Heritage Institute of Technology

DEPARTMENT OF CHEMICAL ENGINEERING
M.TECH. PROGRAMME IN RENEWABLE ENERGY

Curriculum and Syllabus, June 2019
PART I: COURSE CURRICULUM
### 1st Year 1st Semester (Semester 1)

#### THEORY

<table>
<thead>
<tr>
<th>S.No</th>
<th>Code</th>
<th>Course Title</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>H</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>REEN 5101</td>
<td>Energy Resource and Characteristics</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>02</td>
<td>REEN 5102</td>
<td>Renewable Energy –I</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>03</td>
<td>REEN 5103</td>
<td>Research Methodology and IPR</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>04</td>
<td>REEN 5141-5143</td>
<td>Professional Elective I</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>05</td>
<td>REEN 5144-5146</td>
<td>Professional Elective II</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>06</td>
<td>DIMA 5116</td>
<td>Disaster Management</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PDLS 5118</td>
<td>Personality Development through Life Enlightenment Skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>YOGA 5119</td>
<td>Stress Management by Yoga</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SANS 5120</td>
<td>Sanskrit for Technical Knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>INCO 5177</td>
<td>Constitution of India</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Theory** 14

#### LABORATORY

<table>
<thead>
<tr>
<th>S.No</th>
<th>Code</th>
<th>Course Title</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>H</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>REEN 5151</td>
<td>Measurement Analysis Laboratory</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>02</td>
<td>REEN 5152</td>
<td>Power Laboratory</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

**Total Practical** 4

**Semester Total** 18

<table>
<thead>
<tr>
<th>Professional Elective I</th>
<th>Code</th>
<th>Course Title</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject name</td>
<td>REEN 5141</td>
<td>Material for Renewable Energy Application</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REEN 5142</td>
<td>Thermal and Electrical Energy Fundamentals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REEN 5143</td>
<td>Sustainable Application in Renewable Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional Elective II</td>
<td>REEN 5144</td>
<td>Numerical Methods in Optimization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REEN 5145</td>
<td>Applied Numerical Methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>REEN 5146</td>
<td>Statistical Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 1st Year 2nd Semester (Semester 2)

#### THEORY

<table>
<thead>
<tr>
<th>S.No</th>
<th>Code</th>
<th>Course Title</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>H</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>REEN 5201</td>
<td>Renewable Energy –II</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>02</td>
<td>REEN 5202</td>
<td>Renewable Power Generation</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>03</td>
<td>REEN 5241-5243</td>
<td>Professional Elective III</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>04</td>
<td>REEN 5244-5246</td>
<td>Professional Elective IV</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>05</td>
<td>Audit Course – any one subject from Elective III or Elective IV bucket</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total Theory</strong></td>
<td></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

#### LABORATORY/SESSIONAL

<table>
<thead>
<tr>
<th>S.No</th>
<th>Code</th>
<th>Course Title</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>H</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>REEN 5251</td>
<td>Renewable Energy I Laboratory</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>02</td>
<td>REEN 5252</td>
<td>Renewable Energy II Laboratory</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>03</td>
<td>REEN 5221</td>
<td>Term Paper and Seminar</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><strong>Total Practical</strong></td>
<td></td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><strong>Semester Total</strong></td>
<td></td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>18</td>
</tr>
</tbody>
</table>

**Professional Elective III**

<table>
<thead>
<tr>
<th>Subject name</th>
<th>REEN 5241</th>
<th>REEN 5242</th>
<th>REEN 5243</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hydrogen and Fuel Cell Technology</td>
<td>Bio Energy</td>
<td>Industrial Energy Analysis</td>
</tr>
</tbody>
</table>

**Professional Elective IV**

<table>
<thead>
<tr>
<th>Subject name</th>
<th>REEN 5244</th>
<th>REEN 5245</th>
<th>REEN 5246</th>
</tr>
</thead>
</table>
# M.TECH. IN RENEWABLE ENERGY

