Heritage Institute of Technology

DEPARTMENT OF CHEMICAL ENGINEERING
M.TECH. PROGRAMME

IN RENEWABLE ENERGY

Curriculum and Syllabus, July 2020

PART I: COURSE CURRICULUM

M.TECH. IN RENEWABLE ENERGY

1stYear 1stSemester (Semester 1)

THEORY

Sl. No	Code	Course Title	L	T	P	H	Credit
01	REEN 5101	Renewable Energy Resource and Characteristics	3	0	0	3	3
02	REEN 5102	Non-Solar Renewable Energy	3	0	0	3	3
03	REEN 5103	Research Methodology and IPR	2	0	0	2	2
04	REEN 5141 - 5142	Professional Elective I	3	0	0	3	3
05	REEN 5144-5145	Professional Elective II	3	0	0	3	3
06	DIMA 5116	Disaster Management	2	0	0	0	0
	PDLS 5118	Personality Development through Life Enlightenment Skills					
	YOGA 5119	Stress Management by Yoga					
	SANS 5120	Sanskrit for Technical Knowledge					
	INCO 5177	Constitution of India					
	Total Theory						**14**

LABORATORY

Sl. No	Code	Course Title	L	T	P	H	Credit
01	REEN 5151	Measurement Analysis Laboratory	0	0	4	4	2
02	REEN 5152	Power Laboratory	0	0	4	4	2
	Total Practical						**4**
	Semester Total						**18**

Professional Elective I	**REEN 5141**	**REEN 5142**
Subject name	Material for Renewable Energy Application	Bio Energy
Professional Elective II	**REEN 5144**	**REEN 5145**
Subject name	Thermal and Electrical Energy Fundamentals	Modeling and Analysis of Renewable Energy System

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1stYear 2ndSemester (Semester 2)

THEORY							
Sl. No	**Code**	**Course Title**	**L**	**T**	**P**	**H**	**Credit**
01	REEN 5201	Solar Energy Engineering	3	0	0	3	3
02	REEN 5202	Technology of Renewable Power Generation	3	0	0	3	3
03	REEN 5241-5242	Professional Elective III	3	0	0	3	3
04	REEN 5244-5246	Professional Elective IV	3	0	0	3	3
05		Audit Course – any one subject from Elective III or Elective IV bucket	3	0	0	0	0
	Total Theory						**12**
LABORATORY/SESSIONAL							
Sl. No	**Code**	**Course Title**	**L**	**T**	**P**	**H**	**Credit**
01	REEN 5251	Non-Solar Renewable Energy Laboratory	0	0	4	4	2
02	REEN 5252	Solar Energy Laboratory	0	0	4	4	2
03	REEN 5221	Term Paper and Seminar	0	0	4	4	2
	Total Practical						**6**
	Semester Total						**18**

Professional Elective III	**REEN 5241**	**REEN 5242**	**REEN 5243**
Subject name	Hydrogen and Fuel Cell Technology	Sustainable Application in Renewable Energy	Industrial Energy Analysis

Professional Elective IV	**REEN 5244**	**REEN 5245**	**REEN 5246**
Subject name	Solar Photovoltaic System Design	Sustainable Energy Conversion and Storage	Waste Management With Renewable Energy Systems

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2nd Year 1st Semester (Semester 3)

THEORY							
Sl. No	**Code**	**Course Title**	**L**	**T**	**P**	**H**	**Credit**
01	REEN 6141-6143	Professional Elective V	3	0	0	3	3
02	REEN 6121	Composite Materials	3	0	0	3	3
	REEN 6122	Safety and Hazards in Energy Industry					
	BIOT 6121	Engineering Mathematics and Biostatistics					
	CSEN 6121	Business Analytics					
	Total Theory						**6**
LABORATORY/SESSIONAL							
Sl. No	**Code**	**Course Title**	**L**	**T**	**P**	**H**	**Credit**
01	REEN 6195	Dissertation / Industrial Project – Phase I	0	0	20	20	10
	Total Practical						**10**
	Semester Total						**16**

Professional Elective V	**REEN 6141**	**REEN 6142**	**REEN 6143**
Subject name	Energy Management	Renewable Energy Policy and Regulation	Environment Impact Assessment

Open Elective – I	
REEN 6121	Composite Materials
REEN 6122	Safety and Hazards in Energy Industry
BIOT 6121	Engineering Mathematics and Biostatistics
CSEN 6121	Business Analytics

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2nd Year 2nd Semester (Semester 4)							
LABORATORY/SESSIONAL							
S. No	**Code**	**Course Title**	**L**	**T**	**P**	**H**	**Credit**
01	REEN 6295	Dissertation / Industrial Project - Phase II	0	0	28	28	14
02	REEN 6297	Grand Viva	0	0	0	0	2
	Semester Total						**16**

PART II: DETAILED SYLLABUS

1st Year 1st Semester (Semester I)

Theory

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Subject Name: Renewable Energy Resource and Characteristics					
Paper Code: REEN5101					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. recognize the need of renewable energy technologies and their role in the India and world energy demand.
2. distinguish between the sustainable energy sources and fossil energy sources with emphasis on wind and photovoltaic systems.
3. understand the operating principles of geothermal heat pumps and principles of renewable energy production from various renewable sources, especially.
4. compare the advantages and disadvantages of various renewable energy technologies and propose the best possible energy conversion system for a particular location.
5. understand security and operational requirements of autonomous and net connected renewable energy systems.

Module 1: [10L]

World energy resources - Indian energy scenario - Environmental aspects of energy utilization; review of conventional energy resources - coal, gas, oil reserves and resources; Different form of non- conventional energy; Renewable energy resources and their importance – solar, wind, hydro, biomass, geothermal, and ocean energy, role of energy in economic development and social transformation; solar spectrum; electromagnetic spectrum, basic laws of radiation. A brief history of energy consumption; Energy flow in ecosystem; Fuel cells - types of fuel cells; thermodynamic efficiency of PEM fuel cell; Environmental impact of the PEM fuel cell in the transportation sector as compared to internal combustion engine.

Module 2: [10L]

Solar Energy: Solar radiation: Measurements and prediction; Solar energy conversion techniques to heat and electricity; Spectrum of electromagnetic radiation, sun structure and characteristics, Heat transfer processes applicable to solar energy, solar radiation, and its analysis; solar radiation characteristics of opaque materials and transmission through glazing. Natural convection case studies. Heat transfer in packed beds and perforated plates. Instruments for measurement of solar energy (Pyranometer / pyrheliometer / sunshine recorder), solar radiation on the collector; Introduction to solar cells; Relation between solar radiation spectrum and UV-vis & IR component.

Module 3: [10L]

Wind Energy: Wind Energy scenario in India & World. Power available in the wind. Wind speed and direction measuring instruments. Factors influencing global & amp; local wind circulation. Environmental benefits and problems of wind energy. Factors influencing the cost of wind energy. Wind energy conversion system (WECS): classification, characteristics, and applications. Betz limit. Tip speed ratio.

Hydropower: Hydropower scenario India & World. Classification of hydropower plants. Overview of micro, mini, and small hydro systems. Advantages and disadvantages of Hydropower. Head and Discharge measurement.

Module 4: [10L]

Biomass: Origin of biomass - plant derived, residues, aquatic, marine biomass, various wastes, photosynthesis; Biomass resource assessment - Estimation of woody biomass, non woody biomass and wastes, ASTM standards. Bulk chemical properties - Moisture content, proximate and ultimate analyses, calorific value, and waste water analysis for solids; Chemical composition of biomass - Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass; Structural properties - Physical structure, particle size and size distribution, permeability; Physical properties - Bulk density, angle of repose, thermal analysis (TGA, DTA, and DSC).

Ocean, Tidal, and Geothermal Energy: Ocean energy resources, ocean energy routes; principles of ocean thermal energy conversion systems; principles of ocean wave energy conversion and tidal energy conversion; Availability of geothermal energy-size and distribution; recovery of geothermal energy, various types of systems to use geothermal energy; Power generation using geothermal heat, Sustainability of geothermal source, Geothermal heat pump and geothermal energy scenario in India.

Text/Reference Books:

1. Garg H.P., Advances in Solar Energy Technology. D. Publishing Company, Tokyo, 1990.
2. Alan L.F. & R.H. Buse, Fundamentals of Solar Cells, Academic Press, London, 1983.
3. Khandelwal, K.C. &Mandi, S.S., Practical hands boo Biogas Technology, 1990.
4. Rai, G.D., Non-Conventional Energy Sources, Kh Publishers, New Delhi.
5. Mathur A.N. &Rathore N.S. Renewable Energy Sources, Bohra Ganesh Publications, Udaipur, 1992
6. Kothari, Renewable Energy Sources and Emerging Technologies, PHI, Eastern Economy Edition, 2012.
7. Bansal N. K., Kleeman M. K., Mells M. Renewable Sources of Energy and Conversion Technology, Tata McGraw-Hill, 1990.

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Subject Name: Non-Solar Renewable Energy					
Paper Code: REEN5102					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. solve the fundamentals of reaction engineering problem as applicable to biomass energy.
2. understand basic fluid flow phenomena for the application in wind turbine and hydro power etc.
3. identify different technologies in generating energy from biomass.
4. describe the process used in harnessing and implementation of wind energy.
5. categorize hydraulic turbines in generating hydropower.

Module 1: [10L]

Introduction - Basics of reaction kinetics: Mole concept, order of reaction, rate of the reaction. Reversible and irreversible reaction, Rate equation development, Brief idea on Batch, CSTR, PFR, Enzyme and kinetics of enzyme, Michaelis-Menten model, Digester and Monod growth model.

Continuum concept in fluid mechanics, Continuity Equation; Fluid metering devices – Rotameter, Venturimeter and Orificemeter, Bernoulli's principle: Concept of priming, cavitation in case with the centrifugal pump; Aerodynamics of aerofoil; lift; drag; stall; Effect of Reynold's number; Actuator disc and Froudes' Momentum Theory.

Module 2: [10L]

Principles of biomass energy conversion processes: Chemical, Biochemical and Thermo- chemical technologies.

Chemical and mechanical processes involved in the biochemical conversion of lignocellulosic biomass to biofuel; Algae and biofuels; Hydrolysis & hydrogenation; Solvent extraction of hydrocarbons.

