar PV and hybrid system—desalination, hot water production, sewage treatment in vehicular system, solar passive architecture and green building. Carbon trading, sequestration and carbon credit.

Text/ Reference Book/ Literature:
1. Renewable Energy Resources—Basic Principles and Applications, Tiwari, G N & Ghosal, M K , Narosa Publishing House, New Delhi 2006
2. Standard Methods: APHA & AWWA, 21st edition, 2005
3. CPHEEO Manual 2015, GOI Publications

4. www.wbpcb.gov.in
5. Solar Energy Materials and Solar Cells, Volume 94, Issue 9, Pages 1429-1552, September 2010, Bibek Bandyopadhyay and K L. Chopra, Elsevier

Subject Name: Bio Energy					
Paper Code: REEN5243					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Introduction to biomass; Basic photosynthesis process: C3 and C4 plants on biomass production; classification of biomass; conversion of biomass into fuels; physicochemical characteristics of biomass as fuel; CO_2 fixation potential of biomass, Biomass resource assessment, application of remote sensing for resource assessment; biomass productivity study, energy plantation; basis of selection of plants for energy plantation; potential of biomass as energy sources: Worldwide and India.
Energy from waste: characterisation and classification of waste as fuel – agrobased, forest residues, industrial waste, Municipal solid waste. Waste to energy options: combustion (unprocessed and processed fuel), gasification, anaerobic digestion, fermentation, and pyrolysis.

Module 2: [10L]
Anaerobic digestion, biogas production mechanism and technology, types of digesters, design of biogas plants, installation, operation and maintenance of biogas plants, biogas slurry utilization and management, biogas applications, cost benefit analysis of biogas for cooking, lighting, power generation applications, Feedstock for biogas, Microbial and biochemical aspects, operating parameters for biogas production. Kinetics and mechanism, Bio-hydrogen production: hydrolysis, fermentation.
Landfills: Gas generation and collection in landfills, Introduction to transfer stations. Comparison with non-energy options like Vermiculture, Composting, and case studies.

Module 3: [10L]
Bio-fuels different processes of production, different generation of bio-fuel: based on raw material used. Biodiesel production, different types of raw materials, non-edible oil-seeds, Pyrolysis, mechanism of transesterification, fuel characteristics of biodiesel; Alcohol production: types of raw materials, lignocellulosic biomass for alcohol production, process description, distillation etc.

Module 4: [10L]
Introduction to bioreactor, anaerobic digesters, fluidized bed, airlift reactor, conversion devices: combustors (Spreader Stokes, Moving grate type, fluidized bed), gasifier, digesters. Briqueting technology: Production of RDF and briquetted fuel. High rate digesters for industrial waste water treatment, Photo-bioreactors: raceway pond, tubular, flat panel, helical etc. numerical problems

Text/ Reference Book:

1. Tom B Reed, Biomass Gasification – Principles and Technology, Noyce Data Corporation, 1981
2. David Boyles, Bio Energy Technology Thermodynamics and costs, Ellis Hoknood Chichester,1984.
3. Khandelwal KC, Mahdi SS, Biogas Technology – A Practical Handbook, Tata McGrawHill, 1986
4. Mahaeswari, R.C. Bio Energy for Rural Energisation, Concepts Publication,1997
5. Best Practises Manual for Biomass Briquetting, I R E D A, 1997
6. Eriksson S. and M. Prior, The briquetting of Agricultural wastes for fuel, FAO Energy and Environment paper, 1990
7. Iyer PVR et al, Thermochemical Characterization of Biomass, M N E S

LABORATORY

Subject Name: Non-Solar Laboratory					
Paper Code: REEN5211					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**6**	**6**	**2**

Experiments:

At least any five experiments are to be carried out by students

1. Experiments on biomass gasification
2. Extraction of Bio-oil from biomass feedstock
3. Development of fuel characteristics from bomb calorimeter.
4. Characterization of energy from waste
5. Experiments on biomass resource assessment
6. Measurement of figure of merit of Wind Energy

SESSIONAL

Subject Name: Internship					
Paper Code: REEN5221					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**0**	**0**	**2**

Students will be sent for training to an industry for a period of 4 to 6 weeks after completion of 1st Semester examination. After completion of the training the students will submit a comprehensive report consisting of general overview of the plant, process description of with process flow diagram, details of different equipments with specifications, process instrumentation and control, product with production capacity, raw materials utility and energy consumed per unit of product**.** Assessment would be made on the basis of the submitted report and the viva voce examination conducted by a board of examiners constituted by the Departmental Academic Committee consisting of two faculty members and training coordinator with Head of the Department as Chairman during 2nd Semester examination.