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

<table>
<thead>
<tr>
<th>S.No</th>
<th>Code</th>
<th>Course Title</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>H</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>REEN 6141-6143</td>
<td>Professional Elective V</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>02</td>
<td>REEN 6121</td>
<td>Composite Materials</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>REEN 6122</td>
<td>Safety and Hazards in Energy Industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIOT 6121</td>
<td>Engineering Mathematics and Biostatistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CSEN 6121</td>
<td>Business Analytics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total Theory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S.No</th>
<th>Code</th>
<th>Course Title</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>H</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>REEN 6195</td>
<td>Dissertation/Industrial Project – Phase I</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total Practical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Semester Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Professional Elective V</th>
<th>REEN 6141</th>
<th>REEN 6142</th>
<th>REEN 6143</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject name</td>
<td>Energy Management</td>
<td>Renewable Energy Policy and Regulation</td>
<td>Environment Impact Assessment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open Elective – I</th>
</tr>
</thead>
<tbody>
<tr>
<td>REEN 6121</td>
</tr>
<tr>
<td>REEN 6122</td>
</tr>
<tr>
<td>BIOT 6121</td>
</tr>
<tr>
<td>CSEN 6121</td>
</tr>
<tr>
<td>S. No</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>01</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>02</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
PART II: DETAILED SYLLABUS
1\textsuperscript{st} Year 1\textsuperscript{st} Semester (Semester I)
Theory
Subject Name: Renewable Energy Resource and Characteristics

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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 technologies and propose the best possible energy conversion system for a particular location.
7. Knowledge of 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, 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/pyrhiometer/ 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:

Course Outcomes:

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

Reference Books:
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]

Module 3: [6L]
Text/ Reference Book:
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:
Subject Name: Thermal and Electrical Energy Fundamentals

Paper Code: REEN5142

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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]

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:
M.TECH. IN RENEWABLE ENERGY

Reference Books:

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; CO2 trapping mechanism and geological storage; CO2 fluid properties and interaction with rocks; Wettability, capillary pressure and relative permeability; Impact of impurities on rock and fluid properties; Application of CO2 in retrieving geothermal energy; Energy generation for CO2 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 Joule-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 cryogenic 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]
Module 4: [10L]

Text Books:

Reference Books:
Subject Name: Numerical Methods in Optimization
Paper Code: REEN5144

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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:
Subject Name: Applied Numerical Methods
Paper Code: REEN5145

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>L节/时</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
1. Students will be able to develop the mathematical model 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.
5. Students will be able to simulate Wind Turbine with a Hydraulic Transmission System, photovoltaic systems etc.

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:
Reference Books:
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]

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:

Reference Books:
M.TECH. IN RENEWABLE ENERGY

<table>
<thead>
<tr>
<th>Subject Name: Disaster Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper Code: DIMA5116</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

**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.
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:
- 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 Books:
2. Sahni, Pardeep et.al. (Eds.),” Disaster Mitigation Experiences And Reflections”, Prentice Hall of India, New Delhi.
Course Name: Personality Development through Life Enlightenment Skills
Course Code: PDLS5118

Course Outcomes:
1. After the completion of this course, students should be able to:
2. Study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life.
3. The person who has studied Geeta will lead the nation and mankind to peace and prosperity.
4. Study of Neetishatakam will help in developing versatile personality of students.

Module I (6L)
Neetisatakam-Holistic development of personality
1. Verses - 19,20,21,22 (wisdom)
2. Verses - 29,31,32 (pride & heroism)
3. Verses - 26,28,63,65 (virtue)

Module II (6L)
Approach to day to day work and duties.
1. Verses - 52,53,59 (dont’s)
2. Verses - 71,73,75,78 (do’s)
3. Shrimad Bhagwad Geeta : Chapter 2-Verses 41, 47,48

Module III (6L)
Statements of basic knowledge.
1. Chapter 3-Verses 13, 21, 27, 35, Chapter 6-Verses 5,13,17, 23, 35,
2. Chapter 18-Verses 45, 46, 48.
3. Shrimad Bhagwad Geeta: Chapter2-Verses 56, 62, 68
4. Chapter 12 -Verses 13, 14, 15, 16,17, 18