Different processes for thermo chemical conversion: Direct combustion, incineration, pyrolysis, gasification and liquefaction; Biomass gasification – types, gasifier burner arrangement for thermal heating, gasifier engine arrangement for electrical power; Design, construction and operation of gasifiers.

Module 3: [10L]

Analysis of wind data: Mean wind speed and distribution of wind velocity.

Statistical model for wind data analysis: Weibull distribution. Energy estimation of wind regimes. Cut-in and cut-out wind speed. Noise level. EMF exposures. Shadow flicker. Icing. Yawing mechanism. Pitch controlling system. Wind turbine power and torque characteristics. Stall effect. Wind turbine blade materials. Fatigue & Structural failure.

Transmission and Generator Efficiencies. Methods of Generating Synchronous Power. Features of the Electrical Network. Supervisory Control and Data Acquisition (SCADA) system architecture for wind farm.

Module 4: [10L]

Introduction to Hydropower, Hydrology – descriptive hydrology, hydrograph, mass curve, storage, dams; Classification of Hydropower Plants, Small Hydropower, Systems: Overview of micro, mini and small hydro systems Status of Hydropower Worldwide; Essential elements of a hydroelectric power plant.

Components of hydropower plants Hydraulic Turbines: Types and Operational Aspects Classification of Hydraulic Turbines, Theory of Hydro-turbines; Francis, Pelton, Kaplan and Propeller Turbine; Differences between impulse and reaction turbines; Operational Aspects of Turbines Efficiency and selection of turbines; Weirs, Dam and Spillway, Surge Chambers, Penstock, Tailrace.

Text Books:

1. Boyle, Renewable Energy: Power for a Sustainable Future, 3rd edition, Oxford University Press, 2012.
2. Kishore V.V.N., Renewable Energy, Engineering and Technology: A Knowledge Compendium, The Energy and Resources Institute, TERI, 2009.

Reference Books:

Singal R.K., Non-Conventional Energy Resources, S.K. Kataria& Son, 2012.

1. Fogler H.C., Elements of Chemical Reaction Engineering, 4th edition, Prentice Hall India Learning Private Limited, 2008.
2. Bansal R.K., A Textbook of Fluid Mechanics, 1st edition, Laxmi Publications, 2016.
3. McCabe W., Smith J., Harriott P., Unit Operations of Chemical Engineering, 7th Edition, McGraw Hill Education,2017.
4. Wanger H., Mathur J., Introduction to Hydro energy Systems: Basics, Technology and Operation, Springer, 2011.
5. Jain P., Wind Energy Engineering, McGraw-Hill Education, 2010.
6. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind turbine Engineering, American Society of Mechanical Engineers, 1994.

Subject Name: Research Methodology and IPR					
Paper Code: REEN5103					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	2	**0**	**0**	**2**	**2**

Course outcomes:

Upon completion of the course, students will be able to:

1. understand research problem formulation and analyze the same.
2. follow research ethics.
3. carry out research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.
4. understand that when IPR would take such important place in growth of individuals & nation and its protection would provide an incentive to inventors for further Research and Development.

Module 1: [6L]

Introduction to research; Definitions and characteristics of research; Types of research;
Main components of any research work.

Analysis and Statement of the problem: Learning Objectives; Analyzing the problem; Formulating the problem statement.

Literature review: Uses of literature review; Source of information; Aims & Objectives, Formulation and Scheduling of Objectives; Definitions; of the research objectives. Basic Quality Management tools and Acceptance Sampling, Numerical Problems.

Module 2: [6L]

Development of Research Hypotheses, Data Collection — Primary and Secondary Data, 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, Basic concepts of Descriptive Statistics, Basic concepts of Design of Experiments. Numerical Problems.

Module 3: [6L]

Basic Spreadsheet tools: Introduction to spread-sheet applications, features & functions, using formulae & functions, data storing, features for statistical data analysis, generating charts/graphs & other features.

Basic Presentation tool: Introduction to presentation tool, features & functions, creating presentations Basic Concepts of Web Search: search engines using for research data bases, Basics of Thesis writing editing tools. Writing style of Reference and Nomenclature. Basics of IPR. Need for patent filing and its basic methodologies.

Text/ Reference Book:

1. Montgomary, Douglas C. Design and Analysis of Experiments, WileyIndia, 5/e, 2007.
2. Kothari C.K. Research Methodology – Methods and Techniques, NewAge International, 2/e, 2004.
3. Krishnswamy, K.N., Shivkumar, AppaIyer and Mathiranjan M., Management Research Methodology; Integration of Principles, Methods and Techniques, Pearson Education, 2006.
4. Stephan L. Nelson, Gujulia Kelly, The Complete reference Office Xp, TMH, 2001.
5. University of Chicago Press, Chicago Manual of Style, University of Chicago Press, 2003.
6. Udpa, S. R., Quality Circles in India: Participation for Progress, TMH, 1988.
7. Chopra, S., A Book on Indian Patenting System, Notion Press, 2018
8. Ramakrishna, B. and Kumar, Anil, H. S., Fundamentals of IPR for Students, Notion Press, 2017

Subject Name: Material for Renewable Energy Application					
Paper Code: REEN5141					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. familiarize with the properties of different materials- metals and nonmetals.
2. understand the manufacturing process of nano-material and its characterizations techniques.
3. design photovoltaic material and its electronic properties for the solar energy application.
4. understand the role of selection for the wind turbine material and it required properties.
5. apply the knowledge on the characterization of materials by modern tools.

Module 1: [10L]

Nanomaterial for renewable energy: Classification of nanomaterials – zero-dimensional, one- dimensional, two-dimensional, three- dimensional; Synthesis of nanomaterials: Bottom up and top down approaches, colloidal method, chemical vapor deposition (CVD) methods, wet chemical methods, sol- gel synthesis, and mechanical exfoliation methods, physical vapor deposition (PVD), sputtering, plasma enhanced CVD (PECVD), hot wire CVD (HWCVD), Nano-structured materials with applications - quantum dots, nano-tubes, nano-wires, nano- crystals.

Module 2: [10L]

Materials for photovoltaic conversions, Si and non-Si materials, crystalline, semi crystalline, polycrystalline and amorphous materials; Nano, micro, and poly-crystalline Si for solar cells, mono- micro silicon composite structure; Technology for Si extraction, purification; Method of doping and junction fabrication; Cell fabrication and metallization techniques; Networking the PV cell; P-N junction, sources of losses and prevention, Concepts on high efficiency solar cells, tandem and multi- junction solar cells, photo-voltaic materials and photo-voltaic modules and their applications; Solar PV concentrator cells and systems, III-V, II-IV compound materials thin film solar cells.

Module 3: [10L]

Materials for wind turbines- blades, nacelles, and tower; Important properties of the blade, Metal and polymer-composite material for blade and tower; Rotor blade – properties and application; Erecting of the tower material, Support materials for wind tower, Corrosion issues; importance of nacelles in wind turbine and its component.

Mechanical properties: flexural strength, bending moment, strength of material- yield strength, ultimate strength, Young's modulus, Poisson's ratio, and fatigue; Universal testing machine (UTM); shear webs for wind turbine blades.

Module 4: [10L]

Electronic and atomic structures of solar cell material; Atomic bonding in solids, crystal structure, microstructure, solidification, alloys; Description of optical and thermal materials for solar cell application.
Material characterization: Scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), Single crystal X-Ray diffraction, Ultraviolet visible spectroscopy, Raman spectroscopy, atomic force microscopy (AFM), and X-ray photoelectron spectroscopy (XPS); Pulse layer deposition (PLD), PV cell diode properties, PV cell series resistance, PV cell shunt resistance.

Text/Reference Books:

1. Rosa A. Fundamentals of Renewable Energy Processes, 3rd ed., 2012.
2. Martin A.G., Solar cells: Operating principles, technology and system applications, Prentice- Hall Inc, Englewood Cliffs, NJ, USA, 1981.
3. Rao C.N.R., Muller A. & Cheetham A.K. Nanomaterials Chemistry - Recent Developments and New Directions, Wiley VCH, 2007.
4. Moller H.J. Semiconductor for solar cells, Artech House Inc, MA, USA, 1993.
5. Barbec C., Dyakonov V., Parisi J., Saricittci N.S. Organic photovoltaics: Concepts and realization, Springer-Verlag 2003.
6. Nijssen R.P.L. & Brondsted P. Advances in wind turbine blade design and materials, Elsevier, 2013..

Subject Name: Bio Energy					
Paper Code: REEN 5142					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course Outcomes:

Upon completion of the course, students will be able to:

1. identify different technologies for biomass conversion to energy.
2. justify the unit operations necessary to generate bioenergy.
3. identify different bio-resources to produce energy.
4. describe technologies required for bio-gas.
5. design processes for bio fuel production.
6. solve problems with the application of bioreactors to generate bio- energy.

Module 1: [10L]

Introduction to biomass; Basic photosynthesis process for C3 and C4 plants on biomass production; classification of biomass; brief overview on the 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: characterization and classification of waste as fuel – agro based, 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 (fermentation), distillation / pervaporation.

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

Text Books:

1. Mahaeswari R.C. Bio Energy for Rural Energisation, Concepts Publishing Co., 1997.
2. Khandelwal K.C. & Mahdi S.S. Biogas Technology – A Practical Handbook, Tata McGrawHill, 1986.

Reference Books:

1. Reed T.B. Biomass Gasification – Principles and Technology, Noyce Data Corporation,1981
2. Boyles D.T. Bio Energy Technology Thermodynamics and costs, Ellis Hoknood Chichester, 1984.
3. Eriksson S. & Prior M. The briquetting of Agricultural wastes for fuel (FAO Energy and Environment paper), Food & Agriculture Org, 1990.

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Subject Name: Thermal and Electrical Energy Fundamentals					
Paper Code: REEN5144					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

After completing the course students will be able to

1. apply the knowledge of different modes of heat transfer to design equipments for harnessing renewable energy.
2. understand the basics of characteristics and behavior of laws of thermodynamics and its applications to process.
3. understand the basics of DC and AC sources along with their applications on electrical circuits.
4. solve the problems related to applications of network theorems and solving complex DC circuits.
5. solve the problems related to R-L-C circuits connected to single phase and three phase AC.