Subject Name: Seminar -II					
Paper Code: REEN5222					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**3**	**3**	**2**

A Seminar topic will be allotted to individual student according to his/her subject of interest. The seminar topic must be different from the topic already presented in Seminar-I. Topic of the seminar should not be on internship training. A thorough report should be prepared based on which seminar presentation and question- answer session will be conducted. Assessment of the student would be done by the faculty members on the basis of presentation, performance in the question - answer session and the report submitted.

Semester III

THEORY

Subject Name: Energy Management and Audit					
Paper Code: REEN6101					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
General Philosophy and need of Energy Audit and Management. Definition and Objective of Energy Management, General Principles of Energy Management, Energy Management Skills, Energy Management Strategy. Energy Audit: Need, Types, Methodology and Approach. Energy Management Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution.

Module 2: [10L]
Procedures and Techniques:
Data gathering: Level of responsibilities, energy sources, control of energy and uses of energy get Facts, figures and impression about energy /fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering.
Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation.
Evaluation of saving opportunities: Determining the savings in Rs, Noneconomic factors, Conservation opportunities, estimating cost of implementation.
Energy Audit Reporting: The plant energy study report- Importance, contents, effective organization, report writing and presentation.

Module 3: [10L]
Energy Policy Planning and Implementation:
Key Elements: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation.
Format and Ratification, Organizing: Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability. Motivating–Motivation of employees, Requirements for Energy Action Planning. Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning.

Module 4: [10L]
Energy Balance & MIS:
First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses,

Improvements. Energy Balance sheet and Management Information System (MIS) Energy Modeling and Optimization.

Energy Audit Instruments: Instruments for Audit and Monitoring Energy and Energy Savings, Types and Accuracy

Text/ Reference Books:

1. Energy Management: W.R.Murphy, G.Mckay (Butterworths).
2. Energy Management Principles: C.B.Smith (Pergamon Press).
3. Efficient Use of Energy : I.G.C.Dryden (Butterworth Scientific)
4. Energy Economics -A.V.Desai (Wieley Eastern)
5. Industrial Energy Conservation : D.A. Reay (Pergammon Press)
6. Industrial Energy Management and Utilization – L.C. Witte, P.S. Schmidt, D.R. Brown (Hemisphere Publication, Washington)

Subject Name: Renewable Energy III					
Paper Code: REEN6102					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Water Resources & Hydro Planning: Categorization, development and purposes of water resources, Classification of hydro projects, Small Hydro Power (SHP) development and its relevance, allotment of sites, opportunities; hydropower planning on existing structures and new sites; Different methods for stream gauging, rainfall, runoff and its estimation by different methods, peak flood estimation, demonstration of discharge measuring instruments ; Flow duration studies, assessment of power potential and optimisation of installed capacity; Topographical, geological and power evacuation surveys and investigations, demonstration of surveying instruments, site selection for SHP and other projects;Financing of projects, cost estimation for different components, financial and economic analysis,valuation of Hydro Assets, clean development mechanism, management of Hydro plants.

Module 2: [10L]
Design of SHP and other Hydro Structures: Hydraulics and structural designs of civil works, national and international standards and codes of practice, diversion works and intake structures, site selection, innovative designs; Power house layouts , channel (lined and unlined), under drainage works, tunnels and tail race channel; Sediment properties and transport, desilting devices, silt disposal; Cross drainage works; Balancing reservoir, spillway and forebay tank;Penstock, anchor block and saddle, surge tank; Power house buildings, material handling, machine foundation,Seismolgical consideration.

Module 3: [10L]
Electro Mechanical Hydro Equipments: Types, characteristics and testing of ac generators; Sizing and specification of single and three phase generators ; Power factor and its correction methodologies, excitation systems; Electro-mechanical and digital governor, electronic load controller ; Types of relays, contactors and control schemes for hydro stations; Supervisory control and data acquisition (SCADA), integrated computer control system ; Switchyard equipments, power and instrument transformers, circuit breakers, bus-bar; Protection schemes for generator, transformer and bus-bar, design of circuit diagram for auxiliary and grounding systems.