Module IV (6L)
Personality of Role model.
1. Shrimad Bhagwad Geeta: Chapter2-Verses 17, Chapter 3-Verses 36,37,42,
2. Chapter 4-Verses 18, 38,39
3. Chapter18 – Verses 37,38,63

Text/ Reference Books:
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

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

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 Training-Part-I” :Janardan Swami Yogabhyasi Mandal, Nagpur.
2. “Rajayoga or conquering the Internal Nature” by Swami Vivekananda, AdvaitaAshrama (Publication Department), Kolkata.
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]
1. Alphabets in Sanskrit.
2. Past/Present/Future Tense.

Module 2: [6L]
1. Simple Sentences.
2. Order.

Module 3: [6L]
1. Introduction of roots.
2. Technical information about Sanskrit Literature.

Module 4: [6L]

Text/Reference Books:
Course Name: Constitution of India
Course Code: INCO5117

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

**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:**
1. After the completion of this course, students should be able to:
2. Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
3. Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
4. 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.

**Module 1: [8L]**

**Module 2: [4L]**

**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 IV (8L)**
1. 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: ZilaPachayat; Elected officials and their roles; CEO ZilaPachayat: Position and role; Block level: Organizational Hierarchy (Different departments); Village level: Role of Elected and Appointed officials, Importance of grass root democracy.
2. 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.
1st Year 1st Semester (Semester I)
Laboratory
Subject Name: Measurement Analysis Laboratory

Paper Code: REEN5111

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

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:
1. At least any five experiments are to be carried out by students
2. Characterization of fuel (Measurement of Flash point, Fire point, Cloud point, Pour point etc.).
3. Determination of calorific value of fuel.
4. Analysis of moisture content and kinematic viscosity of fuel.
5. Measurement of energy consumption using energy meter.
7. Determination of thermal conductivity of insulating materials.
8. Analysis of forced convection heat transfer.
10. Solute concentration analysis of an aqueous solution using UV-Vis spectrophotometer.
M.TECH. IN RENEWABLE ENERGY

Subject Name: Power Laboratory
Paper Code: REEN5112

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

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 characterize various types of motors and generators.
4. 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.
1st Year 2nd Semester (Semester II) Theory
M.TECH. IN RENEWABLE ENERGY

Subject Name: Renewable Energy –II
Paper Code: REEN5201

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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

Module 1: [10L]
One dimension steady state heat conduction with and without heat generation. Convective heat transfer coefficient. Thermo siphon system and forced convection system. Film wise and drop wise condensation. Pool boiling curve. **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.

Module 2: [10L]

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, process control measures, quality control techniques Single and poly crystalline silicon solar cells, Materials and process requirements for module assembly, routine and type tests, qualification test standards, types of degradation 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, Quantum-dot, Hot-carrier, Up conversion and down conversion Latest benchmark efficiencies.

Text Books:

Reference Books:
Subject Name: Renewable Power Generation
Paper Code: REEN 5202

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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

Module 1: [10L]
Solar Thermal Power Generation:

Module 2: [15L]
Solar PV power generation:

Module 3: [7L]
Wind power generation:

Module 4: [8L]
Other forms of renewable energy generation:
Geothermal power generation: liquid dominated and vapour dominated geothermal electric power plant.

**Text/ Reference Books:**

Subject Name: Hydrogen and Fuel Cell Technology
Paper Code: REEN 5241

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
The objective of the course is to provide comprehensive and logical knowledge of hydrogen production, storage, and utilization. In addition,

1. Ability to demonstrate knowledge of renewable energy technology.
2. Able to understand the role of nanotechnology in energy conversion.
3. Provide an understanding of various fuel cell technologies.
4. To build knowledge to design nano-systems, component or process as per need and specification.
5. To acquire knowledge layered Integration and performance for micro fuel cell systems.
6. To acquire knowledge about the different types of fuel cell and their application.