Module 1: [10L]

Introduction on conduction, convection& radiation heat transfer; The electromagnetic spectrum, The Black body radiation, Plank's law & Wien's displacement law, Stefan-Boltzman law, Sky radiation, Radiation heat transfer coefficient, Absorbance & Emittance. Natural convection between flat plate & between concentric cylinders, Heat transfer relations for internal flow, Wind convection coefficient.

Module 2: [10L]

Introduction to first and second laws of thermodynamics; importance of thermodynamics laws to Renewable energy systems, Energy balance of open system and closed system process. Work done in adiabatic and isothermal process. Steady flow energy equation for pump, compressor, turbine, heat exchangers etc. Concept of Reversibility, Irreversibility; Carnotcycle. Concept of entropy. Clausius inequality. Power cycle and its efficiencies. Chemical reaction equilibrium. Energy and mass balance calculation of fuel combustion.

Module 3: [10L]

Resistance (R), Inductance (L) and Capacitance (C). Ohm’s law. DC and AC sources – voltage and current, ideal and practical, dependent and independent. KCL & KVL, loop or mesh analysis, nodal analysis, star-delta transformation, Thevenin’s and Norton’s theorem, superposition theorem, maximum power transfer theorem.

Module 4: [10L]

RepresentationofsinusoidalquantitiesSteadystateanalysisofR-L-Cseriesand parallel circuits, resonance in electrical circuits, energy and power, complex power – apparent, active and reactive power, three phase ac circuits – phase & line voltages and currents. Magnetic flux and mmf, analogy between electrical and magnetic circuits, magnetic materials, eddy current & hysteresis losses.

Text Books:

1. Cengel Y.A. and Boles M.A., Thermodynamics: An Engineering Approach, Sixth Edition (Tata McGraw-Hill, 2008).
2. Duffie J.A. & Beckman W.A.; Solar Engineering of Thermal Processes; John Wiley & Sons Inc., 2013
3. Theraja B. L., Theraja A.K., "A text book of Electrical Technology", S. Chand Publication

Reference Books:

1. Nag P.K., Engineering Thermodynamics, Third Edition (Tata McGraw-Hill,2005).
2. Arora C.P., Thermodynamics, Tata McGraw-Hill, New Delhi,2003.
3. Kothari D.P, Nagrath I.J., "Fundamentals of electrical engineering", Tata McGraw-Hill Publication,2016.
4. Prasad R., Fundamentals of Electrical Engineering, PHI publication.

Subject Name: Modeling and Analysis of Renewable Energy System					
Paper Code: REEN5145					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

After completion of the course students will be able to:

1. apply the correct optimization method to solve an unconstrained optimization problem related to Renewable Energy.
2. develop the objective function and apply appropriate methods to solve a constrained optimization problem.
3. apply appropriate optimization methods to determine the optimal scheduling of power generation and find out the most economic load dispatch scheduling for power generating units.
4. identify the appropriate method to mathematically model a Renewable Energy system to predict relevant variables.
5. apply regression methods to develop a statistical model for a multivariable physical system.

Module 1: [10 L]

Essential features of optimization problems, General methods to solve optimization problems,continuity of functions, unimodal, multimodal, convex and concave functions; Concept of Hessian matrice; Unconstrained-Optimality conditions, Newton and quasi-newton methods of unidimensional search; multivariate search; Introduction to simple Constrained Optimization: Lagrange multipliers – Necessary and sufficient conditions for optimality; sensitivity analysis

Module 2: [10 L]

Least square method for linear regression; Levenberg Marquardt algorithm for non-linear regression; Multivariate first order regression**.** Introduction to Response Surface Methodology, the Method of Steepest Ascent, analysis of a second order model, location of the stationery point, characterizing the response surface, experimental designs for fitting response surfaces, applications and numerical problems.

Module 3: [10 L]

Initial value problems solution by Runge-Kutta Method. Concept of partial differential equation (PDE); Discretization in space and time; Implicit and explicit scheme; Finite difference: Crank-Nicholson method to solve parabolic PDE;

Module 4: [10 L]

Optimal power generation scheduling, economic load dispatch of power generating units; Multiobject stochastic power dispatch-stochastic problem formulation; algorithm; application of the method.
Case studies of optimisation in Energy systems – problems.

Text/Reference Books:

1. Himmelblau D.M. & T.F. Edgar T.F., Optimization of Chemical Processes:, McGraw-Hill, 2001.
2. Kothari D. P. & Dhillon J.S. Power System Optimization, PHI, 2nd Edition, 2004.
3. Soliman S.A.H., Mantawy A.A.H., Modern Optimization Techniques with Applicationsin Electric Power Systems, Springer, 2011.
4. Chung K L, Elementary probability theory with stochastic processes, Springer, 4/e, 2013.
5. Montgomery, Douglas C., Design and Analysis of Experiments, Wiley International Student Version 8/e, 2012.
6. Chapra S., Canale R., Numerical Methods for Engineers, McGraw Hill Education India Private Limited, 7th Edition, 1985.
7. Gilat A., Subramaniam V., Numerical Methods for Engineers and Scientists, John Wiley and Sons, 3rd Edition, 2017.

Subject Name: Disaster Management					
Paper Code: DIMA5116					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	2	**0**	**0**	**2**	**0**

Course outcomes:

Upon completion of the course, students will be able to:

1. understand the concepts of disaster, types of disasters, causes, impact of disaster on environment and society, disaster profile of India.
2. analyze various phases of disaster management (DM) cycle, local, state, and central government organizations and international agencies involved in DM .
3. explain the terms: hazards, risks, vulnerability, capacity and their inter-relationship, process of hazard analysis and vulnerability assessment, disaster preparedness.
4. learn various methods for post disaster situational information collection, current practices and standards for post-disaster damage and need assessment and response operations.
5. understand the concepts, strategies and activities during recovery and mitigation.
6. apply the knowledge of technology tools to build conceptual architecture of ICT based Emergency Management Systems and smart phone apps for disaster management.

Module 1: [6L]

Introduction on Disaster:

Disaster: definition, types of disasters, different phases including four emotional stages of disaster (heroic phase, honeymoon phase, disillusionment phase, reconstruction phase), nature and magnitude of disaster, factors contributing to disaster impact and severity, natural disaster-prone areas in India, trends of major disasters and their impact in India.

Introduction to Disaster Management:

Disaster Management: definition, disaster management cycles Components of disaster management: hazard analysis, vulnerability assessment, prevention and mitigation, preparedness, prediction and warning, response, recovery Disaster management act, 2005, organizations involved in disaster management.

Module 2: [6L]

Hazard Analysis:

Identifying possible hazards, characterizing hazards, hazard assessment metrics.

Vulnerability Assessment:

Key concept, types of vulnerabilities, process of vulnerability assessment.

Disaster Preparedness:

Disaster risk assessment, disaster risk, reduction, preparedness plans.

Community preparedness:

emergency exercises/ trainings/mock drills, disaster prediction and warning mechanism, public education, evacuation planning, emergency resource networks Smartphone/ web based apps for disaster preparedness and early warning.

Module 3: [6L]

Disaster Response:

Need for coordinated disaster response: search, rescue, evacuation, medical response and logistics management, psychological response (trauma, stress, rumor and panic), SPHERE standards in disaster response, role of Government, International agencies and NGOs.

Post-disaster Situation Awareness:

Challenges in communication of situational data from affected areas, Crowd-sourcing of situational data: Issues and challenges.

Post-disaster Damage and Need Assessment:

Current trends and practices: RAPID damage and need assessment.

Module 4: [6L]

Rehabilitation, Reconstructions and Recovery:

Reconstruction and rehabilitation as a means of development, post disaster effects and remedial measures, long-term counter disaster planning.

Disaster Mitigation:

Meaning, concept and strategies of disaster mitigation, structural mitigation and non-structural mitigation, disaster mitigation initiatives in India.

Text/ Reference Books:

1. R. Nishith, Singh AK, "Disaster Management in India: Perspectives, issues and strategies", New Royal book Company.
2. Sahni, Pardeepet.al. (Eds.)," Disaster Mitigation Experiences And Reflections", Prentice Hall of India, New Delhi.
3. Goel S. L., Disaster Administration And Management Text And Case Studies", Deep & Deep Publication Pvt. Ltd., New Delhi.

Course Name : Personality Development through Life Enlightenment Skills					
Course Code: PDLS5118					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	2	**0**	**0**	**2**	**0**

Course Outcomes:

After the completion of this course, students should be able to:

1. study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life.
2. the person who has studied Geeta will lead the nation and mankind to peace and prosperity.
3. study of Neetishatakam will help in developing versatile personality of students.

Module 1: [6L]

Neetisatakam-Holistic development of personality: Verses- 19,20,21,22 (wisdom); Verses- 29,31,32 (pride & heroism) ; Verses- 26,28,63,65 (virtue).

Module 2: [6L]

Approach to day to day work and duties: Verses- 52,53,59 (dont's); Verses- 71,73,75,78 (do's);
Shrimad Bhagwad Geeta: Chapter 2-Verses 41, 47,48.

Module 3: [6L]

Statements of basic knowledge: Chapter 3-Verses 13, 21, 27, 35, Chapter 6-Verses 5,13,17, 23, 35;
Chapter 18-Verses 45, 46, 48; ShrimadBhagwadGeeta: Chapter2-Verses 56, 62, 68 4. Chapter 12 -Verses 13, 14, 15, 16,17, 18.

Module 4: [6L]

Personality of Role model: Shrimad Bhagwad Geeta: Chapter2-Verses 17, Chapter 3-Verses 36,37,42; Chapter 4-Verses 18, 38,39; Chapter18 – Verses 37,38,63.

Text/ Reference Books:

1. "Srimad Bhagavad Gita" by Swami Swarupananda Advaita Ashram (Publication 2. Department), Kolkata.
2. Bhartrihari's Three Satakam (Niti-sringar-vairagya) by P. Gopinath, Rashtriya Sanskrit Sansthanam, New Delhi.