Module 4: [10L]
Classification and working principles of hydro turbines, different components of impulse and reaction turbines; Design concepts of hydro turbines, pump-as-turbine and other non conventional hydro turbines; Characteristics of hydro turbines, geometric similarity, main characteristic and operating characteristic curves, hill curves; Governing of hydro turbines,

mechanical and electro-mechanical governors, electronic load controller, mechanical drives, gear box, pulleys ; Selection of hydro turbines; Classification, components and selection of gates and valves; Model testing of hydro turbines, performance testing of turbines at site; Causes and impact of cavitation, silt erosion and their combined effect on operation of hydro turbines; Erection, commissioning, operation and maintenance of turbines.

Text/ Reference Book/ Literature:

1. Nigam, P.S., "Handbook of Hydroelectric Engineering", Nem Chand and Brothers.
2. Clemen, D.M., "Hydro Plant Electrical Systems", HCI Publication.
3. Kundur, P., "Power System Stability and Control", McGraw Hill Inc.
4. Fritz, J.J., "Small and Mini Hydro Power Systems: Resource Assessment and Project Feasibility", McGraw Hills.
5. Gulliver, J.S. and Arndt, E.A., "Handbook of Hydro Electric Engineering", McGrawHills.
6. Varshney, R.S., "Hydropower Structures", Nem Chand and Brothers.

Subject Name: Energy Transmission Technology					
Paper Code: REEN6141					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Introduction to DC-DC converter, Control strategies, Types of DC choppers and its classification, Brief idea about Buck, Boost and Buck-Boost chopper.
Introduction to inverters, Classification of inverters, Principle of operation of single phase and three phase bridge inverter with R and R-L loads.

Module 2: [10L]
Introduction of Smart Grid. Application of smart Grid. Capabilities of Smart Grid, Phasor measurement Unit. Communication technologies for the Smart Grid. Wide area monitoring System. Automatic Meter reading System. Basic concept of demand side planning. Concept of Micro-Grid.

Module 3: [10L]
Overhead Transmission Line: Choice of frequency & voltage, Types of Conductors, Line Resistance, Inductance and Capacitance of single phase and three phase overhead lines. Influence of earth on conductor capacitance. Basic concept of Transmission Tower, Insulators, Spacer, Damper.

Module 4: [10L]
Transmission System: Short, Medium (nominal T and π) and Long transmission lines (equivalent T and π) and their representation. ABCD constants. Concept of HVAC-HVDC transmission system.
Distribution Systems: Introduction of Distributing System. Radial and Ring main systems. D.C. Three-wire system. Different types of distributors. Method of calculations. A.C. Distributors with Concentrated loads.

Text/ Reference Book:

1. Elements of power system analysis, C.L. Wadhwa, New Age International
2. Electrical Power System, Ashfaq Hussain, CBS Publishers & Distributors
3. Power Electronics, P.S Bimbhra, Khanna Publishers
4. Smart Grid Technology and Applications, Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Nick Jenkins, Wiley Publications.
5. A Text book on Power system Engineering, Soni, Gupta, Bhatnagar & Chakrabarti, Dhanpat Rai & Co.
6. Power Electronics: Circuits, Devices and Applications (English) 3rd Edition, M.H Rashid, Pearson, India.

Subject Name: Energy Trading and Pricing					
Paper Code: REEN6142					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**1**	**0**	**4**	**4**

Module 1: [10L]
Overview of Energy Markets & Pricing: Integrated framework for Energy Pricing, Basic Pricing Principles, Short run and Long run Marginal Cost Pricing, Peak load &seasonal Pricing, Energy Prices and Markets, Prices of Exhaustible Energy Resources, Economic Regulation of Energy Markets, Drivers of Energy Demand, Concept of Energy Intensity & Energy Elasticity, Statistical tools & techniques for scenario forecasting, Interpretation of results & Policy implications.

Module 2: [10L]
Energy Trading: Renewable Energy Guidelines of Central Regulatory Energy Commission & State Policies, Power Purchase Agreement framework, Modelling for determining Feed in Tariff for Power Producers and Utilities, Peak Power Trading ,Regional Load Despatch Centres, Renewable Energy Credit mechanism, Cost benefit of selecting Feed in tariff as against REC route for Power Producers, Outlook for REC Demand & Pricing, Interventions by the Government for stimulating REC Offtakes & Price, Indian Energy Exchange ,International Platforms for Energy Trading, Energy Futures, Crude and Natural Gas Pricing & Futures, Risk Management in Energy Trading.

