M. TECH

IN

ENERGY ENGINEERING

CURRICULUM

(For students admitted in 2019-20)

DEPARTMENT OF ENERGY AND ENVIRONMENT

NATIONAL INSTITUTE OF TECHNOLOGY, TIRUCHIRAPPI – 620015

TAMILNADU, INDIA

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

SEMESTER I

S. No	Course Code	Course Title	Credits
1	EN 601	FOUNDATION FOR ENERGY ENGINEERING	3
2	EN 603	ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL	3
3	EN 605	SOLAR ENERGY UTILIZATION	3
4		ELECTIVE I	3
5		ELECTIVE II	3
6	EN 648	ELECTIVE III - NPTEL/CERFITIED COURSES	3
7	EN 607	ENERGY AND ENVIRONMENTAL ENGINEERING LAB	1
8	EN 609	PROFESSIONAL SKILL DEVELOPMENT	1
Total			**20**

SEMESTER II

S. No	Course Code	Course Title	Credits
1	EN 602	BIO ENERGY TECHNOLOGIES	3
2	EN 604	COMPUTATIONAL FLUID DYNAMICS	3
3	EN 606	ENERGY AUDIT AND MANAGEMENT	3
4		ELECTIVE IV	3
5		ELECTIVE V	3
6		ELECTIVE VI	3
7	EN 608	COMPUTATIONAL FLUID DYNAMICS LABORATORY	1
8	EN 610	MINI PROJECT	3
Total			**22**

SEMESTER III

S. No	Course Code	Course Title	Credits
1	EN 667	PROJECT WORK - PHASE I	9
2	EN 612	INTERNSHIP*	2
3		SHORT TERM COURSE	1
Total			**12**

*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 at the starting of third semester.

SEMESTER IV

S. No	Course Code	Course Title	Credits
1	EN 668	PROJECT WORK - PHASE II	12
		Total	**12**

LIST OF ELECTIVES - I/II/III

S. No	Course Code	Course Title	Credits
1	EN 613	ENERGY SYSTEMS MODELING AND ANALYSIS	**3**
2	EN 615	FUELS AND COMBUSTION TECHNOLOGY	**3**
3	EN 617	HEAT AND MASS TRANSFER	**3**
4	EN 619	AIR CONDITIONING AND REFRIGERATION	**3**
5	EN 621	THERMAL ENGINEERING	**3**
6	EN 623	POWER PLANT TECHNOLOGY	**3**
7	EN 625	ELECTRICAL ENERGY TECHNOLOGY	**3**
8	EN 627	POWER GENERATION, TRANSMISSION AND DISTRIBUTION	**3**
9	EN 629	POWER SYSTEMS PLANNING AND OPERATION	**3**
10	EN 648	NPTEL/CERTIFIED COURSES	**3**

11	EN649	ADVANCED FOSSIL FUEL TECHNOLOGIES	**3**

LIST OF ELECTIVES – III/IV

S. No	Course Code	Course Title	Credits
1	EN 614	BATTERIES AND FUEL CELLS	**3**
2	EN 616	DESIGN OF HEAT TRANSFERS EQUIPMENTS	**3**
3	EN 618	DIRECT ENERGY CONSERVATIONS	**3**
4	EN 620	ENERGY EFFICIENT BUILDINGS	**3**
5	EN 622	OPTIMUM UTILIZATION OF HEAT AND POWER	**3**
6	EN 624	POWER GENERATION & SYSTEMS PLANNING	**3**
7	EN 626	RENEWABLE POWER GENERATION SOURCES	**3**
10	EN 631	INSTRUMENTATION AND CONTROL IN ENERGY SYSTEMS	**3**

LIST OF RESERVED ELECTIVES

S. No	Course Code	Course Title	Credits
1	EN 628	ADVANCED HEAT TRANSFER	**3**
2	EN 630	ADVANCED THERMODYNAMICS	**3**
3	EN 632	ADVANCED REACTION ENGINEERING	**3**
4	EN 633	COMPUTATIONAL HEAT TRANSFER	**3**
5	EN 634	ENERGY RESOURCES, ECONOMICS & ENVIRONMENT	**3**
6	EN 635	ENVIRONMENTAL IMPACT ASSESSMENT AND ECONOMIC	**3**
7	EN 636	NUCLEAR, HYDEL & OTEC POWER PLANTS	**3**
8	EN 637	NUCLEAR REACTOR THEORY	**3**
9	EN 638	OPTIMIZATION	**3**
10	EN 639	POWER SOURCES FOR ELECTRIC VEHICLES	**3**
11	EN 640	TECHNOLOGY MANAGEMENT	**3**
12	EN 641	THERMAL ENVIRONMENTAL ENGINEERING	**3**
13	EN 642	UNIT OPERATIONS IN INDUSTRIES	**3**

14	EN 643	WASTE MANAGEMENT AND ENERGY GENERATION TECHNOLOGY	**3**
15	EN 644	WASTE TO ENERGY	**3**
16	EN 645	INSTRUMENTATION IN ASSESSMENT OF WATER AND WASTEWATER QUALITY	**3**
17	EN 811	PRINCIPLES OF DOWNSTREAM TECHNIQUES IN BIOPROCESS	**3**

Course Code	**:**	EN 601
Course Title	**:**	**FOUNDATION FOR ENERGY ENGINEERING**
Number of Credits	**:**	**3**
Course Type	**:**	Core

Course Content

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

Fluid Mechanics: stress-strain relations and viscosity, mass and momentum balance, flow through pipe. Heat Transfer: conduction, radiation, convective heat transfer. Network analysis: simple network analysis, power factor improvement.

