# Chemical Engineering


## DEPARTMENT OF CHEMICAL ENGINEERING

## M.TECH. PROGRAMME IN RENEWABLE ENERGY

**July, 2018**

# PART I: COURSE STRUCTURE

**M.TECH. IN RENEWABLE ENERGY**

## 1st Year 1st Semester (Semester 1)

| THEORY | | | | | | | |
|---|---|---|---|---|---|---|---|
| **S.No** | **Code** | **Course Title** | **L** | **T** | **P** | **H** | **Credit** |
| 01 | REEN 5101 | Energy Resource and Characteristics | 3 | 0 | 0 | 3 | 3 |
| 02 | REEN 5102 | Renewable Energy –I | 3 | 0 | 0 | 3 | 3 |
| 03 | REEN 5103 | Research Methodology and IPR | 2 | 0 | 0 | 2 | 2 |
| 04 | REEN 5141 - 5143 | Professional Elective I | 3 | 0 | 0 | 3 | 3 |
| 05 | REEN 5144-5146 | Professional Elective II | 3 | 0 | 0 | 3 | 3 |
| 06 | DIMA 5116 | Disaster Management | 2 | 0 | 0 | 0 | 0 |
| | PDLS5118 | Personality Development through Life Enlightenment Skills | | | | | |
| | YOGA5119 | Stress Management by Yoga | | | | | |
| | SANS5120 | Sanskrit for Technical Knowledge | | | | | |
| | **Total Theory** | | | | | | **14** |
| | **LABORATORY** | | | | | | |
| **S.No** | **Code** | **Course Title** | **L** | **T** | **P** | **H** | **Credit** |
| 01 | REEN 5151 | Measurement Analysis Lab | 0 | 0 | 4 | 4 | 2 |
| 02 | REEN 5152 | Power Lab | 0 | 0 | 4 | 4 | 2 |
| | **Total Practical** | | | | | | **4** |
| | **Semester Total** | | | | | | **18** |

| **Professional Elective I** | **REEN 5141** | **REEN 5142** | **REEN 5143** |
|---|---|---|---|
| **Subject name** | Material for Renewable Energy Application | Thermal and Electrical Energy Fundamentals | Sustainable Application in Renewable Energy |
| **Professional Elective II** | **REEN 5144** | **REEN 5145** | **REEN 5146** |
| **Subject name** | Optimization Techniques | Applied Numerical Methods | Statistical Analysis |

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## 1st Year 2nd Semester (Semester 2)

| THEORY | | | | | | | |
|---|---|---|---|---|---|---|---|
| **S.No** | **Code** | **Course Title** | **L** | **T** | **P** | **H** | **Credit** |
| 01 | REEN 5201 | Renewable Energy –II | 3 | 0 | 0 | 3 | 3 |
| 02 | REEN 5202 | Renewable Power Generation | 3 | 0 | 0 | 3 | 3 |
| 03 | REEN 5241-5243 | 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** | | | | | | |
| **S.No** | **Code** | **Course Title** | **L** | **T** | **P** | **H** | **Credit** |
| 01 | REEN 5251 | Solar Lab | 0 | 0 | 4 | 4 | 2 |
| 02 | REEN 5252 | Renewable Energy Lab | 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 | Bio Energy | Industrial Energy Analysis |

| **Professional Elective IV** | **REEN 5244** | **REEN 5245** | **REEN 5246** |
|---|---|---|---|
| **Subject name** | Solar Photovoltaic System Design | Energy Storage from Renewable Resource | Waste Management with Renewable Energy Systems |

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## 2nd Year 1st Semester (Semester 3)

| THEORY | | | | | | | |
|---|---|---|---|---|---|---|---|
| **S.No** | **Code** | **Course Title** | **L** | **T** | **P** | **H** | **Credit** |
| 01 | REEN 6141-6143 | Professional Elective V | 3 | 0 | 0 | 3 | 3 |
| 02 | REEN 6121 | Waste to Energy<br>Composite Materials<br>Current Trend in Solar Photovoltaic | 3 | 0 | 0 | 3 | 3 |
| | **Total Theory** | | | | | | **6** |
| | **LABORATORY/SESSIONAL** | | | | | | |
| **S.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** |
|---|---|
| **Subject name** | Waste to Energy |
| | Composite Materials |
| | Current Trend in Solar Photovoltaic |

