M. Tech.

IN

ENERGY ENGINEERING

CURRICULUM

(For students admitted in 2017-18)

DEPARTMENT OF ENERGY AND ENVIRONMENT
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI – 620 015

TAMIL NADU, INDIA
CURRICULUM

The total minimum credits for completing the M.Tech. Programme in Energy Engineering is 66.

SEMESTER I

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>EN 601</td>
<td>FOUNDATION FOR ENERGY ENGINEERING</td>
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<tr>
<td>2.</td>
<td>EN 603</td>
<td>ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL</td>
<td>3</td>
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<td>3.</td>
<td>EN 605</td>
<td>SOLAR ENERGY UTILIZATION</td>
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<td>7.</td>
<td>EN 607</td>
<td>SOLAR AND ENVIRONMENTAL ENGINEERING LABORATORY</td>
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<td>8.</td>
<td>EN 609</td>
<td>PROFESSIONAL SKILL DEVELOPMENT</td>
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SEMESTER II

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<tr>
<td>1.</td>
<td>EN 602</td>
<td>BIO ENERGY TECHNOLOGIES</td>
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<td>2.</td>
<td>EN 604</td>
<td>COMPUTATIONAL FLUID DYNAMICS</td>
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<td>3.</td>
<td>EN 606</td>
<td>ENERGY AUDIT AND MANAGEMENT</td>
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<td>4.</td>
<td>ELECTIVE 4</td>
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<td>ELECTIVE 5</td>
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<td>6.</td>
<td>ELECTIVE 6</td>
<td>EN 648 NPTEL/CERTIFIED COURSES</td>
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<td>COMPUTATIONAL FLUID DYNAMICS LABORATORY</td>
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<td>EN 610</td>
<td>MINI PROJECT</td>
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### SEMESTER III

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<td>EN 667</td>
<td>PROJECT WORK - PHASE I</td>
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<tr>
<td>EN 612</td>
<td>INTERNSHIP*</td>
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* Students need to undergo an internship for a period of minimum one month in CSIR LABS/ Industries before starting the project work during the vacation of second semester. The outcome of internship will be evaluated (PASS/FAIL) at the starting of third semester.

### SEMESTER IV

<table>
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<tr>
<td>EN 668</td>
<td>PROJECT WORK - PHASE II</td>
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## LIST OF ELECTIVES - I/II/III

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<th>Course Code</th>
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<tbody>
<tr>
<td>1.</td>
<td>EN 613</td>
<td>ENERGY SYSTEMS MODELING AND ANALYSIS</td>
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<tr>
<td>2.</td>
<td>EN 615</td>
<td>FUELS AND COMBUSTION TECHNOLOGY</td>
<td>3</td>
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<td>3.</td>
<td>EN 617</td>
<td>HEAT AND MASS TRANSFER</td>
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<td>4.</td>
<td>EN 619</td>
<td>AIR CONDITIONING AND REFRIGERATION</td>
<td>3</td>
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<td>EN 621</td>
<td>THERMAL ENGINEERING</td>
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<td>6.</td>
<td>EN 623</td>
<td>POWER PLANT TECHNOLOGY</td>
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<td>7.</td>
<td>EN 625</td>
<td>ELECTRICAL ENERGY TECHNOLOGY</td>
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<td>8.</td>
<td>EN 627</td>
<td>POWER GENERATION, TRANSMISSION AND DISTRIBUTION</td>
<td>3</td>
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<td>9.</td>
<td>EN 629</td>
<td>POWER SYSTEMS PLANNING AND OPERATION</td>
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<td>10.</td>
<td>EN 631</td>
<td>INSTRUMENTATION AND CONTROL IN ENERGY SYSTEMS</td>
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## LIST OF ELECTIVES - IV/V/VI

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<tr>
<td>11.</td>
<td>EN 614</td>
<td>BATTERIES AND FUEL CELLS</td>
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<td>12.</td>
<td>EN 616</td>
<td>DESIGN OF HEAT TRANSFERS EQUIPMENTS</td>
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<td>13.</td>
<td>EN 618</td>
<td>DIRECT ENERGY CONSERVATIONS</td>
<td>3</td>
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<td>14.</td>
<td>EN 620</td>
<td>ENERGY EFFICIENT BUILDINGS</td>
<td>3</td>
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<td>15.</td>
<td>EN 622</td>
<td>OPTIMUM UTILIZATION OF HEAT AND POWER</td>
<td>3</td>
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<tr>
<td>16.</td>
<td>EN 624</td>
<td>POWER GENERATION &amp; SYSTEMS PLANNING</td>
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<tr>
<td>17.</td>
<td>EN 626</td>
<td>RENEWABLE POWER GENERATION SOURCES</td>
<td>3</td>
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<tr>
<td>18.</td>
<td>EN 646</td>
<td>WNID ENERGY AND HYDRO POWER SYSTEMS</td>
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<tr>
<td>19.</td>
<td>EN 648</td>
<td>NPTEL/CERTIFIED COURSES</td>
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**LIST OF RESERVED ELECTIVES**