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/Refrences

- M. W. Zemansky, Heat and Thermodynamics 4th Edn. McGraw Hill, 1968.
- A. L. Prasuhn, Fundamentals of Fluid Mechanics, Prentice Hall, 1980
- S. P. Sukhatme, A Text book on Heat Transfer, Orient Longman, 1979.
- P. C. Sen, Modern Power Electronics, Wheeler, New Delhi, 1998.
- N. Balbanian, T. A. Bickart, Electrical network theory, John Wiley, New York, 1969
- B. L. Theraja, A. K. Theraja, Text-book of electrical technology: in S.I. units: v.2 AC and DC machines, Nirja Construction & development, New Delhi, 1988.

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

Incineration- Processing for liquid fuel production. Pyrolysis - Effect of particle size, temperature, and products obtained. Gasification - Effect of pressure, temperature, steam and oxygen.

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:

1. *Chakraverthy A, "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing Co, 1989.*
2. *Mital K.M, "Biogas Systems: Principles and Applications", New Age International publishers (P) Ltd., 1996.*
3. *Nijaguna, B.T., Biogas Technology, New Age International publishers (P) Ltd., 2002 VVN Kishore, Renewable energy engineering and Technology, Principles and Practices, TERI, 2009.*
4. *Venkata Ramana P and Srinivas S.N, "Biomass Energy Systems", Tata Energy Research Institute, 1996.*
5. *Rezaiyan. J and N. P. Cheremisinoff, "Gasification Technologies, A Primer for Engineers and Scientists", Taylor & Francis, 2005*
6. *Khandelwal. K. C. and Mahdi S. S, "Bio-Gas Technology", Tata McGraw-Hill Pub. Co. Ltd, 1986.*
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.

Solid Waste Management-Sources & Classification –Solid Waste Disposal Options – Toxic Waste Management.

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:

1. *Rao C .S. "Environmental Pollution Control Engineering," 2nd Edition, New Age International Publishers, 2006*
2. *Gilbert M. Masters, "Introduction to Environmental Engineering and Science", 2nd Edition, Prentice Hall, 1998.*
3. *A. P. Sincero and G.A. Sincero , Environmental Engineering: A Design Approach,Prentice Hall of India pvt Ltd, N.Delhi.1996m*
4. *Pandey G.N and Carney G.C., "Environmental Engineering", Tata McGraw HillPublishing Co., 1989.*
5. *Bishop P., Pollution Prevention: Fundamentals and Practice, McGraw-Hill InternationalEdition, McGraw-Hill book Co, Singapore, 2000*

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

Structured and Unstructured Mesh- Introduction to CAD systems and Different Standards used for DATA Exchange. Governing Equations for Turbulent Flow, Rotating Machinery, Combusting Flow, Multiphase Flow.

Simple Internal Flows: T-Junction, Driven Cavity, Manifold, Valves, External Flows: Flow Over Ahmed Body, Car-Reacting Flow in a Gas Burner, Multiphase Flow in an Air Lift Reactor.

Reference Books:

1. *H.K. Versteeg& W. Malalasekera, "An Introduction to Computational Fluid Dynamics - The finite volume approach" Longman, 1995*
2. *Segerlind .L. J., "Applied finite Element Analysis", 2nd edition, John Wiley, 198*
3. *Anderson, "Computational Fluid Dynamics" McGraw Hill Company, 1995*
4. *D.A. Caughey and M.M.Hafez, "Frontiers of Computational Fluid Dynamics 1994" JohnWiley & Sons, 1994*

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 solarpanels-choppers-inverters-batteries-charge regulators, Construction concepts.

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

Reference Books:

1. *D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003*
2. *Edward E. Anderson, "Fundamentals for solar energy conversion", Addison WesleyPubl. Co., 1983.*
3. *Duffie J. A and Beckman, W .A., "Solar Engineering of Thermal Process", John Wiley,1991.*
4. *G. N. Tiwari and M. K. Ghosal, "Fundamentals of Renewable energy Sources", NarosaPublishing House, New Delhi, 2007*
5. *Energy Studies, Second Edition, by W. Shepherd and D. W. Shepherd, Imperial CollegePress, London, 2004.*
6. *S. P. Sukhatme, Solar Energy - Principles of thermal collection and storage, second edition, Tata McGraw-Hil, New Delhi, 1996*
7. *M. S. Sodha, N. K. Bansal, P. K. Bansal, A. Kumar and M. A. S. Malik, Solar Passive*
8. *M. A. S. Malik, G. N. Tiwari, A. Kumar and M.S. Sodha, Solar Distillation. Pergamon Press, New York, 1982.*

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

Course Content

Energy Scenario - Role of Energy Managers in Industries – Energy monitoring, auditing & targeting – Economics of various Energy Conservation schemes. Total Energy Systems Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation

Steam engineering, steam traps and various Energy Conservation Measures in Steam; Boilers - types, losses and efficiency calculation methods. Boiler controls.

Energy conservation in Centrifugal pumps, Fans & Blowers, Air compressor – energy consumption & energy saving potentials – Design consideration.

Refrigeration & Air conditioning - Heat load estimation -Energy conservation in cooling towers & spray ponds – Case studies Electrical Energy -Energy Efficiency in Lighting – Case studies.