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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

**M.TECH. IN RENEWABLE ENERGY**

## 1st Year 1st Semester (Semester I)
## Theory

| 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 have:

1. Ability to recognize the need of renewable energy technologies and their role in the India and world energy demand.
2. Ability to distinguish between the sustainable energy sources and fossil energy sources with emphasis on wind and photovoltaic systems.
3. Knowledge of the operating principles of renewable energy production from various renewable sources, especially.
4. Ability to design simple small autonomous photovoltaic and wind energy systems.
5. Knowledge of operating principles of geothermal heat pumps.
6. Ability to compare the advantages and disadvantages of various renewable energy techno logies and propose the best possible energy conversion system for a particular location.
7. Knowledge of security and operational requirements of autonomous and net connected re newable 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, extraterrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution; Heat transfer processes applicable to solar energy, solar radiation, and its analysis; Solar geometry covering all parameter related to the position of the sun with respect to observer; Instruments for measurement of solar energy (Pyranometer/pyrheliometer/ sunshine

recorder), solar radiation on the collector; Depletion of solar radiation - absorption, scattering; beam radiation, diffuse and Global radiation; measurement of solar radiation; solar time - local apparent time (LAT) and equation of time (E); Introduction to solar cells; Relation between solar radiation spectrum and UV-vis & IR component.

**Module 3: [10L]**

**Wind Energy:** current status and future prospects; wind energy in India; power available in the wind; Anemometers and wind directions; environmental benefits and problems of wind energy; factors influencing the cost of energy generation - site specific parameters, World Meteorological Organization (WMO) specification, and machine parameters; wind energy conversion system (WECS): classification, characteristics, and applications; characteristics of wind rotor; wind turbine power and torque characteristics; types of rotors - horizontal and vertical axis wind turbine; Betz limit; Wind pumps - wind driven piston pumps, limitations, and performance analysis; atmospheric circulations, classification, factors influencing wind, wind shear, turbulence, wind speed monitoring, Wind pump basics: Its application and tip speed ratio calculation in withdrawing water; Dynamic wind pumps; Pulsating torque calculation.

**Hydropower:** classification of hydropower plants, small hydropower systems: overview of micro, mini, and small hydro systems; status of hydropower worldwide; advantages and disadvantages of Hydropower; Methods for determining head and flow.

**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: Farredbruch & R.H. Buse. Fundamentals of solar Academic Press, Lundon, 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.
6. Kothari: Renewable Energy Sources and Emerging Technologies, PHI, Eastern Economy Edition, 2012.

7. Renewable Sources of Energy and Conversion Systems: N. K. Bansal and M. K. Kleeman.

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

**Course outcomes:**

1. Students will be able to solve the fundamentals of reaction engineering and fluid mechanics problem as applicable to biomass energy and wind energy respectively.
2. Students will be able to identify different technologies in generating energy from biomass.
3. Students will be able to describe the process used in harnessing and implementation of wind energy.
4. Students will be able categorise 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]**

Wind Energy in India; Measurement of wind: Ecological indicator, Wind speed statistics: Time and Frequency distribution; Mean wind speed and distribution of wind velocity; Statistical model for wind data analysis: Weibull distribution; Annual Energy Output estimation; Uncertainties in estimation; Probabilities of Estimation; Betz criterion Factors influence the cost of energy generation: Site specific parameters, machine. Environmental benefits and problems associated with wind energy/Safety: Noise level, EMF exposures, Shadow flicker, Icing, Structural failure, Effect on biodiversity and effect on climate; Safety devices, Yawing mechanism, pitch controlling system.

Betz coefficient or limit; Understanding of parameters to design of a wind turbine blade; Discussion on blade element theory, momentum element theory, combine element theory, and tip loss theory; Effect of stall and blade pitch on coefficient of power; Tip speed ratio and Cut-in and cut-out wind speeds.