<table>
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<tr>
<td>20.</td>
<td>EN 628</td>
<td>ADVANCED HEAT TRANSFER</td>
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<tr>
<td>21.</td>
<td>EN 630</td>
<td>ADVANCED THERMODYNAMICS</td>
<td>3</td>
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<td>22.</td>
<td>EN 632</td>
<td>ADVANCED REACTION ENGINEERING</td>
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<td>23.</td>
<td>EN 633</td>
<td>COMPUTATIONAL HEAT TRANSFER</td>
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<tr>
<td>24.</td>
<td>EN 634</td>
<td>ENERGY RESOURCES, ECONOMICS &amp; ENVIRONMENT</td>
<td>3</td>
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<tr>
<td>25.</td>
<td>EN 635</td>
<td>ENVIRONMENTAL IMPACT ASSESSMENT AND ECONOMIC</td>
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<tr>
<td>26.</td>
<td>EN 636</td>
<td>NUCLEAR, HYDEL &amp; OTEC POWER PLANTS</td>
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<td>27.</td>
<td>EN 637</td>
<td>NUCLEAR REACTOR THEORY</td>
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<td>28.</td>
<td>EN 638</td>
<td>OPTIMIZATION</td>
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<td>29.</td>
<td>EN 639</td>
<td>POWER SOURCES FOR ELECTRIC VEHICLES</td>
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<td>30.</td>
<td>EN 640</td>
<td>TECHNOLOGY MANAGEMENT</td>
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<td>31.</td>
<td>EN 641</td>
<td>THERMAL ENVIRONMENTAL ENGINEERING</td>
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<td>32.</td>
<td>EN 642</td>
<td>UNIT OPERATIONS IN INDUSTRIES</td>
<td>3</td>
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<tr>
<td>33.</td>
<td>EN 643</td>
<td>WASTE MANAGEMENT AND ENERGY GENERATION TECHNOLOGY</td>
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<td>34.</td>
<td>EN 644</td>
<td>WASTE TO ENERGY</td>
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<td>35.</td>
<td>EN 645</td>
<td>INSTRUMENTATION IN ASSESSMENT OF WATER AND WASTEWATER QUALITY</td>
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<td>36.</td>
<td>EN 811</td>
<td>PRINCIPLES OF DOWNSTREAM TECHNIQUES IN BIOPROCESS</td>
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<tr>
<td>Course Code</td>
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<td>FOUNDATION FOR ENERGY ENGINEERING</td>
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<td>Course Type</td>
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**Course Content**

**Thermodynamics**: first law and its application, second law and its application, Irreversibility and energy, basic power generation cycles.


**Electrical Machines**: Transformer, Induction motor and generators, Synchronous generators, Introduction to modern speed control techniques, DC machines. Power systems: Introduction to power transmission and distribution.

**Text/References**

Course Code : EN 602
Course Title : BIO ENERGY TECHNOLOGIES
Number of Credits : 3
Course Type : Core

Course Content
Sources and Classification - Chemical composition, properties of biomass - Energy plantations. Size reduction, Briquetting, Drying, Storage and handling of biomass

Feedstock for biogas, Microbial and biochemical aspects - operating parameters for biogas production. Kinetics and mechanism- High rate digesters for industrial waste water treatment


Industrial effluents [Food waste, Textile, Distilleries, Glue, paper and pulp, Dairy and miscellaneous]; Waste to Energy [Domestic sewage, Municipal solid wastes]; Biorefineries; Biohydrogen production.

Combustion of rice husk and woody biomass - Life Cycle Analysis of biofuels - Environmental aspects of biofuel utilization - Techno-economic features of bio-fuels

Reference Books:
7. Bioenergy and Biofuel from Biowastes and Biomass edited by Samir Kumar Khana, ASCE Publications, 2010
Course Code : EN 603
Course Title : ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL
Number of Credits : 3
Course Type : Core

Course Content
Environmental Pollution- units of measurements, material balance and energy fundamentals, classification of pollution

Air Pollution Control Methods & Equipment- sources and effects of air pollution – Sampling measurement and analysis of air pollutants- design, control and modeling. Air pollution Act, standards.


Water Pollution - sources of water pollutants– Classification and effects of Water Pollutants –Water pollution Laws and Standard

Environment For Comfort Living & Working - Comfort & Climate –Temperature, humidity and ventilation Control– AC load, Natural & Artificial Lighting, Noise Sources, control.

Reference Books:
Course Code: EN 604
Course Title: COMPUTATIONAL FLUID DYNAMICS
Number of Credits: 3
Course Type: Core

Course Content
Governing Equations of Fluid Flow, Finite Difference, Finite Volume, Finite Element Methods, Laplace Equation, Diffusion Equation or Wave Equation

Application of Finite Volume Method to Fluid Flow problems - Pressure Correction Techniques Gauss Siedel - Gauss Jordan. Introduction to Multi grid Methods - Boundary Conditions


Reference Books:
Course Code : EN 605
Course Title : SOLAR ENERGY UTILIZATION
Number of Credits : 3
Course Type : Core

Course Content
Solar radiation, availability, measurement and estimation; Isotropic and anisotropic models; empirical relations, solar collectors and types: flat plate, concentrating solar collectors, advanced collectors and solar concentrators, Selective coatings

Solar water heating, Solar cooking, Solar drying, Solar distillation and solar refrigeration, Active and passive heating and cooling of buildings, Solar Chimney, Solar drying

Solar thermal power generation, Home lighting systems, Solar lanterns, Industrial process heat systems, Solar thermal power generation and sterling engine, Solar economics.