Course Name : Stress Management by Yoga					
Course Code: YOGA5119					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	2	**0**	**0**	**2**	**0**

Course Outcomes:

After the completion of this course, students should be able to:

1. develop healthy mind in a healthy body thus improving social health also.
2. improve efficiency.

Module 1: [6L]

Definitions of Eight parts of yog. (Ashtanga).

Module 2: [6L]

Yam and Niyam; Do`s and Don't's in life; Ahinsa, satya, astheya, bramhacharya and aparigraha, Shaucha, santosh, tapa, swadhyay, ishwarpranidhan.

Module 3: [6L]

Asan and Pranayam: Various yog poses and their benefits for mind & body.

Module 4: [6L]

Regularization of breathing techniques and its effects-Types of pranayam.

Text/ Reference Books:

1. 'Yogic Asanas for Group Tarining-Part-I": Janardan Swami Yogabhyasi Mandal, Nagpur.
2. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata.

Course Name : Sanskrit for Technical Knowledge					
Course Code: SANS5120					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	2	**0**	**0**	**2**	**0**

Course Objectives:

1. To get a working knowledge in illustrious Sanskrit, the scientific language in the world.
2. Learning of Sanskrit to improve brain functioning.
3. Learning of Sanskrit to develop the logic in mathematics, science & other subjects.
4. Enhancing the memory power.
5. The engineering scholars equipped with Sanskrit will be able to explore the huge knowledge from ancient literature.

Course Outcomes:

After the completion of this course, students should be able to:

1. understanding basic Sanskrit language.
2. ancient Sanskrit literature about science & technology can be understood.
3. being a logical language will help to develop logic in students.

Module 1: [6L]

Alphabets in Sanskrit; Past/Present/Future Tense.

Module 2: [6L]

Simple Sentences; Order.

Module 3: [6L]

Introduction of roots; Technical information about Sanskrit Literature.

Module 4: [6L]

Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics.

Text/ Reference Books:

1. "Abhyaspustakam" – Dr. Vishwas, Samskrita-Bharti Publication, New Delhi.
2. "Teach Yourself Sanskrit" Prathama Deeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication.
3. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi.

Course Name : Constitution of India					
Course Code: INCO5117					
Contact Hours Per Week	L	T	P	Total	Credit Points
	2	0	0	2	0

Course Objectives:

1. Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
2. To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.
3. To address the role of socialism in India after the commencement of the Bolshevik Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

Course Outcomes:

After the completion of this course, students should be able to:

1. discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
2. discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
3. discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
4. discuss the passage of the Hindu Code Bill of 1956.

Module 1: [8L]

History of Making of the Indian Constitution: History, Drafting Committee, (Composition &Working); Philosophy of the Indian Constitution: Preamble, Salient Features.

Module 2: [4L]

Contours of Constitutional Rights & Duties: Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

Module 3: [4L]

Organs of Governance: Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications, Powers and Functions.

Module 4: [8L]

Local Administration: District's Administration head: Role and Importance; Municipalities: Introduction, Mayor and role of Elected Representative, CEO of Municipal Corporation;
Pachayati raj: Introduction, PRI: Zila Pachayat; Elected officials and their roles; CEO Zila;
Pachayat: Position and role; Block level: Organizational Hierarchy (Different departments); Village level: Role of Elected and Appointed officials, Importance of grass root democracy;
Election Commission: Election Commission: Role and Functioning; Chief Election Commissioner

and Election Commissioners; State Election Commission: Role and Functioning; Institute and Bodies for the welfare of SC/ST/OBC and women.

Text/ Reference Books:

1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
3. M. P. Jain, Indian Constitution Law, 7th Edn. Lexis Nexis, 2014.
4. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

1st Year 1st Semester I

Laboratory

Subject Name: Measurement Analysis Laboratory					
Paper Code: REEN5151					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**4**	**4**	**2**

Course outcomes:

After completing the course, students will be able to

1. characterize and analyze of liquid fuel property.
2. measure the insulating property of material.
3. analyze forced convective heat transfer.
4. analyze concentration of solution using sophisticated analytical equipments.
5. determine the moisture content and kinematic viscosity of fuel.
6. determine energy efficiency of various process equipments.

Experiments:

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

1. Characterization of fuel (Measurement of Flash point, Fire point, Cloud point, Pour point etc.).
2. Determination of calorific value of fuel.
3. Analysis of moisture content and kinematic viscosity of fuel.
4. Measurement of energy consumption using energy meter.
5. Measurement of efficiency of fuel cell.
6. Determination of thermal conductivity of insulating materials.
7. Analysis of forced convection heat transfer.
8. Measurement of illumination using Luxmeter.
9. Solute concentration analysis of an aqueous solution using UV-Vis spectrophotometer.
10. Solute concentration analysis of a non-aqueous solution using GC analyser.

Subject Name: Power Laboratory					
Paper Code: REEN5152					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**4**	**4**	**2**

Course outcomes:

Upon completion of the course, students will be able to:

1. understand the operation of electrical equipment like AC and DC motor.
2. understand the concept of power generation and effective distribution and transmission.
3. characterize various types of motors and generators.
4. understand the characteristics and behavior of various power system equipment through experimental verification.

Experiments:

1. Determination of the generalized ABCD Constant of a transmission line.
2. OC and SC test and Polarity test of a single phase transformer.
3. Different methods of starting of a 3 phase Induction Motor & their comparison.
4. Speed control of 3 phase squirrel cage induction motor by different methods & their comparison.
5. Study of the characteristics of a separately excited DC generator.
6. Study of the characteristics of a DC motor.

1st Year 2nd Semester (Semester II)

Theory

Subject Name: Solar Energy Engineering					
Paper Code: REEN5201					
Contact Hours	**L**	**T**	**P**	**Total**	**Credit Points**
Per Week	**3**	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. characterize different modes of heat transfer with emphasis on solar radiation.
2. identify different technologies used for solar collectors.
3. evaluate the performance and efficiency of different devices that extract power from solar energy.
4. explain the basics of solar PV cells and relevant parameters for its characterization.
5. explain the important features of first to third generation solar cell technology.

Module 1:[10L]

Solar radiation: sun earth geometric relationship, solar angles, sun's trajectories in different seasons, zenith solar time, air mass, solar beam, total solar radiation & diffuse radiation, 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.

Solar water heating; active and passive. Forced and natural circulation system. Solar process loads. Solar system thermal calculations; component models, collector heat exchanger factor and duct and pipe loss factors. System models. Collector models.

Module 2: [10L]

Flat plate collector, Liu & Jordan relation. Unglazed, Single and double glazed solar collectors, Optical losses and thermal losses, thermal analysis and performance characteristics.

Water and air heating collectors: their specific features. Evacuated tube collectors: characteristics, materials, thermal analysis.

Concentrating solar collectors: General description; concentrators, receivers, Orienting/tracking requirements, Materials General characteristics Optical features of solar concentrators. Optical and thermal losses, Thermal performance characteristics parabolic trough collectors (PTC), Parabolloid dish collectors, Scheffler dish, Linear Fresnnel Reflector Collector.

Module 3:[10L]

Introduction to Solar PV: Crystal structure, band theory, energy band diagrams, Fermi level, intrinsic and extrinsic semiconductor, doping, n-type and p-type silicon, p-n junctions, drift and diffusion current, absorption of radiation and excess minority carriers, generation, recombination and carrier separation Standard solar cell structure, I-V characteristics, FF, Voc, Isc, Pmax, conversion efficiency, losses in solar cell, Rs, Rsh, impact of radiation and temperature, PC1D simulation of industrial solar cell structure Concepts of heterojunctions, multi junction and concentrated solar cell.

Module 4: [10L]

First generation: Silicon wafer based technology: Materials and process requirements for solar cell fabrication, process flow, Single and poly crystalline silicon solar cells,

Second generation: Thin film technologies: Merits and demerits of thin film technologies, amorphous - Si, CdTe and CIGS solar cell module, manufacturing steps .

Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Materials and process requirements for module assembly, routine and type tests, qualification test standards, types of degradation

Text Books:

1. Sukhatme S. & Nayak J.: Solar Energy: Principles of Thermal Collection and Storage, Third Edition (Tata McGraw Hill, 2008).
2. Solanki C.S., Solar Photovotaics – Fundamentals, Technologies and Applications, (PHI Learning).

Reference Books:

1. Sukhatme S.P., A Textbook on Heat Transfer, Fourth Edition, University Press India Ltd., 2005.
2. Goswami D.Y., Kreith F. & Kreider J.F., Principles of solar Engineering, Tyalor and Francis, Philadelphia, 2000.
3. Duffie J. A. & Beckman W.A., Solar Engineering of Thermal Processes, Third Edition, John Wiley & Sons, 1974.
4. Kalogirou S.A., Solar Energy Engineering: Process and Systems, Academic Press, 2nd Edition, 2014.
5. Würfel P., Physics of Solar Cells: From Basic Principles to Advanced Concepts, Wiley VCH, 2009.

Subject Name: Technology for Renewable Power Generation					
Paper Code: REEN 5202					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. understand of design and evaluation solar thermal power plants.
2. develop a comprehensive technological understanding in solar PV system components.
3. get in-depth understanding of design parameters to help design and simulate the performance of a solar PV power plant.
4. update themselves with the latest trends in wind turbine technology.
5. understand of power systems, their operation and control focussed on the issues related to the integration of distributed renewable generation into the network.
6. understand geothermal and ocean thermal technologies.

Module 1: [10L]

Solar Thermal Power Generation:

Radiation optics. Second Law of thermodynamics for solar concentrators. Comparison of concentrators and flat plate collectors, Performance analysis and characteristics. Solar Parabolic trough: design considerations, thermal design of receivers. Thermodynamic cycle and solar plant. Solar thermal power plant, central receiver power plant, solar pond, solar air conditioning and refrigeration, solar kiln, solar cooker, solar greenhouse, overview on energy efficient building construction.

Module 2: [15L]

Solar PV power generation:

PV module technology: response to weather parameters, commercial module ratings, standards, module reliability .