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:

1. *Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists,.Logman Scientific & Technical, ISBN-0-582-03184, 1990.*
2. *Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.*
3. *Bureau of Energy Efficiency - Energy Management Series*
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

Course Code	**:**	EN 608
Course Title	**:**	**COMPUTATIONAL FLUID DYNAMICS LABORATORY**
Number of Credits	**:**	**1**
Course Type	**:**	LABORATORY

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

Course Code	**:**	EN 609
Course Title	**:**	**PROFESSIONAL SKILL DEVELOPMENT**
Number of Credits	**:**	**1**
Course Type	**:**	LABORATORY

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:

1. *Andrea J. Rutherford. (2007). Basic Communication Skills for Technology. New Delhi: Pearson Education in South Asia.*
2. *R.C. Sharma and Krishnamohan. (2011). Business Correspondence and Report Writing. New Delhi: Tata McGraw Hill.*
3. *J. Herbert.(1965).The Structure of Technical English, London: Longman.*
4. *Ashraf Rizvi.(2005). Effective Technical Communication. New Delhi: Tata McGraw Hill.*
5. *David Lindsay. (1995). A Guide to Scientific Writing. Macmillan.*
6. *Leo Jones & Richard Alexander. (1996). New International Business English. Cambridge University Press.*
7. *Christopher Turk & John Kirkman.(1989). Effective Writing; Improving Scientific, Technical and Business Communication. 2nd Ed., London: Taylor & Francis Ltd.*
8. *L.J. Gurak & J.M. Lannon (2010). Strategies for Technical Communication in the Workplace. 2nd Ed.,New York: Pearson Education, Inc.*
9. *M. Monippally. (2001). Business Communication Strategies. Tata McGraw Hill.*
10. *V.R. Narayanaswami (2005). Strengthen Your Writing, 3rd ed. Hyderabad: Orient Longman Pvt. Ltd.*

Course Code	**:**	EN 612
Course Title	**:**	**INTERNSHIP**
Number of Credits	**:**	**1**
Course Type	**:**	Core

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:

1. *W.F. Stoecker: "Design of Thermal Systems", 3rd Ed., McGraw Hill,1989.*
2. *B.K.Hodge: "Analysis and Design of Thermal Systems", Prentice Hall Inc., 1990*.
3. *J. Nagrath& M .Gopal: "Systems Modelling and Analysis", Tata McGraw Hill.*
4. *D.J. Wide: "Globally Optimal Design", Wiley- Interscience, 1978*

Course Code	**:**	EN 614
Course Title	**:**	**BATTERIES AND FUEL CELLS**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

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:

1. *Hand Book of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas. B.Reddy, McGraw Hill Book Company, N.Y. 2002.*
2. *Modern Electrochemistry 2A, Fundamentals of Electrodics, 2nd Edition, John O'M Bockris, Amulya K. N. Reddy and Maria Gamboa-Aldeco, Kluwer Academic Publishers, Newyork.*
3. *Principles of Fuel Cells, by Xianguo Li, Taylor & Francis, 2006*
4. *Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M, Universities Press, 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

Flame, Flame Structure, Ignition and Igniters – flame propagation – deflagration – detonations- flame front – Ignition – self & forced ignition – Ignition temperature

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

Reference Books:

1. *S.P. Sharma &Chander Mohan, "Fuels & Combustion", Tata McGraw Hill PublishingCo. Ltd., 1984*
2. *Dr. Samir Sarkar, "Fuels & Combustion", Orient Longman, Second edition, 1990.*
3. *Blokh A.G, "Heat Transmission in Steam Boiler furnaces", Hemisphere PublishingCorpn.ISBN-089-116-626-2*
4. *Gupta O.P, "Elements of Fuels, Furnaces & Refractories", 3rd edition, KhannaPublishers, 1996.*
5. *Combustion Fundamentals by Roger A. Strehlow – McGraw-Hill*
6. *Combustion Engineering and Fuel Technology by Shaha A.K. – Oxford and IBH.*
7. *Principles of Combustion by Kenneth K. Kou – John Wiley & Sons.*

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:

1. *D. G. Kern: "Process Heat Transfer," McGraw-Hill Book Co., N.Y. 1997.*
2. *W.L.McCabe, J.C. Smith, P. Harriott, "Unit Operations of Chemical Engineering SixthEdition, McGraw Hill Company, 2001.*
3. *M. NecatiOzisik "Heat Transfer A Basic Approach", International Edition, McGraw- Hill Company, 1985.*
4. *S. Kokac: "Heat Exchangers-Thermal Hydraulic Fundamentals andDesign", McGrawHill.*
5. *J .P. Gupta: "Heat Exchanger Design".*
6. *A Heat Transfer Textbook, by J.H. Lienhard IV and J.H. Lienhard V, Phlogiston Press,Cambridge, Massachusetts, 2005*

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.

Convective mass transfer. Reacting flows. Mass transfer. Transport equations. Mass transfer across interface. Heat and mass transfer in separated flows.

Reference Books:

1. *W.M. Rays, Convective Heat and Mass Transfer, McGraw Hill, 1966. E.R.G.*
2. *Eckert R.M. Drake Jr., Analysis of Heat Transfer, McGraw-Hill, 1972.*

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

Course Content

Energy conversion process, indirect and direct energy conversion. Preview of semiconductor physics: Basic ideas of quantum physics, Fermi Energy, band diagram, Intrinsic and extrinsic semiconductors, p-n junction Introduction to irreversible thermodynamics.

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

Thermionic conversion: thermionic effects, analysis of converters, application of heat pipes. Magneto hydrodynamic conversion: gaseous conductors, analysis of MHD generators.