Module 1: [10L]

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.

Module 3: [10L]

Module 4: [10L]
M.TECH. IN RENEWABLE ENERGY

Reference Books:
Subject Name: Bio Energy
Paper Code: REEN 5242

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
1. The students will be able to identify different technologies for biomass conversion to energy.
2. The students will be able to justify the unit operations necessary to generate bioenergy.
3. The students will be able to identify different bio-resources to produce energy.
4. The students will be able to describe technologies required for bio-gas.
5. The students will be able to design processes for biofuel production.
6. The students will be able to solve problems with the application of bioreactors to generate bioenergy.

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; CO₂ 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.

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:

Reference Books:
Subject Name: Industrial Energy Analysis
Paper Code: REEN 5243

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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

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.
M.TECH. IN RENEWABLE ENERGY

Text Books:

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

Module 1: [10 L]

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.
M.TECH. IN RENEWABLE ENERGY

Reference Books:
Subject Name: Energy Storage from Renewable Resource

Paper Code: REEN 5245

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
1. Ability to recognize the need to store the renewable energy and their role in the world energy demand.
2. To build basic knowledge of the energy storage material properties.
3. To utilize the technological methods related to efficient storage of renewable energy.
4. To study a detailed overview of the energy storage equipment and problems associated.
5. To build a bridge between theoretical and practical concept used in industry.
6. To study the importance of battery storage for sustainable energy.

Module 1: [10 L]

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]

Module 4: [10 L]

Reference Books:
3. 
Subject Name: Waste Management With Renewable Energy System

Course Outcomes:
1. The students will be able to identify the need for Waste Management Principles in Renewable Energy Systems.
2. The students will be able to analyze different technologies and Legislations/Rules associated with the subject.
3. The students will be able to design Waste Management Plan.
4. The students will be able to identify new indigenous technologies and their utilization.
5. The students will be able to implement Do’s & Don’ts practices for Waste Management in Renewable Energy Endeavors.

Module 1: [10 L]

Module 2: [10 L]

Module 3: [10 L]

Module 4: [10 L]

Text/Reference Books:
4. www.wbpcb.gov.in
1st Year 2nd Semester (Semester II)
Laboratory
Subject Name: Renewable Energy I Laboratory

Paper Code: REEN-5251

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Course Outcomes:

1. To study a detailed working function of the energy storage equipment
2. Able to understand the working principle of different solar cell arrangements
3. To build a basic knowledge on the solar cell performance with respect to different environmental factors
4. To study the effect of solar radiation on the solar cell efficiency.

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.
Course Outcomes:
1. Student will be able to design processes producing alternative source of energy.
2. Students will be able to characterize the quality of fuel generated from alternative source.
3. Students will be able to operate electrical equipments for power generation.
4. Students will be able to understand chromatographic technique used for gas mixture analysis.

Experiments:
At least any four experiments are to be carried out by students
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 power factor and load characteristics of Power generator.
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: Term Paper and Seminar  
Paper Code: REEN 5221  

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

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 1st Semester (Semester III)
Theory
Subject Name: Energy Management
Paper Code: REEN 6141

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
1. Given a specific energy system, students will be able to match energy usage with energy requirements and optimize input energy requirements.
2. Students will be able to prepare specific questionnaires and perform special tests for gathering data about energy usage for a particular energy system.
3. Students will be able to simulate the given energy system by performing material and energy balance, heat transfer and electrical load calculations and will be able to prepare inventories of energy inputs and rejections.
4. Students will be able to 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. Students will be able to 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. Students will be able to formulate the energy policy for a particular plant and motivate employees towards effective implementation of the policy.