Inverter technology: types of inverters, inverter selection, voltage levels, performance, power quality **,**

Balance of system/plant: Module mounting structure, tracking system, Cabling and electrical design, single line diagrams, metering Safety systems: Hotspot, Blocking and bypass diodes, surge protection, PID and its protection, Lighting protection, anti-islanding Rooftop PV plant: design consideration, types of mounting structures, standards Ground mounted PV plant: Array design and PV panel mounting, electrical layout, standards Performance parameter: Losses in solar PV power plant, Yield, Capacity Utilization Factor and Performance Ratio shadow analysis. Grid interactive solar PV power systems. Solar power plant using a satellite.

Module 3: [7L]

Wind Turbine Loads. Wind Turbine Rotor Dynamics. One-dimensional Momentum Theory and Betz Limit.

Blade Design for Modern Wind Turbines: Momentum Theory and Blade Element Theory. Introduction to Computational Aerodynamics in wind turbine design.

Module 4: [8L]

Other forms of renewable energy generation: Geothermal power generation.

Ocean power generation: Tidal energy estimation. Tidal power plant. Wave energy. Ocean Thermal Energy Conversion (OTEC). Power Generation from landfill gas, liquid waste.

Text/ Reference Books:

1. Kothari D.P., Singal K.C., Ranjan R. 'Renewable Energy Sources and Emerging Technologies' PHI Learning Pvt. Ltd, 2nd edition, 2013, New Delhi, India.
2. Sukhatme S.P. and Nayak J., Solar Energy: Principles of Thermal Collection and Storage, Third Edition (Tata McGraw Hill, 2008).
3. Solanki C.S., Solar Photovoltaics – Fundamentals, Technologies and Applications, 2nd ed. (PHI Learning, 2011).
4. Balderas M.H., Renewable Energy Grid Integration, Nova Science Publishers, New York, 2009.

Subject Name: Hydrogen and Fuel Cell Technology					
Paper Code: REEN 5241					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course Outcomes:

Upon completion of the course, students will be able to:

1. get comprehensive and logical knowledge of hydrogen production, storage, and utilization. In addition,
2. demonstrate knowledge of renewable energy technology.
3. understand the role of nanotechnology in energy conversion.
4. understand of various fuel cell technologies.
5. design nano-systems, component or process as per need and specification.
6. get knowledge layered Integration and performance for microfuel cell systems.
7. acquire knowledge about the different types of fuel cell and their application.

Module 1: [10L]

Introduction of hydrogen energy systems: Properties of hydrogen as fuel, Hydrogen pathways introduction-current uses, general introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants.

Hydrogen production processes: Thermal-Steam reformation, thermo chemical water splitting, gasification-pyrolysis, nuclear thermal catalytic and partial oxidation methods. Electrochemical- Electrolysis, photo electro chemical, Biological-Anaerobic digestion, fermentation micro-organism, PM based electrolyser.

Module 2: [10L]

Hydrogen storage: Physical and chemical properties, general storage methods, compressed storage- composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, carbon based materials for hydrogen storage.

Hydrogen utilization: Overview of hydrogen utilization, IC Engines, gas turbines, hydrogen burners, power plant, domestic cooking gas, marine applications, hydrogen dual fuel engines.

Module 3: [10L]

Fuel cells: History – principle - working - thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell, Types of fuel cells – Proton Exchange Membrane Fuel Cell, Molten Carbonate Fuel Cells, Acid Alkaline Fuel Cells, Direct Methanol, Solid Oxide Fuel Cells, Microbial Fuel Cells, Other non-hydrogen fuel cells, relative merits and demerits, Polarization curve-Activation loss, Ohmic loss, and Mass transport loss.

Module 4: [10L]

Applications of fuel cells: 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, portable fuel cells, laptops, mobiles, submarines. Hydrogen safety: Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles.

Reference Books:

1. EG&G Technical Services Inc., Eg & g Technical Services Inc, U. S. Department of Energy Fuel Cell Handbook (Seventh Edition), Lulu.com, 2016.
2. Basu, S. Recent Trends in Fuel Cell Science and Technology, Springer, 2007.

Subject Name: Sustainable Application in Renewable Energy					
Paper Code: REEN5242					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

1. Upon completion of the course, students will be able to:
2. identify the technologies pertaining to sustainable and renewable energy application.
3. analyze different sources of renewable energy and innovative technologies in harnessing energy from these renewable sources.
4. design CCS and cryogenic energy storage facility in harnessing renewable energy.
5. construct green building in the context of energy savings.
6. describe the application of solar energy in green building application.

Module 1: [10L]

A brief on green-house effect; Kyoto Protocol, Clean Development Mechanism (CDM); Afforestation and Reforestation projects, Reduced Emissions from Deforestation and Degradation (REDD); Life cycle analysis of CCS technologies; Pre and Post combustion capture; CO_2 trapping mechanism and geological storage; CO_2 fluid properties and interaction with rocks; Wettability, capillary pressure and relative permeability; Impact of impurities on rock and fluid properties; Application of CO_2 in retrieving geothermal energy; Energy generation for CO_2 to methane formation through catalytic process; Economic analysis of the power generation process.

Module 2: [10L]

Concept of intrinsic, extrinsic properties, state variable, energy, exergy, entropy, reversible and irreversible process; Free energy; Equation of state and Joul-Thomson coefficient; PVT, T-H and T-S diagram; Properties and uses of cryogenic fluids like air and nitrogen; Refrigeration cycle; Isentropic and Isenthalpic expansion process; Refrigeration and Liquefaction Methods; Stirling cycle; Vuilleumier Refrigerator; Rakine cycle; Cryocoolers.

Brief on cyrogenic energy storage (CES), Role of CES in Renewable Energy; Storage and delivery of cryogen; Grid-scale CES system; CES modeling; Liquid Air Energy Storage (LAES); Environmental effect for CES; Safety with Cryogenic system.

Module 3: [10L]

Concepts of Green Building, Energy Conservation Building Code (ECBC), Framed Construction, Masonry Construction, Fenestration and glazings. Resources for Building Materials, Alternative concepts, Green Composites for buildings: Concepts of Green Composites. Water Utilization in Buildings, Low Energy Approaches to Water Management. Rain water harvesting, Management of Solid Wastes. Management of Sullage Water and Sewage. Mosquito nuisances and its removal, Urban Environment and Green Buildings. Different strategies for Environmental Remediation: Green Cover and Built Environment, Recycling of Industrial and Buildings Wastes. Biomass Resources for buildings, Solar heat gain system and related area, HVAC, Case Studies.

Module 4: [10L]

Comfort in Green Building, Solar passive Architecture, Thermal Comfort in Buildings, Issues, Incidence of Solar Heat on Buildings-Implications of Geographical Locations, Concepts of Solar Passive Cooling and Heating of Buildings, Low Energy Cooling, Natural ventilation and Louvre system; Utility of Solar energy in buildings, Solar Panel on windows and roof, Applications of Illumination engineering, Use of LED, Case studies of Solar Passive Cooled and Heated Buildings. Approaches for Certification of Green Building.

Text Books:

1. Rackley S.A. Carbon Capture and Storage, Butterworth-Heinemann, 1st edition, 2010.
2. Yan J. (Eds) Handbook of Clean Energy Systems (vol 5), John Wiley & Sons Ltd., 2015.
3. .Jagadish, K S, Venkataramareddy, B U and Nanjundarao, K S, Alternative Building Materials and Technologies. New Age International, 2007.
4. Ursula Eicker, Low Energy Cooling For Sustainable Buildings. John Wiley and Sons Ltd, 2009.
5. Brewer D.C. Green My Home: 10 Steps to Lowering Energy Costs and Reducing Your Carbon Footprint, Kaplan Publishing, 2008.
6. Givoni, B, Man, Climate and Architecture Elsevier, 1969.
7. Krishan, Arvind (Ed), Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings, TMH, 2001.
8. Sustainable Building Design Manual. Vol. 1 and 2, TERI, 2004.

Reference Books:

1. Yan J. (Eds) Handbook of Clean Energy Systems (vol 3), John Wiley & Sons Ltd., 2015.
2. Flynn T.M. Cryogenic Engineering, CRC Press, 2nd Edition, 2004.
3. Osman Attmann, Green Architecture Advanced Technologies and Materials. McGraw Hill, 2010.
4. Michael F. Ashby, Materials and the Environment, Elsevier, 2009.
5. Jerry Yudelson, Green building Through Integrated Design. McGraw Hill, 2009.
6. Majumdar, Mili, (Ed), Energy Efficient Building in India. TERIi and Ministry of Non- conventional Energy System, 2001 / 2002.

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

Course Outcomes:

Upon completion of the course, students will be able to:

1. perform material balance calculations for a specific problem.
2. carry out energy balance calculations for different operations.
3. estimate the energy consumed and suggest means for improving energy efficiencies for boiler and furnace operations.
4. analyze a fluid flow system to select a pump/blower/compressor and estimate the efficiency of the operation.
5. estimate efficiencies for electrical systems in industries e.g. heating, lighting and motors.
6. suggest measures for improving energy efficiency of a small or medium sized industry.

Module 1: [10 L]

Concepts of basis; mole fraction, mass fraction; Material balance without reaction – applications in renewable energy systems; Recycle and bypass calculations; Basics of energy balance – calculation of enthalpy in systems without reaction from mean/temperature-dependent heat capacity data, calculation of heat of reaction and adiabatic reaction temperature in reactive systems; Examples on combined material and energy balances in industrial processes.

Module 2: [10 L]

Heat transfer equipment fundamentals; methods for improving thermal and flow efficiency in
Heat-exchangers – selection of suitable material of construction for tubes, optimizing shell and tube pressure drops; Energy efficiency analysis in boilers and furnaces; heat recovery in waste-heat boilers; heat recovery systems for gas turbines; efficiency analysis of wind turbine systems.

Module 3: [10 L]

Energy efficiency of compression systems – basics of pumps, performance characteristics of centrifugal pumps, BEP in characteristic curve, analysis of series/parallel operation of centrifugal pumps, ways of avoiding cavitation; efficiency of fans and blowers; estimation of single stage and multistage compressor efficiency; estimation of piping losses; efficient design of piping networks by Hardy-Cross method.

Module 4 [10 L]

Efficiency analysis of electrical heating systems – resistance, induction, microwave and radiant heating; characteristics of industrial electrical heating techniques; Lighting control systems for improving energy efficiency of lighting; Efficiency analysis of D.C. motors and Induction motors; control arrangements for D.C. motors and Induction motors.
Analyzing energy efficiency for industrial SMEs.