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

Reference Books:

1. *Kettani, M.A., Direct energy conversion, Addison-Wesley, Reading, Mass,1970*
2. *AngristS.W. ,Direct Energy Conversion. 4th Ed. Allyn And Bacon, Boston,1982*
3. *Green M.A. ,Solar Cells, Prentice-Hall, Englewood Cliffs, 1982*
4. *Hand book Batteries and Fuel Cells. Linden, McGraw Hill, 1984.*

Course Code	**:**	EN 619
Course Title	**:**	**AIR CONDITIONING AND REFRIGERATION**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

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.

Refrigeration cycle : Refrigerators - Heat pumps - Thee reversed Carnot cycle - Refrigeration by non-cyclic process - Reversed heat engine cycle - Ideal & actual vapor compression Refrigeration cycle-absorption refrigeration cycle - gas refrigeration cycle - Absorption refrigeration systems - Liquefaction of gases.

Air Compressor : Reciprocating air compressors. Types.Construction. Work ofcompression without clearance. Effect of clearance.Multistaging. Optimum intermediate pressure for perfect inter cooling. Compressor efficiencies and mean effective pressure

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:

1. *Stoecker W.F. "Refrigeration and Air Conditioning", TMH edition, McGraw Hillpublication, (1980).*
2. *Ballaney P.L. "Refrigeration and Air Conditioning" V Ed. Khanna Publishers (1980)*
3. *Trott A.R." Refrigeration and Air Conditioning" 2nd Ed.ButterworthPublishers.1980*

Course Code	**:**	EN 620
Course Title	**:**	**ENERGY EFFICIENT BUILDINGS**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

Course Content

Architecture- Building Science and its significance. Indoor Environment. Components of Indoor Environment. Quality of Indoor Environment.

Human Comfort-Thermal, Visual, Acoustical and Olfactory comfort. Concept of Sol- air temperature and its significance. Ventilation and is significance.

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

Energy Management of Buildings and Energy Audit of Buildings. - Energy management matrix monitoring and targeting. Energy Efficient Landscape Design **-**Modification of microclimate through landscape elements for energy conservation.

Reference Books:

1. *Sodha M.,Bansal N.K., Bansal,P.K Kumar, A. and Malik, M.A.S.,"SolarPassiveBBuildings", Pergamon Press, 1986.*
2. *Koenigsberger, O.H., Ingersoll, T.G., Mayhew Alan and Szokolay, S. V., "Manual of Tropical Housing and Building part 1: Climatic Design", OLBN 0 002120011,OrientLongman Limited, 1973.*

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 ofcompression 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.

Gas power cycles : Otto cycle - Diesel Cycle - Dual cycle - Comparison of Otto, Diesel & Dual cycles - Brayton cycle – Aircraft propulsion - Brayton cycle with intercooling, reheating & regeneration.

Refrigeration & Air conditioning : Refrigerators - Heat pump systems - Ideal & actual vapor compression Refrigeration cycle – Vapour absorption refrigeration cycle - Gas refrigeration cycle – Production of solid ice.

Steam Turbines : Principles of operation - Classification of turbines - Simple impulseturbine - 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 strokecycles, 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:

1. *Nag. P.K., " Engineering Thermodynamics ",Tata McGraw-Hill Publishing Co., Ltd.,1994*
2. *Moran, Shapiro, Munson and Dewitt, "Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics and Heat Transfer", John Wiley, N. Y 2000*
3. *Sonntag, R.E and Van Wylen, G.J.., "Fundamentals of Thermodynamics", Sixth Edition,2003.*
4. *Khurmi. R.S, Gupta. J.K, " A textbook of Thermal Engineering", 2002*
5. *Bacon, D.H., "Engineering Thermodynamics ", Butterworth & Co., London, 1989.*

6. *Saad, M.A., "Thermodynamics for Engineers ", Prentice-Hall of India Pvt. Ltd., 1989.*
7. *Mayhew, A. and Rogers, B., " Engineering Thermodynamics ", Longman Green & Co.Ltd., London, E.L.B.S. 4th Edition, 1994*
8. *Ganesan, Y.,* Internal Combustion Engines*, Tata McGraw-Hill, 2003.*
9. *Heywood, J.B.,* Fundamentals of Internal Combustion Engines*, McGraw-Hill, 1988*
10. *Ballaney, P.L.,* Thermal Engineering*, Khanna Publishers, 1996.*

Course Code	**:**	EN 622
Course Title	**:**	**OPTIMUM UTILIZATION OF HEAT AND POWER**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

Course Content

Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation

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

Pinch Technology–significance– Selection of pinch temperature difference – Stream splitting – Process retrofit – Installation of heat pumps, heat engines - Grand composite curve.

Insulation – Recuperative heat exchanger – Run –around coil systems – Regenerative heat exchangers – Heat pumps – Heat pipes –. Waste Heat Recovery **-**Cogeneration Technology

Sources of waste heat, Cogeneration - Principles of Thermodynamics - Combined Cycles- Topping -Bottoming - Organic Rankine Cycles- Advantages Of Cogeneration Technology

Reference Books:

1. Eastop, T.D. & Croft D.R, "Energy efficiency for engineers and Technologists", 2nd edition, Longman Harlow, 1990.
2. O"Callaghan, Paul W, "Design and Management for energy conservation", Pergamon,1993.
3. Osborn, peter D, "Handbook of energy data and calculations including directory of products and services", Butterworths, 1980.
4. Charles H.Butler, Cogeneration, McGraw Hill Book Co., 1984.
5. Horlock JH, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford,1987

Course Code	**:**	EN 623
Course Title	**:**	**POWER PLANT TECHNOLOGY**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

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

Integrated Gasification Combined Cycle (IGCC) – Indirect Fired Combined Cycle (IFCC) – Magneto Hydrodynamics (MHD) – Fuel Cells – Micro turbines– RDF based power plants.