Control of wind turbine:

Mechanical and Electrical perspective; Wind farm electrical design; Planning of wind farms, special application for developing countries, maintenance and operation, wind farm management, site selection; 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 Hydroturbines; 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. V.V.N. Kishore, Renewable Energy, Engineering and Technology: A Knowledge Compendium, The Energy and Resources Institute, TERI, 2009.

**Reference Books:**

1. R. K. Singal, Non-Conventional Energy Resources, S.K. Kataria & Son, 2012.
2. H. Scott Fogler, Elements of Chemical Reaction Engineering, 4th edition, Prentice Hall India Learning Private Limited, 2008.
3. R. K. Bansal, A Textbook of Fluid Mechanics, 1st edition, Laxmi Publications, 2016.
4. W. McCabe, J. Smith, P. Harriott, Unit Operations of Chemical Engineering, 7th Edition, McGraw Hill Education, 2017.

5. H. Wanger, J. Mathur, Introduction to Hydro energy Systems: Basics, Technology and Operation, Springer, 2011.
6. P. Jain, Wind Energy Engineering, McGraw-Hill Education, 2010.
7. D.A. Spera, Wind Turbine Technology: Fundamental Concepts of Wind turbine Engineering, American Society of Mechanical Engineers, 1994.

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| **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:**

1. The students will be able to understand research problem formulation.
2. The students will be able to Analyze research related information.
3. The students will be able to Follow research ethics
4. The students will be able to 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.
5. The students will be able to 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.

**Module 3: [6L]**

Introduction to Detailed Project Report – Incorporating Technical, Marketing, Environment, Social, Financial Part. How to study DPR. Basic Concepts of Feasibility Analysis
Basics of IPR, Methodology of filling patents., follow up action. Basics of Network Analysis and Scheduling, Numerical Problems.

**Text/ Reference Book:**

1. Montgomary, Douglas C. (2007) 5/e, Design and Analysis of Experiments (Wiley India).
2. Kothari C.K. (2004) 2/e, Research Methodoloy – Methods and Techniques (New Age International, New Delhi).
3. Krishnswamy, K.N., Shivkumar, Appa Iyer and Mathiranjan M. (2006) Management Research Methodology; Integration of Principles, Methods and Techniques (Pearson Education, New Delhi).
4. The Complete reference Office Xp- Stephan L. Nelson, Gujulia Kelly (TMH).
5. Chicago Manual of Style.
6. Ouality Circle by S R Udpa.

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| **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:**

1. To get familiarized with the properties of different materials- metals and non metals
2. To learn about the manufacturing process of nanomaterial and its characterizations techniques.
3. Ability to design photovoltaic material and its electronic properties for the solar energy application.
4. Ability to understand the role of selection for the wind turbine material and it required properties.
5. To acquire 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. A. da Rosa, Fundamentals of Renewable Energy Processes, 3rd ed., 2012.
2. Solar cells: Operating principles, technology and system applications, by Martin A.Green, Prentice- Hall Inc, Englewood Cliffs, NJ, USA, 1981.
3. Nanomaterials Chemistry - Recent Developments and New Directions- C.N.R. Rao, A. Muller and A.K. Cheetham (Eds)- Wiley VCH.
4. Semiconductor for solar cells, H.J. Moller, Artech House Inc, MA, USA, 1993.
5. Organic photovoltaics: Concepts and realization, C. Barbec, V.Dyakonov, J.Parisi, N.S.Saricittci, Springer-Verlag 2003.
6. Advances in wind turbine blade design and materials, R.P.L. Nijssen, P. Brøndsted, Elsevier, 2013.

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| **Subject Name: Thermal and Electrical Energy Fundamentals** | | | | | |
|---|---|---|---|---|---|
| **Paper Code: REEN5142** | | | | | |
| **Contact Hours Per Week** | **L** | **T** | **P** | **Total** | **Credit Points** |
| | **3** | **0** | **0** | **3** | **3** |

**Course outcomes:**

1. Understanding the basics of characteristics and behaviour of laws of thermodynamics and its applications to process.
2. Solving the problems related power and refrigeration cycles.
3. Understanding the basics of DC and AC sources along with their applications on electrical circuits.
4. Solving the problems related to applications of network theorems and solving complex DC circuits.
5. Solving the problems related to R-L-C circuits connected to single phase and three phase AC.