Module 3: [10L]
Investment in Energy Resources: Levelized cost of Energy Resources, Financial and Economic analysis of Energy Technologies, Private and Social Costs, Cash Flow Projections and Discounting, Enterprise Valuation of Renewable Energy Assets, Funding options, Case Studies on Acquisition and Disinvestment of Renewable Energy Assets, Risk Return analysis for Renewable Energy Assets, RE Portfolio for Risk mitigation & Hedging.

Module 4: [10L]
Energy Modelling, Planning and Policy Evolution: Concepts in Modelling Energy Resources, Review of various Energy Sector Models, Energy Modelling in the context of Climate Change, Key developments and Evolution of Energy Policies in India, Environmental concerns and Regulatory framework, Reforms outlook.

Text/ Reference Book/ Literature:

1. Cooper, John C.B.(2003):"Price elasticity of demand for crude oil: estimates for 23 countries," OPEC Review, 27:1-8.
2. Bohi, D.P. (1981): Analyzing Demand Behavior: A Study of Energy Elasticities, Johns Hopkins University Press.
3. Haider, Ghazi M. (2000):"World oil reserves: Problems in definition and estimation," OPEC Review, 24: 305-327.
4. Adelman, M.A. (2002):"World Oil Production and Prices 1947-2000,"The Quarterly Review of Economics and Finance, 42: 169-191.
5. Barretto,L.,A.Makihiraand,K.Riahi(2003):"The hydrogen economy in the 21st century: a sustainable development scenario," International Journal of Hydrogen Energy, 28: 267-284.
6. Bentley, R.W. (2002):"Global oil & gas depletion: an overview," Energy Policy, 30:189-205.

‘

LABORATORY

Subject Name: Renewable Energy Laboratory					
Paper Code: REEN6111					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**6**	**6**	**2**

Experiments:

At least any five experiments are to be carried out by students

1. Study on thermal performance and efficiency of biomass downdraft gasifier;
2. Sampling and analysis of air and flue gas from biomass energy systems (i.e. gasifier, combustor and cook stoves) using gas chromatography technique;
3. Biogas production by anaerobic digestion and analysis;
4. Fuel Cell operation and electrical power generation;
5. Wind Tunnel: Pressure distribution analysis;
6. Performance analysis of an Electrical Inverter
7. Measurement of power factor and load characteristics of Power generator
8. Air conditioning performance test
9. Refrigeration performance test & COP measurement
10. Step-up and step-down Transformer Characteristics

SESSIONAL

Subject Name: Thesis Part-I					
Paper Code: REEN6121					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**14**	**14**	**6**

Each student shall be required under the supervision of a faculty/ joint supervision of a faculty and an external expert to prepare a project work after carrying out investigation on an industrial research problem. The research work has to be carried out by the student himself occasionally consulting his supervisor(s). The work has to be allotted to the student at the beginning of the 3rd semester indicating the work to be carried out by the student. The report in duplicate has to be submitted in typed and bound form 7 days before commencement of the 3rd semester examination. Assessment would be made on the basis of the submitted report and the viva voce examination conducted by a board of examiners constituted by the Departmental Academic Committee consisting of two faculty members and the supervisor and an external examiner with Head of the Department as Chairman during 3rd Semester examination.

Semester IV

SESSIONAL

Subject Name: Thesis Part-II					
Paper Code: REEN6221					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**35**	**35**	**15**

Each student shall be required under the supervision of a faculty / joint supervision of a faculty and an external expert to prepare a project work after carrying out investigation on an industrial research problem. The research work has to be carried out by the student himself occasionally consulting his supervisor(s). The work has to be allotted to the student at the beginning of the 3rd semester indicating the work to be carried out by the student. The report in duplicate has to be submitted in typed and bound form 7 days before the commencement of the 4th semester examination. Assessment would be made on the basis of the submitted report and the viva voce examination conducted by a board of examiners constituted by the Departmental Academic Committee consisting of two faculty members and the supervisor and an external examiner with Head of the Department as Chairman during 4th Semester examination.

Subject Name: Comprehensive Viva-Voce					
Paper Code: REEN6222					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**0**	**0**	**5**

This is a Viva – Voce examination to ascertain the student's overall grasp of the principles of Renewable energy engineering and allied subjects. Assessment would be made on the basis of the viva voce examination conducted by a board of examiners constituted by the Departmental Academic Committee consisting of three faculty members with Head of the Department as Chairman along with one external examiner during 4th Semester examination.