Reference Books:

1. *Thomas C. Elliott ,"Standard Hand Book of Power Plant Engineering"*
2. *E L Wakil, "Power Plant Engineering", McGraw-hill Book Co, N.Y. 2001*
3. *Arora and Domkundwar, A course in Power Plant Engineering, Dhanpat Ra, N.Delhi.2003*
4. *Nag, P.K., "Power Plant Engineering", 2nd Edition, TMH, 2001*

Course Code	**:**	EN 624
Course Title	**:**	**POWER GENERATION AND SYSTEMS PLANNING**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

Course Content

Overview of the Indian power sector, Thermodynamic analysis of Conventional Power Plants. Advanced Power Cycles, Kalina (Cheng) Cycle, IGCC, AFBC/PFBC

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

Analysis of System load curve -plant load factor, availability, Loss of load Probability calculations for a power system, Maintenance Scheduling Pricing of Power - Project cost components, Analysis of Power Purchase Agreements (PPA), Debt/Equity Ratio and effect on

Return on Investment, Environmental Legislations/Government Policies Optimal Dispatch Scheduling of Hydro-Thermal plants. Load Forecasting - Time series, Econometric, end use techniques. Least Cost Power Planning - Integration of DSM, Renewable into supply.

Reference Books:

1. *R.W.Haywood, Analysis of Engineering Cycles, 4th Edition, Pergamon Press, Oxford, 1991.*
2. *D. Lindsay, Boiler Control Systems, Mcgraw Hill International, London, 1992.*
3. *H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.*
4. *T.M. O' Donovan, Short Term Forecasting: An introduction to the Box Jenkins Approach, Wiley, Chichester, 1983*
5. *A.B.Gill, Power Plant Performance, Butterworths, 1984.*
6. *Wood, A.J., Wollenberg, B.F., Power Generation, operation & control, John Wiley, New York, 1984.*

Course Code	**:**	EN 625
Course Title	**:**	**ELECTRICAL ENERGY TECHNOLOGY**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

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:

1. *John F. Walker and Jenkins N., "Wind energy technology", John Wileyand sons, NChichester U.K, 1997*
2. *Syed A Nasar, "Electric energy conversion and transmission",Macmillan Publishing company, New York, 1985*
3. *Sen P.C. "Power Electronics", NBT Code no (45-36/1980), Tata McGrawHillPublishing company, 1993.*
4. *John J. Graigner and W.D. Stevenson, "Power system analysis", McGraw-Hillpublishing company, 1994*

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

Wind driven induction generators– steady state performance – modeling –integration issues impact on central generation-transmission and distribution systems.

Wind – diesel system– permanent magnet alternators-modeling- steady state equivalent circuit-self – excited induction generators-integrated wind – solar systems.

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

Reference Books:

1. John F. Walker & Jenkins. N., "Wind Energy Technology", John Wiley and sons, Chichester, 1997.

2. Van Overstraeton. R. J. and Mertens R. P., "Physics Technology and use of Photovoltaic" Adam Higher, Bristol, 1996.

3. Freris LL, "Wind Energy Conversion Systems", Prentice Hall, U.K., 1990.

4. Imamura M S .et.al "Photovoltaic System Technology. European hand book" H.S.Stephen & Associates.1992

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:

1. *Wadhawa, C.L. „Electrical Power Systems", New Age International Publishers, 6th edition, 2009*
2. *D. P. Kothari and IJ Nagrath, „Power System Engineering" Tata Mcgraw – Hill, 2nd edition, 2008*
3. *Gupta B.R.,' Power system Analysis & Design', S. Chand and Company Ltd.,2nd edition, 2008*
4. *Padiyar, K.R., "HVDC transmission systems", Wiley Eastern Ltd., New Delhi, 1992.*
5. *Allen J.Wood and Wollenberg B.F., "Power Generation Operation and control", JohnWiley & Sons, Second Edition,1996.*
6. *Pabla, A.S., „Electrical Power Distribution System", 5th edition,Tata McGraw hill, 2004.*

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.

Dropwise condensation.Boiling mechanisms regimes.Basic models, correlations.Mass Transfer- governing laws, transfer coefficients; application.Heat exchangers. Design principles.

TEXT BOOKS

1. E.R.G. Eckerst and R.M. Drake Jr, Analysis of Heat Transfer, McGraw-Hill, 1972.
2. W.M. Roshenow and P. Choi, Heat, Mass and Momentum Transfer, Prentice - Hall, 1961.

REFERENCES

1. B. Gebhart, Heat Transfer, McGraw-Hill, 1971.

Course Code	**:**	EN 629
Course Title	**:**	**POWER STSTEM PLANNING AND OPERATION**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

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:

1. *Sullivan, R.L., „Power System Planning", Heber Hill, 1987.*
2. *Roy Billington, „Power System Reliability Evaluation", Gordan& Breach ScainPublishers, 1990.*
3. *Allen J.Wood and Wollenberg B.F., „Power Generation Operation and control", JohnWiley & Sons, Second Edition,1996.*
4. *Kirchmayer L.K., „Economic Control of Interconnected Systems", John Wiley &Sons,n1959.*
5. *Nagrath, I.J. and Kothari D.P., „Modern Power System Analysis", TMH, New Delhi,2006.*
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 StatisticalMechanics, 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 reactionequilibria.

Reference Books:

1. McQuarrie D.A, Statistical Mechanics, Viva Books Private Limited, 2003.2. Hill Terrel, An Introduction to Statistical Thermodynamics, Dover, 1960.3.