Text Books:

1. Hodge B.K., Analysis and Design of Energy Systems, Prentice Hall.
2. Shields C. D., Boilers – Types, Characteristics and Functions, McGraw Hill.
3. Dryden I.G.C., The Efficient Use of Energy, Butterworth Scientific.
4. Hughes A., Electric Motors and Drives, 3rd edition, Newnes, Elsevier.

Reference Books:

1. Thollander P. and Palm J., Improving Energy Efficiency in Industrial Energy Systems, Springer.
2. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, American Society of Mechanical Engineers.

Subject Name: Solar Photovoltaic System Design					
Paper Code: REEN 5244					
Contact Hours Per	**L**	**T**	**P**	**Total**	**Credit Points**
Week	**3**	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. demonstrate knowledge of different solar cells modules and uses.
2. describe working of the solar cell modules.
3. explain the selection of batteries for different solar systems.
4. apply engineering materials in renewable Energy/ power generation.
5. design grid connected and standalone solar systems.

Module 1: [10 L]

Brief Introduction to Renewable Energy Technologies, Solar radiation and its characteristics, Radiation estimation and Energy output prediction.

Manufacturing of solar cells: Basics of functioning of solar cell, first generation, second generation and third generation solar cells, Nano-structured Solar PV cell, Concentrating PV system.

Module 2: [10 L]

Measurement and analysis of cell: Solar cell efficiency, I-V characteristic, measurement and analysis of solar cell, Cell temperature effect, IPCE measurement, Reliability standards and reliability testing methods, Reliability Modelling. Solar PV module and array, Shading impact: Bypass diode, blocking diode.

Module 3: [10 L]

Solar PV system equipments: Battery, Inverter, Sun tracker, Charge controllers, Battery parameters and their losses, Factors effecting battery performance: voltage level, discharge current, temperature during discharge, Choice of a battery, Charging and discharging methods, Batteries for PV systems: Lead acid batteries, Nickel cadmium (Ni- Cd) Batteries.

Converters:DC-DC convertors: Introduction and their classification, Control of DC to DC converters, DC to AC converters (Inverters): Single phase DC to AC converter, Three phase DC to AC converter.

Module 4: [10 L]

Maximum power point tracking (MPPT), Charge Controllers: Commonly used Set Points, Type of charge controllers (Shunt type, Series type and MPPT).

Design methodology of PV systems: Design of PV powered DC fan without battery, Design of PV powered DC pump, Standalone PV system configurations (with different types of loads e.g. DC, with battery and DC, AC/DC, battery and AC/DC), Grid connected system without energy storage, Load characteristics, Effect of tracking.

Applications of PV System: Direct coupled, Grid connected, Stand alone, Hybrid system, PV System Economics.

Reference Books:

1. Solanki C.S., Solar Photovoltaics – Fundamentals, Technologies and Applications, 2nd ed., PHI Learning, 2011.
2. Roy J.N. & Bose D.N., Photovoltaic Science and Technology, Cambridge University Press 2018.
3. Master G.M., Renewable and Efficient Electric Power System,; IEEE Press.
4. Andrews J. & Jelly D.N., Energy Science: Principles, Technologies and Impacts, Oxford University press.
5. Roy J.N. & Bose D.N., Introduction to VLSI Design and technology, New Age Publication.

Subject Name: Sustainable Energy Conversion and Storage					
Paper Code: REEN 5245					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. recognize the need to store the renewable energy and their role in the world energy demand.
2. get basic knowledge of the energy storage material properties.
3. understand the importance of energy storage technology and utilize the technology for efficient storage of renewable energy.
4. handle the energy storage equipment and the engineering problems associated with it.
5. correlate between theoretical and practical concept used in energy industry.

Module 1: [10 L]

Need and importance of Energy storage in conventional and nonconventional energy systems. Technical Aspects (Measurements, Quantify). Energy Storage: Devices and Systems. Briefing on various forms of Energy Storage: Thermal, Chemical, Mechanical, Electrical and Nuclear. Techno commercial analysis (Economical aspects) – Leontief Input / Output model.

Module 2: [10 L]

Capacitor, Ultra-capacitor, The Importance of Battery Storage for Sustainable Energy, Fundamentals of batteries, their history and development, applications, Primary Batteries, Rechargeable batteries, zinc and lithium based primary batteries, thermal batteries, lead acid batteries, automotive batteries, alkaline batteries, Li-ion batteries and Advanced rechargeable battery, The Current State of Battery Storage, Redox-flow battery.

Module 3: [10 L]

Nanomaterials in Energy Storage Devices: MWNT for Li Ion Batteries, Nanomaterials in Electrodes, **Hybrid Nanotubes:** Anode Material, Supercapacitor, Battery electrodes and Graphene nanomaterial for energy storage. Different methods for the storage of energy in metal surface. Storage of Hydrogen: Gaseous, Hydrogen economy, Metal Hydrides, Desalination, Definition and working principle of Fuel cell and Reversible fuel cell, Purification of reformate hydrogen fuel.

Module 4: [10 L]

Thermal energy storage: Sensible heat storage: Methods of sensible heat storage using solids and liquids, Stratified storage, Rock bed storage. Latent heat storage: Principle of Phase change materials (PCM), packed bed storage, Stefan problem – Mathematical interpretation for solid to liquid and liquid to solid formation in PCM, Limitations of the model. Wind energy storage– Betz's law; Solar Ponds & Solar Refrigeration, Cryogenic Energy Storage – Linde-Hampson cycle, Claude Cycle and Rankine Cycle.

Reference Books:

1. Bansal N. K., Kleeman M. K., Mells M. Renewable Sources of Energy and Conversion Technology, Tata McGraw-Hill, 1990.
2. A. R. Pendse, Energy Storage Science and Technology, SBS Publishers & Distributors, 2010.

Subject Name: Waste Management With Renewable Energy System					
Paper Code: REEN 5246					
Contact Hours Per	**L**	**T**	**P**	**Total**	**Credit Points**
Week	**3**	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. identify the need for Waste Management Principles in Renewable Energy Systems.
2. analyze different technologies and Legislations/Rules associated with the subject.
3. design Waste Management Plan.
4. identify new indigenous technologies and their utilization.
5. implement Do's & Don'ts practices for Waste Management in Renewable Energy Endeavors.

Module 1: [10 L]

Basics of environmental problems associated with Renewable Energy Engineering. Categorization of Renewable Energy Industries, Mode of getting NOC from Statutory Authorities, Environmental Legislations and Practices applicable in India, Study of Waste Management Rules. Basics of Air and Water pollution aspects in conventional power plants and Renewable Energy Power Plants, Carbon foot print, general discussion on its reduction by the use of renewable energy devices.

Module 2:[10 L]

Basics of Solid waste management: Sources and classification, public health aspects, Methods of collection and disposal methods. Characterization of Solid waste. Details of Testing Methodologies for different components of Solid Waste. Pollution Control and Waste-water treatment using Photo-catalysis with solar energy. E-waste Management, Recycling and Reuse of PV panels and batteries associated with Renewable Energy Industries.

Module 3:[10 L]

Waste Management associated with solar PV, Solar thermal, Hydro-power, Nuclear Power, Wind mill, OTEC, Geothermal energy, Bio-energy –case studies. Environmental Impact Assessment for renewable energy industries– Rain water harvesting, structural hazards and Loss of Biodiversity.

Module 4: [10 L]

Generation of valuable products Wastes of REEN industries, Waste management in illumination engineering industries. Waste Management in lagoons used in solar passive architecture -- Case Studies.

Text/Reference Books:

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.

1st Year 2nd Semester (Semester II)

Laboratory

Subject Name: Non-Solar Renewable Energy Laboratory					
Paper Code: REEN-5251					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**4**	**4**	**2**

Course outcomes:

After completing the course, students will be able to

1. Design processes for producing gaseous fuels from organic waste.
2. Design processes to produce liquid fuels from renewable sources.
3. Characterize the quality of fuel generated from alternative source.
4. Operate electrical equipments for power generation.
5. Analyze the performance of generator.
6. Understand chromatographic technique used for gas mixture analysis.

Experiments:

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

1. Biogas production by anaerobic digestion of organic waste. Biogas analysis and waste characterization.
2. Study of electrical power generation from fuel cell operation.
3. Extraction of bio oil by pyrolysis of waste bio mass.
4. Biodiesel production from vegetable oil.
5. Measurement of 3-Phase power and power factor.
6. Study of Inverter with R and R-L load.
7. Sampling and analysis of air and flue gas from biomass energy systems (i.e. gasifier, combustor and cook stoves) using gas chromatography technique.

Subject Name: Solar Energy Laboratory					
Paper Code: REEN5252					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**4**	**4**	**2**

Course outcomes:

Upon completion of the course, students will be able to:

1. design processes producing alternative source of energy.
2. characterize the quality of fuel generated from alternative source.
3. operate electrical equipments for power generation.
4. understand chromatographic technique used for gas mixture analysis.

Experiments:

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

1. Measurement of solar radiation at different location.
2. Estimating the effect of sun tracking on energy generation by solar PV modules.
3. Efficiency measurement of Stand-alone Solar PV System.
4. Determine the effect of colors (wavelengths) on the efficiency of solar cell.
5. V-I Characteristics of the solar cell at different irradiance level using solar simulator.
6. Measurement of current-voltage characteristics of two solar cells connected a) in series and b) in parallel.
7. Extraction of Solar PV Module parameters from the V-I curve: (i) Short Circuit Current (I_{sc}) (ii) Open Circuit Voltage (V_{oc}) (iii) Fill Factor (iv) Efficiency.

Subject Name: Term Paper and Seminar					
Paper Code: REEN 5221					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**20**	**20**	**10**

A topic will be allotted to individual student according to his/her subject of interest which may lead to his subject of dissertation in the next semester. A thorough report based on the literature review on the topic is to be submitted by the student before presenting it as a seminar. Assessment of the student would be done on the basis of quality of presentation, performance in the question - answer session and the report submitted by a board of faculty members constituted by Departmental Academic Committee.