**Module 1: [10L]**

First law of Thermodynamics. Definition of Enthalpy, heat capacities. 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.

**Module 2: [10L]**

Statements of second law of thermodynamics. Reversibility, irreversibility and carnot cycle. Concept of entropy. Clausius inequality. Power cycle and its efficiencies. Refrigeration cycle and COP. 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]**

Representation of sinusoidal quantities, steady state analysis of R-L-C series and 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. YA Cengel and MA Boles: Thermodynamics: An Engineering Approach, Sixth Edition (Tata McGraw-Hill, 2008).
2. B.L.Theraja, A.K.Theraja, "A text book of Electrical Technology", S.Chand Publication, 2012.

**Reference Books:**

1. PK Nag: Engineering Thermodynamics, Third Edition (Tata McGraw-Hill, 2005).
2. C.P Arora: Thermodynamics, Tata McGraw-Hill, New Delhi, 2003.
3. D.P.Kothari, I.J.Nagrath, "Fundamentals of electrical engineering", Tata Mc Graw-Hill Publication, 2016.
4. R. Prasad: Fundamentals of Electrical Engineering, PHI publication, 3rd edition, 2014.

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| Subject Name: Sustainable Application in Renewable Energy | | | | | |
|---|---|---|---|---|---|
| **Paper Code: REEN5143** | | | | | |
| **Contact Hours Per Week** | **L** | **T** | **P** | **Total** | **Credit Points** |
| | **3** | **0** | **0** | **3** | **3** |

**Course outcomes:**

1. The students will be able to identify the technologies pertaining to sustainable and renewable energy application.
2. The students will be able to analyse different sources of renewable energy and innovative technologies in harnessing energy from these renewable sources.
3. The students will be able to design CCS and cryogenic energy storage facility in harnessing renewable energy.
4. The students will be able to construct green building in the context of energy savings.
5. The students will be able to 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. 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. Stephen A. Rackley, Carbon Capture and Storage, 1st edition, Butterworth-Heinemann, 2010.
2. Jinyue Yan (Ed), Handbook of Clean Energy Systems (vol 5), John Wiley & Sons, Ltd., 2015.
3. K.S.Jagadish, B. U. Venkataramareddy and K. S. Nanjundarao. 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. Dennis C. Brewer, Green My Home!: 10 Steps to Lowering Energy Costs and Reducing Your Carbon Footprint, Kaplan Publishing, 2008.
6. B. Givoni, Man, Climate and Architecture Elsevier, 1969.
7. Arvind Krishan (Ed), Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings, Tata McGraw Hill, 2001.
8. Sustainable Building Design Manual. Vol 1 and 2, Teri, New Delhi, 2004.

**Reference Books:**

1. Jinyue Yan (Ed), Handbook of Clean Energy Systems (vol 3), John Wiley & Sons, Ltd., 2015.
2. Thomas M. Flynn, Cryogenic Engineering, 2nd Edition, CRC Press, 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. Mili Majumdar (Ed), Energy Efficient Building in India. Teri and Ministry of Non-conventional Energy System, 2001/2002.

7. T. N. Seshadri, Mela Ram Sharma, Sharafat Ali, Climatological and Solar Data for India: To Design Buildings for Thermal Comfort, Central Building Research Institute and Sarita Prakashan, 1968.