Photo-voltaic cell – characteristics- cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-charge regulators, Construction concepts.

Energy Storage - Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber’s salt-organic compounds. Solar ponds.

Reference Books:
Course Code : EN 606  
Course Title : ENERGY AUDIT AND MANAGEMENT  
Number of Credits : 3  
Course Type : Core

Course Content
Steam engineering, steam traps and various Energy Conservation Measures in Steam; Boilers - types, losses and efficiency calculation methods. Boiler controls.
Organizational background desired for energy management motivation, detailed process of M&T; Specific energy consumption and energy cost calculation methodologies - CUSUM, balanced ratio etc. Case studies across industries. Visit to energy generation / consumption facility.

Reference Books:
4. Larry C Whitetal, Industrial Energy Management & Utilization
**Course Code**: EN 607  
**Course Title**: SOLAR AND ENVIRONMENTAL ENGINEERING LABORATORY  
**Number of Credits**: 1  
**Course Type**: LABORATORY

**Course Learning Objectives**  
To provide the hands on experience on the various Environmental Engineering / Solar Energy related instruments and data analysis.

**Course Content**

**ENVIRONMENTAL ENGINEERING**
1. Air quality measurement using find dust sampler  
2. Air pollution analysis using flue gas analyzer  
3. Measurement of DO for liquid effluents  
4. Measurement of COD for liquid effluents  
5. Measurement of BOD for liquid effluents  
6. Study of aerator design on water treatment  
7. Study on noise pollution of various devices

**SOLAR ENGINEERING**
1. Study of direct and diffused beam solar radiation  
2. Study of green house effect  
3. Performance evaluation of solar flat plate collector  
4. Study the effect of solar flat plate collector in parallel combination  
5. Performance evaluation of concentrating solar collector  
6. Performance evaluation of solar cooker  
7. Performance evaluation of a solar PV panel  
8. Performance of PV panel in series and parallel combination
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<td>Course Title</td>
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<td>Course Type</td>
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</table>

**Course Content**
1. Flow in static mixer
2. Flow in a process injection-mixing pipe
3. Flow from a circular vent
4. Flow in an Axial rotor/stator arrangement
5. Multiphase flow in mixing vessel
6. External flow over Ahmed body
7. Supersonic flow in a Laval nozzle
8. Flow through a butterfly valve
9. Flow through an automatic catalytic converter
10. Flow through an engine inlet valve
11. Conjugate heat transfer in a process-heating coil
12. Combustion and radiation in a Can Combustor
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<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>Course Title</td>
<td>PROFESSIONAL SKILL DEVELOPMENT</td>
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<td>LABORATORY</td>
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**Course Content**

**Communication:**
Concepts, goals and levels of communication - General and technical communication - Significance of technical communication - Barriers to effective communication - Psychology of communication.

**Oral Communication:**
Tools and skills of communication - Presentation skills and Use of PowerPoint Slides, Public Speaking - Extempore / Prepared Speech - Requirements of oral communication - Body language and Non verbal Cues - Difference between Group Discussion and Debate - Interview techniques.

**Written Communication:**
Effective Writing - Focus on Writing; Coherence and Cohesion - Report Writing - CV and Resume Writing - Drafting Proposals, Research papers - preparation of technical / software manuals - Reader Perspective - Comprehending and Summarizing a text - Non verbal cues in Writing.

**Developing Listening Skills:**
Listening as an active skill - Kinds of Listening- Listening for general content; Listening for specific information - Intensive Listening - Developing effective listening skills; Barriers to effective listening skills - Listening Comprehension - Retention of facts, data & figures - Role of speaker in listening. Difference between note taking and note making.

**Technology and Communication:**
Telephone etiquette - Effective email messages - Editing skills - Use of charts and graphs using computer software - Elements of style in technical writing - Role of media in technology and communication - Library and Reference skills.

**Sustainability**

**Reference Books:**

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<tr>
<th>Course Code</th>
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<tbody>
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<td>Course Title</td>
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<td>Course Type</td>
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**Course Learning Objectives**
To make the student to realize the extent of the work related to energy efficiency occurring in other institute / industries.

**Course Content**
A training of eight week duration is to be undergone by students during summer vacation after the completion of 2nd semester. The training will be on the practical aspects of various energy technologies at Energy Industry / Energy Projects / Energy Centres / R&D Institutions / Research Laboratories etc. A technical report and seminar are to be presented after completion of training for evaluation.
Course Code : EN 613
Course Title : ENERGY SYSTEMS MODELLING AND ANALYSIS
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Overview of technologies and conventional methods of energy conversion, Workable and optimum systems, Steps in arriving at a workable system, Creativity in concept selection

Mathematical modeling, Exponential forms - Method of least squares - Counter flow heat exchanger, Evaporators and Condensers, Effectiveness, NTU, Pressure drop and pumping Power

Classes of simulation, flow diagrams, Sequential and simultaneous calculations, Newton-Raphson method- Optimization procedure, mathematical statement of the problem

The Lagrange multiplier equations, Sensitivity coefficients- Single variable – Exhaustive, Dichotomous and Fibonacci, Multivariable unconstrained - Lattice, Univariable and Steepestascent

Dynamic Programming-Geometric Programming-Linear Programming- Linear regression analysis, Internal energy and enthalpy, Pressure temperature relationship at saturated conditions

Reference Books:
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<th><strong>EN 614</strong></th>
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<tr>
<td><strong>Course Title</strong></td>
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<td><strong>BATTERIES AND FUEL CELLS</strong></td>
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**Course Content**
Basic concepts – Components of cells and batteries, Classification of cells and batteries, Operation of a cell, Specifications – Free energy, theoretical cell voltage, specific capacity, specific energy, energy density, memory effect, cycle life, shelf life, state of charge (SOC) and depth of discharge (DOD), internal resistance and coulombic efficiency.