2. Allen MP, Tildesley DJ, Computer simulation of liquids, Oxford, 1989.4. Callen, HB. Thermodynamics and an Introduction to Thermodstatics, 2nd Edition, John Wiley and Sons, 1985.5.

3. Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecularthermodynamics of fluid-phase Equilibria (3rd edition), Prentice Hall Inc., New Jersey,1996.6.

4. J.M. Smith. H.C.Van Ness and M.M.Abott. "Introduction to ChemicalEngineering Thermodynamics:. McGraw Hill International edition (5th ed.). 1996

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 anddynamic 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.

Flow Measurement- Variable head flow meters- Rota meters, Electromagnetic flow meters,Hot wire anemometers, Hot film transducers, Ultrasonic flow meters.

Moving Iron/coil, Energy measurement, power factor meter-Analog signal conditioning, Amplifiers, Instrumentation amplifier, A/D and D/A converters.

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:

1. A. K. Sawhney. PuneetSawney: A course in Mechanical Measurements and Instrumentation.DhanpatRai&Co 2002

2. Bechwith. Marangoni.Lienhard: Mechanical Measurements Fifth edition. Addison-Wesley 2000

3. J.P. Holman: Experimental methods for engineers Sixth edition, McGraw-Hill .1994.

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

Macromixing and micromixing, segregated flow model and Zweitering`s analysis of maximum mixedness, IEM and other models for micromixing. Heterogeneous reactors-I: Gas-solid systems- Review of kinetics of gas-solid catalytic reactions with and without diffusion limitation

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:

1. Froment, F.G. and Bischoff, K.B., Chemical Reactor Analysis and Design,Wiley, 1990.
2. Rawlings, J.B. and Ekerdt, J.G., Chemical Reactor Analysis and Design Fundamentals, Nob Hill, 2002.
3. Carberry, J.J., Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976.
4. Levenspiel, O., Chemical Reaction Engineering, Third edition, Wiley, 1999.
5. . Smith, J.M., Chemical Engineering Kinetics, McGraw Hill, 1981. Doraiswamy, L.K
6. Sharma, M.M., Heterogeneous Reactions, Vol. I and II, Wiley,1984. Danckwerts, P.V., Gas-Liquid Reactions, McGraw Hill, 1970.

Course Code	**:**	EN 633
Course Title	**:**	**COMPUTATIONAL HEAT TRANSFER**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

Course Content

Physical Phenomena Governing Differential Equation - Energy Equation – Momentum Equation - Nature of Co-ordinates -Discretization Methods

Parabolic Equations - Explicit, Implicit and Crank Nicholson Methods. Cartesian and Polar Co-ordinates - Mixed Boundary Condition -Jacobi - Gauss-siedel and SOR Methods.

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

General Applicability of the Method - Approximate Analytical Solution - Raleigh's Method.Galerikin Method, Solution Methods.

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

Reference Books:

1.SuhasV.Patnakar, Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing Corporation, 1980

2. Jaluria and Torrance, Computational Heat Transfer - Hemisphere Publishing Corporation, 1986

3. R. Mitchell and D.F. Grifths, Finite Difference Method in Partial DifferentialEquations, John Wiley & Sons, 1980

Course Code	**:**	EN 634
Course Title	**:**	**ENERGY RESOURCES, ECONOMICS AND ENVIRONMENT**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

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 Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation.

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.

Environmental audits; Emission factors and inventories Global Warming, CO2 Emissions, Impacts, Mitigation Sustainability, Externalities, Future Energy Systems.

Reference Books:

1. Energy and the Challenge of Sustainability, World energy assessment, UNDP New York, 2000.

2. AKN Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997.

3. NebojsaNakicenovic, ArnulfGrubler and Alan McDonald Global energy perspectives, Cambridge University Press, 1998

4. Fowler, J.M., Energy and the environment, 2nd Edn., McGraw Hill, New York, 1984

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

Methodologies for Environmental Impact Assessment – Case studies Assessing Impacts and Setting Priorities – Economic Measurement of Environmental Impacts – Theoretical Basis and Practical Applications.

Selectively Applicable Techniques of Valuing Environmental Impacts – Potentially Applicable Techniques of Valuing Environmental Impacts. The limits of Economic Measurement of Environmental Impacts – case studies

Reference Books:

1. Barthwal, R. R., Environmental Impact Assessment, New Age International publishers (P) Ltd., 2002

2. Adaptive environmental assessment and Management Ed. C. S. Holling, John Wiley and Sons, 2000

3. Environmental Impact Assessment L.W .Canter, McGraw Hill Book Company, 1977.

4. Energy Sources and their Environmental Impact, S.A.Abbasi, N.Abbasi, Prentice Hall of India, New Delhi, 2006

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

Course Content

Nuclear Power–Radioactivity & Radioactive charge, Types of reaction – General problem of reactor operation.

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

Hydrology & Hydro - Electric Power Plants- Hydrographs – Flow duration curve – Mass curve & storage. Site selection for hydroelectric power plants.

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

ion.

Reference Books:

1. Black and Veatch, "Power Plant Engineering", ISBN 0-412-06401-4, CBS Publishersand Distributors, Chapter 23424.
2. S .Rao&Dr .B. B. Parulekar, "Energy Technology" , Third Edition, Khanna Publishers
3. Samuel Glasstone and Alexander Sesonske "Nuclear Reactor Engineering" ThirdEdit

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:

1. J.R. Lamarsh, Introduction to Nuclear Reactor Theory, Wesley, 1966
2. J.J. Duderstadt and L.J. Hamilton, Nuclear Reactor Analysis, John Wiley, 1976

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

Optimization-Necessary and Sufficient Conditions for Constrained Optimum, Quadratic Programming, Generalized Reduced Gradient Method, Successive Linear and Quadratic Programming; Optimization of Staged and Discrete Processes, Dynamic Programming, Integer and Mixed Integer Programming.