**M.TECH. IN RENEWABLE ENERGY**

| **Subject Name: Optimization Techniques** | | | | | |
|---|---|---|---|---|---|
| **Paper Code: REEN5144** | | | | | |
| **Contact Hours Per Week** | **L** | **T** | **P** | **Total** | **Credit Points** |
| | **3** | **0** | **0** | **3** | **3** |

**Course outcomes:**

1. Given an unconstrained optimization problem, students will be able to apply the correct optimization method to solve the problem.
2. Given a constrained optimization problem, students will be able to set up the objective function correctly and apply appropriate methods to solve the problem.
3. Given a power generation system, students will be able to apply appropriate optimization methods to determine the optimal scheduling of power generation and also will be able to find out the most economic load dispatch scheduling for power generating units.
4. Given an optimization problem involving Genetic Algorithm, students will be able to correctly implement the necessary algorithm to solve the problem.
5. Students will be able to implement algorithms for Particle Swarm Optimization/Simulated Annealing/Genetic Algorithm appropriately as required for specific optimization problems in energy systems.

**Module 1: [10 L]**

Essential features of optimization problems, General methods to solve optimization problems, continuity of functions, unimodal, multimodal, convex and concave functions; 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 [Edgar, Himmelblau].

**Module 2: [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 [Power System Optimization-kothari dhillon].

**Module 3: [10 L]**

Evolutionary algorithms - Fundamentals of Evolutionary algorithms; Working Principles of Genetic Algorithm; Genetic Operators – Selection; Crossover and Mutation-Issues in GA implementation.

**Module 4: [10 L]**

Particle Swarm Optimization - Velocity Updating-Advanced operators; Parameter selection

Simulated annealing algorithm – Tabu Search, Case studies of optimisation in Energy systems – problems.

**Text/Reference Book:**

1. Power System Optimization (2nd Edition): D.P. Kothari, J.S. Dhillon, PHI.
2. Optimization of Chemical Processes: D.M. Himmelblau, T.F. Edgar, McGraw-Hill.
3. Modern Optimization Techniques with Applications in Electric Power Systems: S.A.H. Soliman, A.A.H. Mantawy.

**M.TECH. IN RENEWABLE ENERGY**

| **Subject Name: Applied Numerical Methods** | | | | | |
|---|---|---|---|---|---|
| **Paper Code: REEN5145** | | | | | |
| **Contact Hours Per Week** | **L** | **T** | **P** | **Total** | **Credit Points** |
| | **3** | **0** | **0** | **3** | **3** |

**Course outcomes:**

1. Students will be able to develop an the mathematical problem based on physical problems in renewable energy applications.
2. Students will be able to apply appropriate numerical methods to solve numerical problems in renewable energy systems.
3. Students will be able to justify the mathematical concepts underlying the numerical methods considered.
4. Students will be able to construct the appropriate numerical algorithm to solve the engineering problem.

**Module 1: [10 L]**
LU Decomposition; Iteration Methods: Relaxation method; Concept of Jacobian; Concept of Hessian matrice; Multivariate Newton-Raphson method for non-linear root finding; Order of convergence and stability criterion.

**Module 2: [10 L]**
Polynomial interpolation: Need for interpolation and Lagrangian polynomial interpolation; Least square method for linear regression; Levenberg Marquardt algorithm for non-linear regression; Multivariate first order regression; Concept of a numerical solution to a differential equation: Stiff and non-stiff differential equation; Initial value problems solution by Runge-Kutta Methods.

**Module 3: [10 L]**
Concept of partial differential equation (PDE); Discretization in space and time; Implicit and explicit scheme; Finite difference: Crank-Nicholson method to solve parabolic PDE; Numerical Integration: Simpson's 1/3 rule and Gaussian Quadrature formula.

**Module 4: [10 L]**
Case study I: Numerical Simulation of a Wind Turbine with a Hydraulic Transmission System; Case Study II: A Detailed Performance Model for Photovoltaic Systems.

**Text Books:**


1. Steven Chapra, Raymond Canale, Numerical Methods for Engineers, 7th Edition (McGraw Hill Education India Private Limited)
2. Amos Gilat, Vish Subramaniam, Numerical Methods for Engineers and Scientists, 3rd Edition (John Wiley and Sons).