Electrochemical principles and reactions – electrical double layer, discharge characteristics of cell and polarization, Electrode processes and Tafel polarization, thermodynamic background and Nernst equation.

Primary and secondary batteries – Zn/C, Zn/air, alkaline cells, lithium primary batteries, lead-acid, Ni/Cd, Ni/MH and Lithium secondary batteries (Components, Chemistry and Performance characteristics). Applications of storage batteries.

Fuel cell fundamentals, The alkaline fuel cell, Acidic fuel cells, SOFC (components, chemistry and challenges) - Emerging areas in Fuel cells

Fuel cell outlook, Applications of fuel cells – Industrial and commercial.

**Reference Books:**
3. *Principles of Fuel Cells, by Xianguo Li, Taylor & Francis, 2006*
Course Code : EN 615
Course Title : FUELS AND COMBUSTION TECHNOLOGY
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Fuels & Fuel Analysis-Combustion Stoichiometry, theoretical & actual combustion processes – Air fuel ratio.

Combustion Thermodynamics- calculation of heat of formation & heat of combustion – First law analysis of reacting systems
Heat Treatment Furnaces- Industrial furnaces – process furnaces – Kilns – Batch & continuous furnaces


Combustion Appliances- Gas burners- Functional requirement of burners – Gas burner Classification –Stoker firing –pulverized system of firing

Reference Books:
**Course Code**: EN 616  
**Course Title**: DESIGN OF HEAT TRANSFER EQUIPMENTS  
**Number of Credits**: 3  
**Course Type**: ELECTIVE

### Course Content
Types – Details – Specifications for heat exchangers – Standards of heat exchangers Study of different methods used for design of heat exchangers, classification, design methodology, LMTD and NTU methods.

Design of double pipe heat exchanger-study and performance - Design of shell and tube heat exchanger.

Extended surfaces, fin design, longitudinal and transverse fins.

Regenerators - Plate type heat exchangers - Compact heat exchangers- Cross flow heat exchangers

### Reference Books:
**Course Code**  :  EN 617  
**Course Title**  :  HEAT AND MASS TRANSFER  
**Number of Credits**  :  3  
**Course Type**  :  ELECTIVE

**Course Content**

Flow classifications, mass, momentum and energy relations in differential form.

Exact and approximate solutions to forced convection in laminar and turbulent, internal and external flow. 
Solution to natural convection problems.

Heat transfer at high velocity and incompressible fluid. Liquid metal heat transfer.


**Reference Books:**

Course Code : EN 618
Course Title : DIRECT ENERGY CONVERSION
Number of Credits : 3
Course Type : Core

Course Content

Thermoelectric conversion: thermoelectric effects, analysis of thermoelectric generators and coolers, figure of merit, device configuration

Photovoltaic conversion, Optical effects of p-n junction, design and analysis of PV cells. PV cell fabrication, System design


Batteries and fuel cell: Thermodynamic analysis, design and analysis of batteries and fuel cells. Other modes of direct energy conversion.

Reference Books:
2. Angrist S.W., Direct Energy Conversion. 4th Ed. Allyn And Bacon, Boston, 1982
**Course Content**
Thermodynamic concepts, Thermodynamic systems and postulates, thermodynamic equilibrium, thermodynamic relations, stability and phase transition. Principles of air conditioning, methods of refrigeration.

**Vapour and combined power cycles**: Simple steam power cycle - Rankine cycle - comparison of Rankine & Carnot Cycle - reheat cycle-regenerative cycle-direct contact and surface contact regenerators- characteristics of an ideal working fluid in vapor cycle-binary vapor cycle thermodynamics of combined cycles.


Vapour compression system adsorption and adsorption cycles, Air-cycle steam jet. Refrigeration systems and their performances: compressors, expansion devices, evaporators, condensers, absorbers, Cooling towers etc.

Comfort factors - specifications - Limits for humidity, temperature etc. Heat load estimation, air distribution, ventilation, instrumentation.

**Reference Books:**
<table>
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<tr>
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<tbody>
<tr>
<td>Course Title</td>
<td>ENERGY EFFICIENT BUILDINGS</td>
</tr>
<tr>
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</table>

Course Content


Cooling and heating concepts, Passive concepts appropriate for the various climatic zones in India. Classification of building materials based on energy intensity.


Reference Books:
**Course Code**: EN 621  
**Course Title**: THERMAL ENGINEERING  
**Number of Credits**: 3  
**Course Type**: ELECTIVE

### Course Content

**Air Compressor**: Reciprocating air compressors. Types – Construction, work of compression without clearance, effect of clearance. Multi staging. Optimum intermediate pressure for perfect inter cooling. Compressor efficiencies and mean effective pressure.