Reference Books:

1. T.F.Edgar and D.M.Himmelblau, Optimization of Chemical Processes, McGraw Hill International Editions, Chemical Engineering Series (1989)

2. G.S.Beveridge and R.S.Schechter, Optimization Theory and Practice, McGraw Hill, New York l970.

3. G.V.Rekllaitis, A.Ravindran, and K.M.Ragsdell, "Engineering Optimization-Methods and Applications", John Wiley, New York (1983)

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

Course Content

The Electric Vehicle Debate, Primary Energy Sources and Alternative Fuels for Transportation, History of Electric Vehicles, Electrochemical Power Sources – Secondary

Batteries and Fuel Cells Sources- Aqueous Electrolyte Batteries –Lead Acid, Nickel – Iron, Nickel – Zinc, Metal – Air Zinc – Halogen Non Aqueous Electrolyte Batteries- High Temperature Batteries, Organo Electrolyte and
Solid State Batteries

Overview of Performances of Candidate Secondary Battery Systems-Fuel Cells – Acid Systems, Direct Methanol / Air Systems ,Alkaline Systems-Overview of Performances of candidate Fuel Cell Systems, Battery / Fuel cell / Internal

Combustion Engine Hybrid Electric Vehicles, Laboratory Test of Electric Vehicle Batteries, Vehicle tests with Electric Vehicle Batteries, Future of Electric Vehicles

Reference Books:

1. Power Sources for Electric Vehicles, Edited by B.D. McNicol and D.A.J. Rand, ElsevierPublications.1998Lithium Batteries for Hybrid Cars By John Voelcker, IEEE Spectrum, 1990

3. Hand Book of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas.B. Reddy, McGraw Hill Book Company, N.Y. 2002

4. Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M,Universities Press, 2006

5. The Essential Hybrid Car Handbook: A Buyer's Guide (Paperback) by Nick Yost, TheLyons Press, N.Y. 2006

Course Code	**:**	EN 640
Course Title	**:**	**TECHNOLOGY MANAGEMENT**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

Course Content

PASTER program aimed at technological self-reliance-– Strategy Evaluation & Correction, Strategy Implementation - Business Ethics, Knowledge Management, Bench Marking.

Invention, Innovation, Industrial & IPR, Patents, Copyrights, Trademarks, Design Registration, Trade Secrets, WTO, Trade, Patent Specifications, Patent Search Websites.

Technology Transfer Model, Technology Search Strategy, Dimensions of Technology Transfer, Features of Technology Package, Routes of Technology Transfer, Techno market Survey, Technology Evaluation Parameters, Identification of Core

Competence- Constraints in Technology Absorption, Importance of Diffusion Exploratory Method of TF – Delphy Technique, Cross Impact Matrix, Curve Fitting, Morphological Methods, Trend Extrapolation, Regression Analysis

Reference Books:

1. Wright, Peter, Kroll, Mark J. and Parnell, John A: Strategic Management Concepts andCases, Prentice – Hall, N. J. 1996.
2. Coates, V.T.:"A Handbook of Technology Assessment", U.S. Department of Energy,Washington D.C., 1988.
3. Ayres, Robert U: "Technologies forecasting and Long Range planning".
4. Intellectual Property Protection in India: A Practical Guide for Scientists, Technologies and Other Users, Delhi, TIFAC / CSIR, 1993.
5. H. Ansoff "Implementing Strategic Management" by Englewood Cliffs, New Jersey.
6. Michael E. Porter, "Corporate Strategy" – New York Free Press.

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 absorbtion cycles, LiBr/H2O and NH3/H2O, gas cycles and air liquifaction 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:

1. 1993 ASHRAE Handbook - Fundamentals. J.L. Threlkeld, Thermal Environmental Engineering, Prentice Hall, 1970. Manufacturers literature and handouts.

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:

1. P Chattopadhyay, "Unit operations of Chemical Engineering", 2nd edition, Khanna Publishers, 1996.

2. W. L. McCabe and J.C. Smith and P. Harriot, "Unit operations of Chemical Engineering", 6th edition, McGraw Hill International editions, 2001.

3. Alan S Foust, "Principles of Unit Operations", Second Edition, Wiley InternationalEdition, 1960.

4. J.M. Coulson & Richardson, Chemical Engineering,, 5th edition, Butterworth Heinemann,1996.

Course Code	**:**	EN 643
Course Title	**:**	**WASTE MANAGEMENT AND ENERGY GENERATION TECHNOLOGIES**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

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.

Sources and Nature of Hazardous Waste - Impact on Environment - Hazardous Waste - Disposal of Hazardous Waste, Underground Storage Tanks Construction, Installation & Closure

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:

1. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, PrinticeHall, 2000

2. Parker, Colin, & Roberts, Energy from Waste - An Evaluation of ConversionTechnologies, Elsevier Applied Science, London, 1985

Course Code	**:**	EN 644
Course Title	**:**	**WASTE TO ENERGY**
Number of Credits	**:**	**3**
Course Type	**:**	ELECTIVE

Course Content

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

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

Conversion devices: combustors (Spreader Stokes, Moving grate type, fluidized bed), gasifier, digesters. Briqueting 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: Cl and Sl engines.