**Reference Books:**

1. G. Miller, Numerical Analysis for Engineers and Scientists, Cambridge University Press, 2014.
2. Laurene v. Fausett, Applied Numerical Analysis Using MATLAB, 2nd edition, Pearson India, 2007.
3. F. Carl Knopf, Modeling, Analysis and Optimization of Process and Energy Systems, John Wiley & Sons, 2011.
4. S. Sumathi, L. Ashok Kumar, P. Surekha, Solar PV and Wind Energy Conversion Systems: An Introduction to Theory, Modeling with MATLAB/SIMULINK, and the Role of Soft Computing Techniques, Springer, 2016.

**M.TECH. IN RENEWABLE ENERGY**

| **Subject Name: Statistical Analysis** | | | | | |
|---|---|---|---|---|---|
| **Paper Code: REEN5146** | | | | | |
| **Contact Hours Per Week** | **L** | **T** | **P** | **Total** | **Credit Points** |
| | **3** | **0** | **0** | **3** | **3** |

## Course outcomes:

1. The students will be able to understand the need for studying the subject Statistical Analysis.
2. The students will be able to analyze data using different Probability Distributions
3. The students will be able to conduct the basic tests of statistical inferences
4. The students will be able to formulate design of experiments by developing suitable statistical models.
5. The students will be able to perform experiments on Co-relation and regression and involve themselves in decision making processes using Response Surface Methodologies.

**Module 1: [10 L]**
Probability Distributions and its applications: Binomial, Poisson, Normal. Different parameters associated with distributions and their computations, Basic approach towards central limit theorem.

**Module 2: [10 L]**
Null and Alternative Hypothesis: one way and two way classification models, numerical problems Tests of Hypothesis: Type I and type II error, Z, t, F and Chi-square distributions, goodness of fit, Basics of Analysis of Variance.

**Module 3: [10 L]**
Factorial Design of Experiments for fixed effect models: Decomposition of the total sum of squares, the normality assumptions, plot of residuals, estimation of model parameters, model adequacy checking, numerical problems.
Factorial Design of Experiments for random effects models: Latin square and related designs, mixed effect model.

**Module 4: [10 L]**
Partial, multiple correlation and regression; Hypothesis testing in Multiple Linear Regression, numerical problems, 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.

**Text Books:**

1. K L Chung, Elementary probability theory with stochastic processes, 4th Edition, Springer.

2. Douglas C. Montgomery, Design and Analysis of Experiments, Wiley International Student Version 8th Edition.

**Reference Books:**

1. Yule & Kendall, Introduction to the Theory of Statistics, Arnold, 1976 ed.
2. Eugene Grant & Richard Leavenworth Statistical Quality Control, TMH, 2017.

**M.TECH. IN RENEWABLE ENERGY**

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

**Course outcomes:**

Students will be able to:

1. Learn to demonstrate a critical understanding of key concepts in disaster risk reduction and humanitarian response.
2. Critically evaluate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
3. Develop an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
4. Critically understand the strengths and weaknesses of disaster management approaches.
5. Planning and programming in different countries, particularly their home country or the countries they work in.

**Module 1: [6L]**

Introduction on Disaster:
Disaster: Definition:
Types of Disaster:

- Natural Disaster: such as Flood, Cyclone, Earthquakes, Landslides etc.
- Man-made Disaster: such as Fire, Industrial Pollution,
  Nuclear Disaster, Biological Disasters, Accidents (Air, Sea, Rail & Road), Structural failures (Building and Bridge), War & Terrorism etc.
- Differences, Nature and Magnitude.
- Factors Contributing to Disaster Impact and Severity.
- Repercussions of various types of Disasters
    - Economic Damage
    - Loss of Human and Animal Life
    - Destruction of Ecosystem
    - Outbreaks of Disease and Epidemics
    - War and Conflict

Natural Disaster-prone areas in INDIA:

- Areas prone to
    - Earthquake
    - Floods and Droughts,
    - Landslides and Avalanches;

- Cyclonic And Coastal Hazards such as Tsunami;

Trends of major Disasters and their Impact on India

- Lessons Learnt from Recent Disasters.

Introduction to Disaster Management:
What is Disaster Management.
Different Phases of Disasters.
Disaster Management Cycles.
Disaster Management Components:

- Hazard Analysis.
- Vulnerability Analysis.
- Prevention and Mitigation.
- Preparedness.
- Prediction and Warning.
- Response.
- Recovery.