**Vapour and combined power cycles**: Simple steam power cycle - Rankine cycle - comparison of Rankine & Carnot cycle - Reheat cycle - Regenerative cycle – Actual vapour cycle processes - Characteristics of an ideal working fluid in vapor cycle - Binary vapour power cycle – Efficiencies in steam power plant.


**Steam Turbines**: Principles of operation - Classification of turbines - Simple impulse turbine - Velocity, Pressure compounded impulse turbine - Turbine velocity diagrams for flow of steam thro turbine blades - Forces on the blades & work done - Blade or diagram efficiency - Steam turbine performance.

**Internal combustion Engines**: Classification of IC Engine components - Four stroke cycles, valve timing - Spark ignition - Air Fuel mixtures - Mixture requirements of automotive Engines & four stroke Engine - Comparison of two stroke with four stroke 0Engines – Engine power - Indicated power - Break horse power - Engine efficiency - Performance analysis of IC Engine.

### Reference Books:


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<th>Course Code</th>
<th>EN 622</th>
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<tbody>
<tr>
<td>Course Title</td>
<td>OPTIMUM UTILIZATION OF HEAT AND POWER</td>
</tr>
<tr>
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Course Content

Basic concepts of CHP- The benefits and problems with CHP –Balance of energy demand– Types of prime movers - Economics– CHP in various sectors. Application & techno economics of Cogeneration- Cogeneration -Performance calculations, Part load characteristics- financial considerations - Operating and Investments


Reference Books:

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<tbody>
<tr>
<td>Course Title</td>
<td>POWER PLANT TECHNOLOGY</td>
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<tr>
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</table>

**Course Content**
Thermodynamic concepts, Thermodynamic systems and postulates, thermodynamic equilibrium, thermodynamic relations, stability and phase transition

Power Plants - Features, Components and Layouts - Working of Power Plants, Power Plant Economics

Boiler Classification - Boiler Types - Fire Tube & Water Tube Boilers - Fluidized Bed Boilers - Positive Circulation Boilers - Thermal Liquid Heaters & Vaporizers

Classification - Features - Working - Performance of Steam Turbines - Losses in Steam Turbines - Trouble Shooting - Classification and Comparison of Different Types Gas Turbine Power Plants Components - Economics & Future of Combined Cycles


**Reference Books:**
3. Arora and Domkundwar, A course in Power Plant Engineering, Dhanpat Ra, N.Delhi.2003
Course Code: EN 624
Course Title: POWER GENERATION AND SYSTEMS PLANNING
Number of Credits: 3
Course Type: ELECTIVE

Course Content

Steam Turbine - Superheater, reheater and partial condenser vacuum. Combined Feed heating and Reheating. Regenerative Heat Exchangers, Reheaters and Intercoolers in Gas Turbine power plants.

Hydro power plants - turbine characteristics. Auxiliaries - Water Treatment Systems, Electrostatic Precipitator / Flue gas Desulphurisation, Coal crushing / Preparation - Ball mills / Pulverisers, ID/FD Fans, Chimney, Cooling Towers.

Power plant control systems- Review of control principles, Combustion control, pulveriser control, control of air flow, Furnace pressure and feed water, steam temperature control, Safety provisions / Interlocks


Reference Books:

4. T.M. O’ Donovan, Short Term Forecasting: An introduction to the Box Jenkins Approach, Wiley, Chichester, 1983
<table>
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<tr>
<th>Course Code</th>
<th>EN 625</th>
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</thead>
<tbody>
<tr>
<td>Course Title</td>
<td>ELECTRICAL ENERGY TECHNOLOGY</td>
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**Course Content**
Transformers – Parallel operation, auto transformers
DC machines - generator characteristics - motor characteristics - applications
Synchronous machines - permanent magnet alternators – Induction machines.

Transmission line – power flow study – power factor improvement, faults on
power systems, symmetrical components, introduction to HVDC systems

Controlled rectifiers, choppers, inverters, voltage regulators and cycloconverters.
Speed control of dc motors – converter –fed and chopper –fed control.
Speed control
of ac motors – Inverter –fed and ac voltage controller –fed schemes

Wind-driven induction generators, grid connected Photo-voltaic systems, Steady state
performance, integration issues, principles of energy auditing

**Reference Books:**

Course Code : EN 626
Course Title : RENEWABLE POWER GENERATION SOURCES
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Basic characteristics of sunlight – solar energy source- photovoltaic - characteristics – equivalent circuit – photo voltaic for battery charging – charge regulators

Source –energy in the wind- aerodynamics – rotor types – forces developed by blades braking systems - control and monitoring system – power performance


Micro-hydel electric systems- isolated and parallel operation of generators- geothermal operation of generators – geothermal – tidal and OTEC systems.