2nd Year 1stSemester (Semester III)

Theory

Subject Name: Energy Management					
Paper Code: REEN 6141					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course Outcomes:

Upon completion of the course, students will be able to:

1. correlate energy usage with energy requirements and optimize input energy requirements.
2. develop specific questionnaires and perform special tests for gathering data about energy usage for a particular energy system.
3. simulate the given energy system by performing material and energy balance, heat transfer and electrical load calculations and prepare inventories of energy inputs and rejections.
4. identify and suggest energy saving opportunities, determine the total savings for a particular energy system and prepare an effectively organized energy audit report for an industrial plant.
5. prepare process flow diagrams, material & energy balance diagrams and energy balance sheets for a particular energy system and will be able to optimize the energy system.
6. formulate the energy policy for a particular plant and motivate employees towards effective implementation of the policy.

Module 1: [10 L]

Need of Energy Management and Audit. Definition, Objectives and general principles of Energy Management. Energy Management skills, strategies for Energy Management.

Energy Management Approach: Understanding energy costs, Benchmarking, Matching Energy usage to requirements, maximizing system efficiency and optimizing input energy requirements.

Energy Audit: Types, methodology and approach.

Module 2: [10 L]

Procedures and Techniques of energy management:

Data gathering: Level of responsibilities, figures and impression about energy / fuel and system operations, past and present operating data, special tests and questionnaires for data gathering.

Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of energy inputs and rejections, Heat transfer calculations, Evaluation of electrical load characteristics, simulation of process and energy systems.

Evaluation of saving opportunities: Determining the saving in rupees, Noneconomic factors, Conservation opportunities.

Energy Audit Reporting: Plant energy study report – importance, contents, effective organization, writing and presentation.

Module 3: [10 L]

Energy policy planning and implementation:

Key elements: Energy policy – purpose, contents and formulation.

Format and Ratification, Organization: Location of energy manager, Managerial functions, roles and responsibilities of Energy Manager, accountability.

Motivation: Motivating employees, Requirements for Energy Action planning, Marketing and communication training.

Module 4 [10 L]

Energy balance & MIS: First and second laws of efficiency, Methods for preparing process flow diagram, material and energy balance diagram, Identification of losses, improvements, Energy Balance sheet, Management Information System (MIS). Modeling and optimization of energy systems.

Energy Audit instruments: Instruments for audit and monitoring energy and energy savings, types and accuracy.

Text Books:

1. Witte L.C., Schmidt P.S., Brown D.R., Industrial Energy Management and Utilization Hemisphere Publication, Washington.
2. Smith C.B, Energy Management Principles, Pergamon Press.
3. Murphy W.R. and Mckay G., Energy Management, Butterworth Scientific.

Reference Books:

1. Dryden I.G.C., The Efficient Use of Energy, Butterworth Scientific.
2. Desai A.V., Energy Economics, Wiley Eastern.

Subject Name: Renewable Energy Policy and Regulation					
Paper Code: REEN 6142					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course Objective:
The objective of the present course is to provide a gross idea on the regulations followed by policy formulations process for renewable energy sector.

Course Outcome:
1. Upon completion of the course, students will be able to:
2. identify the overall policy, regulatory and institutional framework on Renewable Energy.
3. analyze the main drivers that influence Renewable Energy policy formulation.
4. identify different energy regulatory authorities across the globe.
5. predict emergent policy trends with regard to procurement of renewable energy.
6. identify different initiatives taken by Government of India to enhance the rural energy scenarios.
7. justify and describe the implementation of policy through case studies.

Module 1: [10 L]
Introduction to overall policy environment on energy sector along with policy formulation such as – per capita electricity Consumption, % electrification, GDP, total installed capacity, generation mix and the overall power sector structure, Entities – Consumers and their tariffs, generator, DISCOM, Regulators- Central Electricity Regulatory Commissions (CERC) & State Electricity Regulatory Commissions (SERC), Statutory bodies, SLDC, RLDC, NLDC, CTU, STU, CEA. Typical issues of Indian power sector – Cross Subsidization, Theft of electricity, Transmission losses etc.

Module 2: [10 L]
An Introduction to Indian Renewable Energy Policy, National Solar Missions, Wind Power, National Wind-Solar hybrid policy by MNRE; Regulatory Commissions, Grid Code, Green Corridor, Solar Parks, Hybrid Parks, Repowering, Offshore, Scheduling and Forecasting, Electricity Trading, Open Access, RPO Distributed Generation Regional Grid in the South Asian Region; Electrification and off grid status/scenario in India; Scenario evolving with competitive bidding. National Action Plan on climate Change.

Module 3: [10 L]
Scope and challenges in implementing off grid solutions Policy & regulatory Framework for rural electrification Micro and Mini grids; Relevant policies and frameworks in other countries; Recent off grid programs started by Govt. of India for enhancing the rural electrification through off-grid solutions; Decentralized Distributed Generation (DDG) scheme under Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY); Remote Village Electrification Program Village Energy Security Programme (VESP) Off grid programme under Jawaharlal Nehru National Solar Mission (JNNSM).

Module 4: [10 L]

International regulation of renewable energy; the role of international law and economics in renewable power; Sustainable Energy for All (SE4ALL) Mission; Renewable energy and international trade law; A case study with the first Biogas Bottling Plant towards commercialization in India by Bio- energy Technology Development Group- BGFP; A case study with the 5MW solar project in Anantapura, AP, India highlighting the impact on local environment and related policy making.

Text Books:

1. Abmann D. Renewable Energy: A Global Review of Technologies, Policies and Markets, Earthscan Publications, 1st Edition, 2007.
2. Jolly S. & Jain A. Climate Change: Changing Dimensions of Law and Policy, M D Publications Pvt. Ltd, 1st Edition, 2009.

Reference Books:

1. Lund H. Renewable Energy Systems: A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions, Academic Press, 2014.
2. Dubey S.R. Energy Crisis in India: A Commentary on India's Electricity Sector, Partridge India, 2015.
3. Jones L.E. Renewable Energy Integration: Practical Management of Variability, Uncertainty, and Flexibility in Power Grids, Academic Press, 2nd Edition, 2017.
4. Donovan C.W. Renewable Energy Finance, Powering the Future, World Scientific, 2015.

Subject Name: Environmental Impact Assessment					
Paper Code: REEN6143					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

Upon completion of the course, students will be able to:

1. identify and analyze the Basics of Environmental Engineering Principles and legislations prevalent in India under the purview of Renewable Energy field.
2. conduct EIA Studies.
3. identify new technologies suitable to get EIA certification.
4. implement Do's & Don'ts practices for Renewable Energy Endeavours.

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—Loss of Bio-diversity from Solar Roof-top plant and its remedial measures,, 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/References Books:

1. Tiwari, G N, Ghosal, M K, Renewable Energy Resources—Basic Principles and Applications, Narosa Publishing House, 2006.
2. APHA & AWWA, Standard Methods: APHA & AWWA, 21/e, 2005.
3. MOEF, CPHEEO Manual, GOI Publications, 2015.
4. www.cpcb.nic.in

Subject Name: Composite Materials					
Paper Code: REEN 6121					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course Outcomes:

After completion of the course the students will be able to:

1. understand the structure, fabrication, properties of different advanced composite materials.
2. identify materials for the manufacture of modern devices used in both renewable and non-renewable energy sector.
3. apply knowledge for developing newer advanced materials for the use in renewable energy sector.
4. analyze the economical aspects in solving industrial problems related the development of newer innovative composite materials.
5. conduct research and development activity in the field of materials science & engineering to contribute to the Renewable Energy sector.

Module 1: [9 L]

Learning objective; **Introduction:** Definition; Classification and characteristics of Composite materials; Advantages and application of composites for both general engineering & renewable energy engineering purpose; Functional requirements of reinforcement and matrix; Effect of reinforcement (size, shape, distribution, volume fraction, and orientation of particles and fibres / whiskers) on overall composite performance.

Module 2: **[9 L]**

Applications of composites/nano-composites in renewable energy engineering: Wind turbine, Gas turbine; hydro-turbine; electrical double layer capacitors used in storage devices (conducting polymer carbon nano-tube composites),

tandem & hot carrier solar cells: transition metal- chalcogenides; perovskite-based solar cells, nano-diamond based solar energy converter, graphene-silicon batteries; black phosphorous-based solar photo voltaic; Nickel sulphide anchored graphene composites for high performance super capacitors electrode materials for fuel cell applications; Chromium-doped poly- aniline –CNT nano-composites as super capacitors electrode materials.

Module 3: [9 L]

Reinforcements: Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers, Silicon carbide fibres& Alumina whiskers. Properties and applications of whiskers, particle reinforcements.

Mechanical behaviour of composites: Rule of mixtures, Inverse rule of mixtures. Iso-strain and Iso-stress conditions.

Strength: Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

Module IV: [9 L]

Preparation of Metal Matrix Composites: Casting– Solid State diffusion technique, Cladding – Hot iso-static pressing; Properties and applications;

Preparation of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering; **Preparation of Carbon–Carbon composites:** Knitting, Braiding, Weaving, Properties and applications; Preparation of Polymer Matrix Composites: Preparation of Moulding compounds and pre-pregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding; Properties and applications.

Text Books:

1. R.W. Cahn,P. Haasen, E.J. Kramer eds.Materials science and technology Vol. 13 Structure and Properties of Composites (T.W. Chou ed.) VCH Weinheim, 1993.
2. W D Callister, Jr., Adapted by R. Balasubramaniam, Materials Science and Engineering, An introduction; John Wiley & Sons, NY, Indian edition, 2007.

References Books:

1. Lubin George(Ed). Hand Book of Composite Materials, Van Nostrand Reinhold, 1982.
2. K. K. Chawla. Composite Materials, Composite Materials-Science and Engineering, Springer- Verlag New York, Edition Number 3, 2012.
3. Deborah D.L. Chung. Composite Materials Science and Applications, Springer, 2nd Edition, 2010.
4. Danial Gay, Suong V. Hoa, and Stephen, W. Tasi. Composite Materials Design and Applications; CRC Press, 2002.