IGCC and IPCC concepts. Landfills: Gas generation and collection in land fills, Introduction to transfer stations. Comparison with non-energy options like Vermiculture, Composting.

Reference Books:

1.M.M. EL-Halwagi, Biogas Technology- Transfer and diffusion, Elsevier Applied science Publisher, New York, 1984.

2. D.O Hall and R.P. Overeed, Biomass – regenerable energy, John Willy and Sons Ltd. New York. 1987.

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:

1. D.A. Skoog, D.M. West and T.A. Nieman, Principles of Instrumental Analysis, 5th Ed. Thomson Asion (P) Ltd. Singapore, 2004.
2. C.N. Sawyer, P.L. McCarty, and G.F Parkin, Chemistry for Environmental Engineering, Tata McGraw-Hill, New Delhi, 2003.
3. Metcalf and Eddy, Wastewater engineering, Treatment and Reuse, Tata McGraw-Hill, New Delhi, 2003.

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.

Energy in wind– study of wind applicable Indian standards – Steel Tables, Structural Engineering.Variables in wind energy conversion systems – wind power density – power in a wind stream– wind turbine efficiency – Forces on the blades of a propeller – Solidity and selection curves.

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 -fatiguestress.

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. *S. Rao& B. B. Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.*
2. *Wind energy Handbook, Edited by T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, John Wiley & Sons, 2001*
3. *Wind and Solar Power Systems, Mukund. R. Patel, 2nd Edition, Taylor & Francis,2001*
4. *L .L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.*
5. *D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press*
6. *Anna Mani &Nooley, "Wind Energy Data for India", 1983.*
    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).*
7. *Logan (EARL),"Turbo Machinery Basic theory and applications", 1981.*

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.

Purification Techniques: Principle and practice of chromatography techniques: Gel permeation, Ion exchange, Reverse phase, Hydrophobic and Affinity chromatography. Recent advances in purification techniques of bioproducts.In-situ product removal and process integration, case studies: Ethanol, Antibodies and mammalian proteins.

Reference Books:

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

2) Bio separation and Bioprocessing (2^{nd} Ed) 2-volume set, Ed SUBRAMINIAN Ganapathi,wiley-VCH(2007).

3) Mukesh D,Gaikar V and Anil kumar Biotransformation and Bioprocesses, Marcell Dekker,New Yark(Feb 2004).

COURSE CODE	**EN649**
COURSE TITLE	**ADVANCED FOSSIL FUEL TECHNOLOGIES**
NUMBER OF CREDITS	3
COURSE TYPE	CORE

Conventional Fossil Fuel Conversion Technologies

Fossil fuels and types; Coal conversion technologies; Fuel combustion technologies

Advanced Solid Fossil Fuel Technologies

Fluidized Bed Combustion; pressurised pulverised coal combustion, pressurised oxy-fuel combustion, Calcium and Chemical looping combustion; Co-firing technologies; Supercritical/Ultra-supercritical CO_2 power cycles; Integrated Gasification Combined Cycle (IGCC); Transport Coal Gasifier for Power and Chemical Production; Direct catalytic hydrogenation; Direct and indirect energy conversion in thermochemical, electrochemical, thermomechanical and other processes ; Developments in gasification and liquefaction

Advanced Liquid Fossil Fuel Technologies

I.C Engine Cycles; Otto, Diesel & Dual; Theoretical vis-à-vis actual; Typical diesel power plant; Types; Components; Layout; Performance analysis and improvement; Combustion in CI engines; Fischer-Tropsch process and the advancements; Premixed Combustion Systems; dry low NOx(DLN) systems; Diffusion Flame Combustion Systems

Advanced Fossil Gas Conversion

External Combustion cycles- Gas turbine & Stirling cycles; gas turbine cogeneration systems; reciprocating IC engines cogeneration systems; Binary Cycle

Emission Control

Particulate Matter Controls; Heavy Metal Controls; Technologies to control the formation and emission of SOx, NOx; CO_2 Capture technologies; Physical and Chemical Sorption methods; Amine scrubbing; Electro -catalytic oxidation technology (ECO); Ohio State Carbonation Ash Reactivation (OSCAR); Low Temperature Oxidation (LoTOx); Emission control in liquid fuel systems

REFERENCES

1. *L. Douglas Smoot and Philip J. Smith, Coal Combustion and Gasification, Plenum Press, 1985.*
2. *Paul Fennell and Ben Anthony, Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO2) Capture, Woodhead Publishing, 2015.*
3. *Hartmut**Spliethoff**, Power Generation from Solid Fuels, Springer, 2010*
4. *Christopher Higman and Maarten van der Burgt, Gasification, Gulf Professional Publishing, 2008*

5. *Jaap Koppejan and Sjaak van Loo, The Handbook of Biomass Combustion and Co-firing, Routledge, 2012*
6. *Suddhasatwa Basu, Recent Trends in Fuel Cell Science and Technology, Springer, 2007.*
7. *James G. Speight, The Chemistry and Technology of Coal (3rd Edition), CRC Press, 2016.*
8. *A. Parmaliana,D. Sanfilippo,F. Frusteri, A. Vaccari and F. Arena, Natural Gas Conversion V, Volume 119, 1st Edition, Elsevier Science, 1998.*
9. *A J Wharton, Diesel Engines, 3rd Edition, Butterworth-Heinemann, 2013.*
10. *Meherwan Boyce, Gas Turbine Engineering Handbook, 4th Edition, Butterworth-Heinemann, 2011.*
11. *David A. Tillman, Coal-Fired Electricity and Emissions Control, Butterworth-Heinemann, 2018*