Reference Books:

Course Code : EN 627
Course Title : POWER GENERATION, TRANSMISSION AND DISTRIBUTION
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Generation: Synchronous generator operation, Power angle characteristics and the infinite bus concept, Dynamic analysis and modeling of synchronous machines, Excitation systems, Prime-mover governing systems, Automatic generation control, Auxiliaries, Power system stabilizer, Artificial intelligent controls,

Power quality of AC Transmission: Overhead and cables, Transmission line equations, Regulation and transmission line losses, Reactive power compensation, Flexible AC transmission, HVDC Transmission: HVDC converters, Advantages and economic considerations converter control characteristics, Analysis of HVDC link performance, Multi terminal DC system, HVDC and FACTS,

Distribution: Distribution systems, Conductors size, Kelvin’s law performance calculations and analysis, Distribution inside and commercial buildings entrance terminology, Substation and feeder circuit design considerations, Distributions automation, Futuristic power generation

Reference Books:
**Course Code** : EN 628  
**Course Title** : ADVANCED HEAT TRANSFER  
**Number of Credits** : 3  
**Course Type** : ELECTIVE

**Course Content**
Heat conduction - basic law, governing equations in differential form, solution methods, steady state, unsteady state problems-fins, moving boundaries.

Convective heat transfer - conservation equations, boundary layer approximations. Forced convective laminar and turbulent flow solutions.

Natural convection solutions, correlations. Radiation heat transfer mechanism; properties; exchange between black and non black surfaces, condensation - mechanism, controlling parameters.

Nusselt Theory; solution to laminar film modifications, influence of other parameters, correlations for single horizontal tube, vertical bank of horizontal tubes, other configurations.


**TEXT BOOKS**

**REFERENCES**
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<tr>
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<tr>
<td>Course Title</td>
<td>POWER SYSTEM PLANNING AND OPERATION</td>
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**Course Learning Objectives**
To enable the student to understand the process in planning of power systems and their operation.

**Course Content**
Generation system capacity adequacy planning: Probabilistic models of generating unit outage performance and system load-evaluation of loss of load and loss of energy indices, Probabilistic production costing

Inclusion of power generation from renewable energy sources in the reliability analysis, Interconnected systems: multi-area reliability analysis, power pool operation and power/energy exchange contracts

Quantification of economic and reliability benefits by pool operation, Demand / energy forecasting: sector-wise peak demand and energy forecasting by trend and econometric projection methods

Optimal power system expansion planning: formulation of least cost optimization problem incorporating the capital, operating and maintenance costs of candidate plants of different types (thermal, hydro, nuclear, non conventional etc.) and minimum assured reliability constraint-optimization techniques for solution by linear and dynamic programming approaches-case studies.

**Reference Books:**
6. Eodrenyi, J., "Reliability modelling in Electric Power System" John Wiley,
Course Code : EN 630
Course Title : ADVANCED THERMODYNAMICS
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Review of Basic Postulates, Maxwell’s relations, Legendre Transformation, Pure Component properties, Theory of corresponding states, real fluids Equilibrium, Phase Rule, Single component phase diagrams, Introduction to Multicomponent Multiphase equilibrium

Introduction to Classical Mechanics, quantum Mechanics, Canonical Ensemble, Microcanonical Ensemble, Grand Canonical Ensemble, Boltzmann, Fermi-dirac and Bose Einstein Statistics, Fluctuations, Monoatomic and Diatomic Gases

Introduction to Classical Statistical Mechanics, phase space, liouville equation, Crystals, Intermolecular forces and potential energy functions, imperfect Monoatomic Gases, Molecular theory of corresponding states, introduction to Molecular Simulations, Mixtures, partial molar properties, Gibbs Duhems equations, fugacity and activity coefficients,

Ideal and Non-ideal solutions, Molecular theories of activity coefficients, lattice models, multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Chemical Equilibrium and Combined phase and reaction equilibrium.

Reference Books:
Course Code: EN 631
Course Title: INSTRUMENTATION AND CONTROL IN ENERGY SYSTEMS
Number of Credits: 3
Course Type: ELECTIVE

Course Content
Measurement Errors - Materials, radiant storage- Transducer classification- Static and dynamic characteristics of transducers, Transient analysis of a control system.

Temperature Measurement - Bimaterials, Pressure thermometers, Thermocouples, RTD, Thermisters, and Pyrometry, pyrometers- Calibration of Pressure measuring equipment.


Digital data processing and display, Computer data processing and control, Feedback control system, Stability and transient analysis of control systems, Application of PID controllers, General purpose control devices and controller design

Reference Books:
Course Code : EN 632
Course Title : ADVANCED REACTION ENGINEERING
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Homogeneous reactor design and analysis-I: Ideal reactors, Review of isothermal design for batch, semi-batch and flow reactors, Multiple reactions and reaction networks: Yield-selectivity concepts.

Wei-Prater analysis for first order networks, reaction networks of general order, Reactor energy balance and its applications to reactor design and analysis. Homogeneous reactor design and analysis-II: Non-ideal reactors- Review of the basic concepts of residence time distributions, single parameter models for real reactor behavior.


Reactor design for fixed and fluidized bed reactors, Selected case studies, Non-catalytic gas-solid reactions: review of kinetics; reactor design case studies. Heterogeneous reactors-II:

Gas-liquid systems- Basic theories of mass transfer with chemical reaction model systems and model reactors, Reactor design for mechanically agitated and bubble column reactors. Selected case studies.

Reference Books:
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<tr>
<td>Course Title</td>
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<td>COMPUTATIONAL HEAT TRANSFER</td>
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**Course Content**


Heat Condition And Convection Control Volume Approach - Steady and Unsteady One Dimensional Conduction - Two and Three Dimensional - Power Law Scheme – Simpler Algorithm.