Subject Name: Safety and Hazards in Energy Industry					
Paper Code: REEN 6122					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course outcomes:

By the end of the course the students will be able to:

1. analyze the effect of release of toxic substances
2. apply the methods of prevention of fire and explosions
3. understand the advantages of preventive maintenance.
4. understand the methods of hazard identification and preventive measures
5. apply logic based quantitative risk analysis

Module 1: [9L]

Definition of safety, Hazard and Risk, Safety program, Inherent safety, Safety regulations, OSHA, Process safety management, mechanical and electrical hazards, types, causes and preventive steps/procedure, Hazards due to fire, Distinction between fire and explosion, Upper Flammability limit and Lower Flammability Limit, Fire Triangle, Fire prevention and firefighting, equipment and methods, Safety color codes..

Module 2: [9L]

Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Service life of equipment.

Tools for hazards identification: HAZOP, Fault Tree, Event Tree, FMEA, Wear and Corrosion and their prevention, Application of lubrication and different methods of lubrication, Types of corrosion, corrosion prevention methods.

Module 3: [9L]

Risk analysis concept and methodology: Risk concept and measure of risk, Risk acceptance criteria, Quantitative risk analysis, decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, i. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

Module 4: [9L]

Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance.

Reference Books:

1. Higgins L. R., Maintenance Engineering Handbook, McGraw – Hill Companies, 6th. Ed, 2001.
2. Garg H.P., Industrial Maintenance, S. Chand and Company, 2010.
3. Graham F. D., Audels Pumps, Hydraulic, Air Compressors, , McGraw Hill Compaies, 1949.
4. Fang H-Y. (Editor), Foundation Engineering Handbook, 2nd. Ed. Springer, 2012.
5. Crowl D. A. & Louvar J.F., Chemical Process Safety: Fundamentals with Applications, Prentice Hall, 1990.

Subject Name: Engineering Mathematics and Biostatistics					
Paper Code: BIOT6121					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course Outcomes:

After completion of this course, students will be able to:

1. understand and apply the basic principles of engineering mathematics.
2. estimate men, median, mode and other parameters of central tendency in biological samples.
3. evaluate the probability of occurrence by different methods in an experimental set-up.
4. solve problems regarding differences in parameters between experimental and control groups by testing hypothesis.
5. analyze the relationship between experimental groups in biological samples with the help of correlation and regression.
6. estimate the difference between and within biological parameters in same or different groups by analysis of variance.

Module 1: [9L]

Introduction to Engineering Mathematics:

Linear Algebra: Matrices and Determinants, Eigen values and Eigen vectors; Definite integration with Applications; Differential equations with applications; Numerical solution of ODEs: different methods.

Module 2: [9L]

Central tendency and theoretical distribution: Statistics of dispersion: Variability, Central tendency, Mean deviation, Standard Deviation, Variance; Probability Distribution for discrete random variables and continuous random variables; Skewness, Kurtosis, theoretical probability distributions: binomial, poisson, normal.

Module 3: [9L]

Testing Hypothesis: Concepts and importance in experimental research, type of errors; testing means, Significance of difference between means using Z score; Large sample tests based on normal distribution – Test based on t and F distributions, Chi square test for goodness of fit, independence of attribute, homogeneity, and variance of a normal population.

Module 4: [9L]

Correlation, Regression & Anova: Correlation and Regression analysis; Analysis of Variance: One way and two way classifications of Anova – Applications in Biological Sciences.

Text Books:

1. Introduction to Biostatistics. Pranab K Banerjee. (2^{nd} edition). S. Chand & Co.
2. P.N. Arora, P.K. Malhan, Biostatistics, Himalaya Publishing House.
3. B.K. Pal and K. Das. Engineering Mathematics. Vol. 1 and 2. U.N. Dhur & Sons Pvt. Ltd.

Reference Books:

1. Debajyoti Das and Arati Das. Statistics in Biology and Psychology, Academic Publishers.
2. P. Kandasamy, K. Thilakavthy and K. Gunavathy. Numerical Methods. S. Chand and Co., New Delhi, 1999.
3. B.S. Grewal, J.S. Grewal. Numerical Methods in Engineering and Science. Khanna Publishers, New Delhi, 1999.
4. M.K. Jain, S.R.K. Iyengar and R.K. Jain. Numerical Methods for Engineering and Scientific Computation (3rd Edition). New Age International (P) Ltd., New Delhi, 1995.
5. C.F. Gerald, P.O. Wheatley. Applied Numerical Analysis (5th Edition), Addison – Wesley, Singapore, 1998.
6. S. Narayanan, K. Manickavachakam Pillai and G. Ramanaiah. Advanced Mathematics for Engineering Students-Vol.-III. S. Viswanathan Pvt. Ltd., Chennai, 1993.

Course Name :Business Analytics					
Course Code : CSEN6121					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	3	**0**	**0**	**3**	**3**

Course Outcomes:

Upon completion of the course, students will be able to:

1. demonstrate knowledge of data analytics.
2. understand and critically apply the concepts and methods of business analytics.
3. demonstrate the ability to use various techniques to support data driven business decision-making.
4. demonstrate how to recognize trends, detect outliers, summarize data sets and analyze relationships between variables.
5. develop and test hypotheses.
6. learn various tools used in this area on his/her own.

Module 1: [9L] :

Introduction: Overview of Business analytics, Business analytics vs Business Analysis vs Data Science, Scope of Business analytics, Business Analytics Process, Organization structure needed for effective Analytics, Competitive advantages of Business Analytics, Data and models for Business analytics.

Data Visualization: Summarizing Data (Mean, Mode, Variance, Standard Deviation, Skewness), Tools for Single variable (histogram), Tools for Pairs of variables (box plot, scatter plot, contour plot), Tools for Multiple variables.

Statistical Tools: Statistical Notation, Descriptive Statistical methods, Review of probability distribution and data modeling, sampling and estimation methods overview.

Module 2: [9L]

Types of Statistical Analysis: Descriptive type of statistical Analysis, Inferential Type of Statistical Analysis, Predictive Analytics, Perspective Analytics and its step in the business analytics Process, Causal Analysis, nonlinear Optimization.

Trendiness and Regression Analysis: Modeling Relationships and Trends in Data, simple Linear Regression.

Data Mining techniques: Classification, clustering, Association rules, Outer detection, Sequential Patterns used in business analytics.

Forecasting Techniques: Qualitative and Judgmental Forecasting, Statistical Forecasting Models, Forecasting Models for Stationary Time Series, Forecasting Models for Time Series with a Linear Trend, Forecasting Time Series with Seasonality, Regression Forecasting with Casual Variables, Selecting Appropriate Forecasting Models.

Module 3: [9L]

Monte Carlo Simulation and Risk Analysis: Monte Carle Simulation Using Analytic Solver Platform, New-Product Development Model, News vendor Model, Overbooking Model, Cash Budget Model.

Decision Analysis: Formulating Decision Problems, Decision Strategies with the without Outcome Probabilities, Decision Trees, The Value of Information, Utility and Decision Making.

Module 4: [9L]

Recent Trends in Business Analytics: Embedded and collaborative business intelligence, Visual data recovery, Data Storytelling and Data journalism.

Business Analytics Tool – R: Overview of R, Some basic coding syntax of R, Discuss some Modeling Techniques in Business Analytics with R for simple problems.

Reference Books:

1. Business analytics Principles, Concepts, and Applications by Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, Pearson FT Press.
2. Business Analytics by James Evans, persons Education.

2nd Year 1st Semester (Semester III)

Laboratory / Sessional

Course Name : Dissertation/Industrial Project – Phase I					
Course Code : REEN 6195					
Contact Hours Per	**L**	**T**	**P**	**Total**	**Credit Points**
Week	**0**	**0**	**20**	**20**	**10**

Course Outcomes:

After completion of this training Course, the students will be able to:

1. identify a real-life industrial and engineering problem.
2. plan and organize experiments for obtaining necessary data for solving the problem.
3. analyze and interpret the data obtained from the appropriate experiments.
4. work as part of a team which may be multidisciplinary in some cases.
5. present the results by the way of **written (Publications, Project report)** and/or **oral (viva-voce, presentation)** communication.
6. understand the impact of various socio-economic, environmental and political factors on the design and implementation of a solution to a real-life engineering problem.

Each student shall be required under the supervision of a faculty/ joint supervision of faculty and an external expert to prepare an interim 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 interim 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(s) and an external examiner with Head of the Department as Chairman during 3rd Semester examination.

2nd Year 2nd Semester (Semester IV)

Laboratory / Sessional

Subject Name: Dissertation/Industrial Project – Phase II					
Paper Code: REEN 6295					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**28**	**28**	**14**

Course Outcomes:

After completion of this training Course, the students will be able to:

1. identify a real-life industrial and engineering problem.
2. plan and organize experiments for obtaining necessary data for solving the problem.
3. analyze and interpret the data obtained from the appropriate experiments.
4. work as part of a team which may be multidisciplinary in some cases.
5. present the results by the way of **written (Publications, Project report)** and/or **oral (viva-voce, presentation)** communication.
6. understand the impact of various socio-economic, environmental and political factors on the design and implementation of a solution to a real-life engineering problem.

Each student shall be required to carry out and complete the research work that has been assigned to him/her at the beginning of 3rd semester under the supervision of a faculty / joint supervision of faculty and an external expert. The research work has to be carried out by the student himself occasionally consulting his supervisor(s). The report in duplicate has to be submitted in typed and the bound form 7 days before the commencement of the 4^{th} semester examination. Assessment would be made on the basis of the submitted report and seminar presentation followed by viva voce examination conducted by a board of examiners constituted by the Departmental Academic Committee consisting of at least two faculty members, supervisor and an external examiner with the Head of the Department as Chairman during 4 Semester examination.

Subject Name: Grand Viva					
Paper Code: REEN 6297					
Contact Hours Per Week	**L**	**T**	**P**	**Total**	**Credit Points**
	0	**0**	**0**	**0**	**2**

This is a Viva – Voce examination to ascertain the student's overall grasp of the principles of Renewable energy engineering and allied fields. Students may be asked to give presentation on a topic of his choice for the assessment of his teaching skill. Assessment would also be made on the basis of the viva voce examination conducted by a board of examiners constituted by the Departmental Academic Committee consisting of at least three faculty members with Head of the Department as Chairman during 4 Semester examination.