Disaster Management Act, 2005.
National Disaster Management Structure .
Organizations involved in Disaster Management.

**Module 2: [6L]**

Overview on Hazard Analysis and Vulnerability Analysis:
Disaster Preparedness:

- Disaster Risk Assessment, People's Participation in Risk Assessment.
- Disaster Risk Reduction.
- Preparedness Plans.
- Community preparedness: Emergency Exercises/ Trainings/Mock Drills.

Disaster Prediction and Warning:

- Activities:
  - Tracking of disaster.
  - Warning mechanisms.
  - Organizational response.
  - Public education.
  - Communication.
  - Evacuation planning.
- Current tools and models used for Prediction and Early Warnings of Disaster:
  - Application of Remote Sensing .
  - Data From Meteorological and other agencies.
  - Smartphone/ Web based Apps for Disaster Preparedness and Early Warning used in different parts of Globe.

**Module 3: [6L]**

Disaster Response:

- Crisis Management: The Four Emotional Stages of Disaster:
  - Heroic Phase.
  - Honeymoon Phase.
  - Disillusionment Phase.
  - Reconstruction Phase.
- Need for Coordinated Disaster Response:
  - Search, Rescue, Evacuation, Medical Response and Logistic Management.
  - Psychological Response and Management (Trauma, Stress, Rumor and Panic).
- Role of Government, International and NGO Bodies.

Post-disaster Situation Awareness:

- Need for Situation Awareness in Post Disaster scenario.
- Challenges in communication of situational data from affected areas.
- Need for community-driven disaster management for reliable situation awareness.
- Crowd-sourcing of situational data: Issues and challenges.

Post-disaster Damage and Need Assessment:

- Current Trends and Practices – RAPID Damage and Need Assessment.
- SPHERE standards in Disaster Response.
- ICT based techniques for Post-disaster 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.
- Creation of Long-term Job Opportunities and
- Livelihood Options.
- Disaster Resistant House Construction.
- Sanitation and Hygiene.
- Education and Awareness.
- Dealing with Victims' Psychology.
- Long-term Counter Disaster Planning.

Disaster Mitigation:

- Meaning, Concept and Strategies of Disaster Mitigation .
- Emerging Trends in Mitigation .
- Structural Mitigation and Non-Structural Mitigation .
- Programs of Disaster Mitigation In India.

**Text/ Reference Book:**

1. R. Nishith, Singh AK, "Disaster Management in India: Perspectives, issues and strategies", New Royal book Company.
2. Sahni, Pardeep et.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.

**M.TECH. IN RENEWABLE ENERGY**

## 1st Year 1st Semester (Semester I)
## Laboratory

| **Subject Name: Measurement Analysis Lab** | | | | | |
|---|---|---|---|---|---|
| **Paper Code: REEN5111** | | | | | |
| **Contact Hours Per Week** | **L** | **T** | **P** | **Total** | **Credit Points** |
| | **0** | **0** | **4** | **4** | **2** |

**Course outcomes:**

1. Ability to characterize and analyse of liquid fuel property
2. Ability to measure the insulating property of material
3. Ability to operate various sophisticated analytical equipment
4. Ability to determine energy efficiency of various process equipment

**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 Lux meter.
9. Solute concentration analysis of an aqueous solution using UV-Vis spectrophotometer.
10. Solute concentration analysis of a non-aqueous solution using GC analyser.

**M.TECH. IN RENEWABLE ENERGY**

| **Subject Name: Power Lab** | | | | | |
|---|---|---|---|---|---|
| **Paper Code: REEN5112** | | | | | |
| **Contact Hours Per Week** | **L** | **T** | **P** | **Total** | **Credit Points** |
| | **0** | **0** | **4** | **4** | **2** |

**Course outcomes:**

1. Ability to understand the operation of electrical equipment like AC and DC motor.
2. Ability to understand the concept of power generation and effective distribution and transmission.
3. Ability to 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.