Isoparametric Element Formulations Conduction and Diffusion Equations - Heat Transfer Packages - Heat 2, HEATA X, RADIAT, ANSYS

**Reference Books:**

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<tr>
<th>Course Code</th>
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<td>Course Title</td>
<td>ENERGY RESOURCES, ECONOMICS AND ENVIRONMENT</td>
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**Course Content**

Overview of World Energy Scenario – Dis-aggregation by end-use, by supply Fossil Fuel Reserves - Estimates, Duration Overview of India’s Energy Scenario - Dis-aggregation by end-use, by supply, reserves Country Energy Balance Construction - Examples Trends in energy use patterns, energy and development linkage.


Energy Chain, Primary energy analysis Life Cycle Assessment, Net Energy Analysis. Environmental Impacts of energy use - Air Pollution - SOx, NOx, CO, particulates Solid and Water Pollution, Formation of pollutants, measurement and controls.

Sources of emissions, effect of operating and design parameters on emission, control methods, Exhaust emission test, procedures, standards and legislation.


**Reference Books:**

Course Code : EN 635
Course Title : ENVIRONMENTAL IMPACT ASSESSMENT AND ECONOMIC ANALYSES
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Principles, Production and assessment of impacts due to air and water pollution on the environment. Environment Impact Assessment in the land and biological environment


Reference Books:
**Course Code**: EN 636  
**Course Title**: NUCLEAR, HYDEL AND OTEC POWER PLANTS  
**Number of Credits**: 3  
**Course Type**: ELECTIVE

**Course Content**


Current Generation power reactors- Pressurized water reactors – Boiling water reactors – Gas-cooled reactors – Advanced Design


Design Construction & Operation Of Hydro-Electric Power Plants- Components – Advantages & Disadvantage of under ground power station

Ocean Thermal Energy conversion -Operational problem – Ecological & environmental impacts. Water power – Tidal power – wave power – geothermal power

**Reference Books:**

3. Samuel Glasstone and Alexander Sesonske “Nuclear Reactor Engineering” Third Edit
Course Code : EN 637
Course Title : NUCLEAR REACTOR THEORY
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Radioactivity, Nuclear reactions, Cross sections, Nuclear fission, Power from fission, Conversion and breeding, Neutron transport equation, Diffusion theory approximation, Fick’s law, Solutions to diffusion equation for point source, Planar source, etc. Energy loss in elastic collisions,

Collision and slowing down densities, Moderation in hydrogen, Lethargy concept, Moderation in heavy nucleus.

Moderation with absorption, Resonance absorption, NR and NRIM approximations. Multi-region reactors, Multigroup diffusion methods, Thermal reactors, Heterogeneous reactors.

Reactor kinetics in hour equation, Coefficients of reactivity, Control, Fission product poison. Perturbation theory

Reference Books:
Course Code : EN 638
Course Title : OPTIMIZATION
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Introduction to Process Optimization; Formulation of Various Process Optimization Problems and their Classification;

Basic Concepts of Optimization-Convex and Concave Functions, Necessary and sufficient conditions for Stationary Points; Optimization of one-dimensional Functions.

Unconstrained Multivariable Optimization- Direct Search Methods. Indirect First Order and Second Order Methods; Linear Programming and its Applications; Constrained Multivariable


Reference Books:
Course Code : EN 639
Course Title : POWER SOURCES FOR ELECTRIC VEHICLES
Number of Credits : 3
Course Type : ELECTIVE

Course Content


Reference Books:
Lithium Batteries for Hybrid Cars By John Voelcker, IEEE Spectrum, 1990
Course Code : EN 640
Course Title : TECHNOLOGY MANAGEMENT
Number of Credits : 3
Course Type : ELECTIVE

Course Content


Reference Books:
Course Code : EN 641
Course Title : THERMAL ENVIRONMENTAL ENGINEERING
Number of Credits : 3
Course Type : ELECTIVE

Course Content
Refrigeration cycles: need for refrigeration, various refrigeration cycles, vapour compression cycles, single-stage, two-stage and cascade

Vapour absorption cycles, LiBr/H2O and NH3/H2O, gas cycles and air liquefaction cycles, selection of refrigerants and refrigerant/absorbent combination

Advanced psychometrics: psychometric charts, thermodynamic properties of moist air, typical air conditioning processes and associated energy calculations.

Introduction to advanced refrigeration cycles: vapour compression cycles with solution circuits, cogeneration of power and refrigeration, refrigeration using solar energy and waste heat.