Module 1: [10 L]
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:

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

Text Books:

Reference Books:
Subject Name: Renewable Energy Policy and Regulation

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 Outcomes:
1. The students will be able to identify the overall policy, regulatory and institutional framework on Renewable Energy.
2. The students will be able to analyze the main drivers that influence Renewable Energy policy formulation.
3. The students will be able to identify different energy regulatory authorities across the globe.
4. The students will be able to predict emergent policy trends with regard to procurement of renewable energy.
5. The students will be able to identify different initiatives taken by Government of India to enhance the rural energy scenarios.
6. The students will be able to 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:

Reference Books:
2. Dubey S.R. Energy Crisis in India: A Commentary on India’s Electricity Sector, Partridge India, 2015.
Subject Name: Environmental Impact Assessment
Paper Code: REEN 6143

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
1. The students will be able to identify the Basics of Environmental Engg. Principles need for carrying out EIA.
2. The students will be able to analyze different technologies and Legislations/Rules.
3. The students will be able to conduct EIA Studies.
4. The students will be able to identify new technologies suitable to get EIA certification.
5. The students will be able to implement Do’s & Don’ts practices for Renewable Energy Endeavours.

Module 1: [10L]

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]

Module 4: [10L]
Text/References Books:
4. www.cpcb.nic.in
Subject Name: Composite Materials
Paper Code: REEN 6121

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
By the end of the course the students will be able to
1. Impart updated knowledge and provide strong foundation to the M. Tech. students on the preparation, structure, fabrication, properties and applications of different advanced composite materials.
2. Acquire vast ideas and strong confidence in applications of high tech materials in modern devices used in both renewable and non-renewable energy sector.
3. Carry out R & D activities for developing newer advanced materials for use in renewable energy sector.
4. Solve stringent industrial problems and needs wherever applicable more economically.
5. Pursue higher studies & carry out research works effectively in the field of materials science & engineering.
6. Acquire sound employability in different eminent academic, R & D institutes and industries.

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]

Module IV: [9 L]
Preparation of Metal Matrix Composites: Casting– Solid State diffusion technique, Cladding – Hot isostatic 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:

References Books:
Subject Name: Safety and Hazards in Energy Industry
Paper Code: REEN 6122

<table>
<thead>
<tr>
<th>Contact Hours</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Week</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
By the end of the course the students will be able to
1. Analyze the effect of release of toxic substances.
2. Understand the industrial laws, regulations and source models.
3. Apply the methods of prevention of fire and explosions.
4. Understand the advantages of preventive maintenance.
5. Understand the relief and its sizing methods.
6. Understand the methods of hazard identification and preventive measures.
7. Understand logic tree analysis and 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]

Module 3: [9L]

Module 4: [9L]
M.TECH. IN RENEWABLE ENERGY

Reference Books:
Subject Name: Engineering Mathematics and Biostatistics

Paper Code: BIOT6121

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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

1. Understand and apply the basic principles of engineering mathematics.
2. Estimate mean, 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 of hypothesis:
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:
Reference Books:
Course Name: Business Analytics
Course Code: CSEN6121

<table>
<thead>
<tr>
<th>Contact Hours Per Week</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Total</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Course Outcomes:
1. Students will demonstrate knowledge of data analytics.
2. Understand and critically apply the concepts and methods of business analytics.
3. Students will demonstrate the ability to use various techniques to support data driven business decision-making.
4. Student will demonstrate how to recognize trends, detect outliers, summarize data sets and analyze relationships between variables.
5. Able to develop and test hypotheses.
6. Initiate interest to 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:

Module 3: [9L]
Monte Carlo Simulation and Risk Analysis:

**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:**
2. Business Analytics by James Evans, persons Education.
2nd Year 1st Semester (Semester III)
Laboratory/Sessional
Each student shall be required under the supervision of a faculty/joint supervision of a 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 and an external examiner with Head of the Department as Chairman during 3rd Semester examination.
2nd Year 2nd Semester (Semester IV)
Laboratory/Sessional
Each student shall be required to carry out and complete the research work that has been assigned to him at the beginning of 3rd semester under the supervision of a faculty / joint supervision of a 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 bound form 7 days before the commencement of the 4th 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 Head of the Department as Chairman during 4th Semester examination.
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 4th Semester examination.