Reference Books:
**Course Code**: EN 642  
**Course Title**: UNIT OPERATIONS IN INDUSTRIES  
**Number of Credits**: 3  
**Course Type**: ELECTIVE

**Course Content**
Crushing, Grinding Size Separation & Conveying Of Bulk Solids Various Laws of Crushing - Classification of Crushing and Grinding Machineries -

Mixing of Liquids / Liquids, Liquids / Gases, Liquids / Solids - Types of Mixers - Industrial Filtration

Evaporator- Duhrings Chart - Boiling Point Elevation - Capacity and Economy of Evaporators - Evaporators Classification – Economy and capacity

Humidity Chart - Wet bulb Temperature and Measurement of Humidity Equilibrium Moisture Content - Bound, Unbound, Free Moisture - Drying Rate Curves Classification of Dryers

Distillation Methods - Minimum Reflux Ratio - Total Reflux - Optimum Reflux Ratio - Steam Distillation Calculations Concepts of Azeotropic and Extractive Distillation –

**Reference Books:**
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<th><strong>Course Code</strong></th>
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<tr>
<td><strong>Course Title</strong></td>
<td>WASTE MANAGEMENT AND ENERGY GENERATION TECHNOLOGIES</td>
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**Course Content**
Sources, Types, Compositions, Properties Physical, Chemical and Biological - Collection - Transfer Stations – Waste minimization and recycling of Municipal Waste.

Size Reduction - Aerobic Composting - Incineration for Medical /Pharmaceutical Waste - Environmental Impacts -Environmental Effects due to Incineration.

Land Fill Method- Types, Methods & Siting Consideration - Composition, Characteristics, generation, Control of Landfill Leachate & Gases – Environmental monitoring System for Land Fill Gases.


Biochemical Conversion - Industrial, Agro Residues - Anaerobic Digestion – Biogas Production Types of Biogas Plant-Thermochemical Conversion -Gasification - Types – Briquetting Industrial Applications of Gasifiers - Environment Benefits

**Reference Books:**
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<tr>
<td>Course Title</td>
<td>WASTE TO ENERGY</td>
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**Course Content**

Introduction to energy from waste: characterisation and classification of waste as fuel – agro-based, forest residues, industrial waste, Municipal solid waste.

Waste to energy options: combustion (unprocessed and processed fuel), gasification, anaerobic digestion, fermentation, pyrolysis.

Conversion devices: combustors (Spreader Stokes, Moving grate type, fluidized bed), gasifier, digesters. Briquetting technology: Production of RDF and briquetted fuel. Properties of fuels derived from waste to energy technology: Producer gas, Biogas, Ethanol and Briquettes.

Comparison of properties with conventional fuels. Power generation using waste to energy technologies: CI and SI engines.


**Reference Books:**

Course Code: EN 645
Course Title: INSTRUMENTATION IN ASSESSMENT OF WASTE AND WASTEWATER QUALITY
Number of Credits: 3
Course Type: ELECTIVE

Course Content
Wastewater quality – different kinds of wastewater, characteristics, effluent standards.

Estimation of characteristics – major parameters including pH, chlorides, sulphates, TDS, BOD, COD, TOC, TN.

Modern Instrumentation used for analysis - TOC analyser, XRD, SEM, FTIR, HPLC, AAS, UV – Spectrophotometer.

Emerging Treatment methodologies – natural coagulants, new catalysts - synthesis, advanced oxidation process, Fenton and its different kinds, ozonation, recent developments in advanced oxidation.

Different treatment plants – common effluent treatment plants, zero liquid discharge plants, requirements of a treatment plant, influent and effluent standards, method of treatment selection, HAZOP study.

Reference Books:
**Course Code**: EN 646  
**Course Title**: WIND ENERGY AND HYDRO POWER SYSTEMS  
**Number of Credits**: 3  
**Course Type**: Core

**Course Content**
Measurement and instrumentation – Beau fort number -Gust parameters – wind type – power law index -Betz constant -Terrain value.


HAWT, VAWT- tower design-power duration curves- wind rose diagrams- study of characteristics- actuator theory- controls and instrumentations.

Grid-combination of diesel generator- Battery storage - wind turbine circuits - Wind farms -fatigue stress.

Overview of micro mini and small hydro, Site selection and civil works, Penstocks and turbines, Speed and voltage regulation, Investment issues, load management and tariff collection

Distribution and marketing issues, case studies, Wind and hydro based stand-alone / hybrid power systems, Control of hybrid power systems, Wind diesel hybrid systems.

**Reference Books:**
   1. IS 875 Part IV and IS 1893 semics D+STDS mareials STDS IS 226 (IS 2862, ASTMS 36, BS 4360 GR 43D and A).
Course Code: EN 811
Course Title: PRINCIPLES IN DOWNSTREAM PROCESSING
Number of Credits: 3
Course Type: ELECTIVE

Course Content
Introduction: Role and importance of downstream processing in biotechnology, Economics of downstream processing cost cutting strategies, characteristics of biological mixtures, process design criteria for various bio products.

Primary separation and recovery process: Cell disruption method for intracellular products: chemical, mechanical and enzymatic methods. Principles, operation, design and scale up of sedimentation, flocculation, centrifugal settling and filtration.

Enrichment operation I: Precipitation and Extraction: Precipitation methods by isoelectric precipitation, salt fractionation, polymer and organic solvent. Extraction: Concepts, modelling and design aspects, Principles and application of aqueous two-phase extraction, super critical extraction and crystallization.

Enrichment Operation II: Membrane separation: Theory and application of microfiltration and ultra filtration design and configuration of membrane based separation, structure and characteristics of membrane, concepts, modelling and design aspects of reverse osmosis, dialysis, liquid membranes and membrane reactor.


Reference Books:
1) Bioseparation-Principles and techniques, B.Sivasankar, Prentice Hall of India, New Delhi, 2005.