COURSE STRUCTURE&SYLLABI
for
2 years M.Tech. in Energy Engineering

knowledge to wisdom

Centre for Energy Engineering
Central University of Jharkhand
Brambe, Ranchi 835 205

Course Structure for M. Tech. in Energy Engineering

Centre for Energy Engineering

Central University of Jharkhand

Lecture (L) - Tutorial (T) - Practical (P) - Credit (C)

Course Structure

The students of M. Tech Programme in Energy Engineering are offered:
(a) Core courses, both theoretical and experimental in different areas of energy
(b) Elective courses from diverse areas of energy studies for specialized knowledge
(c) IDC courses available to other departments also to enhance the knowledge in domains parallel to energy studies
(d) Project work, where special emphasis is placed on the application of the knowledge and training for theoretical and experimental research in diverse areas of energy depending on student's interest

Semester - I					
Course Code	**Course Name**	**Credit Structure**			
		L	**T**	**P**	**C**
EEN 611010	Basic of Energy Engineering	3	0	0	**3**
EEN 611080	Energy and Environment	3	0	0	**3**
EEN 611090	Fuel and Combustion	3	0	0	**3**
EEN 611100	Heat Transfer	3	0	0	**3**
EEN 611050	Solar Energy Utilization	3	0	0	**3**
EEN 611070	IDC-I	3	0	0	**3**
EEN 612110	Energy Engineering Lab -I	0	0	4	**2**
Total Credits					**20**

Semester -II					
Course Code	**Course Name**	**Credit Structure**			
		L	**T**	**P**	**C**
EEN 611020	Solar PV Technology	3	0	0	**3**
EEN 611030	Bio Energy System	3	0	0	**3**
EEN 611060	Wind and Hydro Energy	3	0	0	**3**
EEN 621040	Energy Management	3	0	0	**3**
EEN 622050	Energy Engineering Lab-II	0	0	4	**2**
EEN 626060	Elective-I	3	0	0	**3**
EEN 626070	Elective-II	3	0	0	**3**
EEN 726030	IDC-II	3	0	0	**3**
Total Credits					**23**

Semester –III					
Course Code	**Course Name**	**Credit Structure**			
		L	**T**	**P**	**C**
EEN 714010	Major Project(Part-I)	0	0	20	**10**
Total Credits					**10**

Semester – IV					
Course Code	**Course Name**	**Credit Structure**			
		L	**T**	**P**	**C**
EEN 724010	Major Project(Part-II)	0	0	24	**12**
Total Credits					**12**

List of Electives

IDC-I & II					
Course Code	**Course Name**	**Credit Structure**			
		L	**T**	**P**	**C**
EEN 726020	Renewable Energy Resource	3	0	0	**3**
EEN 726030	Developing Renewable Energy Project	3	0	0	**3**
	Direct Energy Conversion	3	0	0	**3**
	Basics of energy Management	3	0	0	**3**
	Rural Energy Systems	3	0	0	**3**
	Environmental Audit and Impact Assessment	3	0	0	**3**
	Energy Materials	3	0	0	**3**
Elective-I					
Course Code	**Course Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Solar Thermal Technology	3	0	0	**3**
	Emerging Renewable Energy Technologies	3	0	0	**3**
	Alternative Fuels for I C Engines	3	0	0	**3**
	Clean Coal Technology	3	0	0	**3**
	Grid Integration of Renewable Energy	3	0	0	**3**
	Power Plant Engineering	3	0	0	**3**
	Instrumentation &Control for Energy Systems	3	0	0	**3**
	Fuel Cell	3	0	0	**3**
	Advanced PV Technology	3	0	0	**3**
	Smart Grid	3	0	0	**3**
Elective-II					
	Energy Efficient Buildings	3	0	0	**3**
	Energy Economics	3	0	0	**3**
	Energy System Modeling &Analysis	3	0	0	**3**
	Remote Sensing &GIS in Energy Resource and Power Management(rename)	3	0	0	**3**
	Energy Storage	3	0	0	**3**
	Nuclear Energy	3	0	0	**3**
	Carbon audit and management	3	0	0	**3**
	Waste to Energy	3	0	0	**3**
	Energy Efficient Lighting	3	0	0	**3**

Minimum Credit to be earned for degree : 65
Maximum Credit that can be registered in a semester : 24
Minimum Credit to be registered in a semester : 16
Minimum Duration of the Course : 4 semesters
Maximum Duration of the Course : 8 semesters

COURSE STRUCTURE&SYLLABI

FOR

INTEGRATED M. TECH. IN ENERGY ENGINEERING

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Centre for Energy Engineering
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Course Structure for Integrated M. Tech. in Energy Engineering

Centre for Energy Engineering

Central University of Jharkhand

Lecture (L) - Tutorial (T) - Practical (P) - Credit (C)

Semester - I					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Communicative English	2	0	1	**3**
	Environmental Studies	2	1	0	**3**
	Engineering Physics-I	2	1	0	**3**
	Engineering Chemistry-I	2	1	0	**3**
	Engineering Mathematics-I	2	1	0	**3**
	Engineering Mechanics	2	1	0	**3**
	Computer Programming & Data Structure	2	1	0	**3**
	Engineering Mechanics Lab.	0	0	2	**1**
	Engineering Physics-I Lab.	0	0	2	**1**
	Engineering Chemistry-I Lab.	0	0	2	**1**
	Computer Programming Lab.	0	0	2	**1**
	Engineering Drawing and Graphics	1	0	3	**2**
Total Credits					**27**

Semester - II					
Paper Code	**Paper Name**	**Credit Structure**			
		L	T	P	**C**
	Engineering Physics-II	2	1	0	**3**
	Engineering Chemistry-II	2	1	0	**3**
	Engineering Mathematics-II	2	1	0	**3**
	Disaster Management	2	1	0	**3**
	Mechanics of Solids	2	1	0	**3**
	Basics of Electrical Engg.	2	1	0	**3**
	Engineering Thermodynamics	2	1	0	**3**
	Engineering Physics-II Lab.	0	0	2	**1**
	Engineering Chemistry-II Lab.	0	0	2	**1**
	Mechanics of Solids Lab.	0	0	2	**1**
	Basics of Electrical Engg. Lab.	0	0	2	**1**
	Workshop Practice	0	1	2	**3**
Total Credits					**28**

Semester - III					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Introduction to Renewable Energy Resources	2	1	0	**3**
	Fluid Mechanics	3	1	0	**4**
	Steam Power System	3	1	0	**4**
	Electric Circuit Theory and Network	3	1	0	**4**
	Basics of Electronics	3	1	0	**4**
	Engineering Mathematics-III	2	1	0	**3**
	Fluid Mechanics Lab.	0	0	2	**1**
	Electric Circuit Theory and Network Lab.	0	0	2	**1**
	Basics of Electronics Lab.	0	0	2	**1**
Total Credits					**25**

Semester - IV					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Theory of Machines	3	1	0	**4**
	I.C. Engines and Gas Turbines	3	1	0	**4**
	Measurement, and Instrumentation	3	1	0	**4**
	Materials Science for Energy Applications	2	1	0	**3**
	Conventional Power Generation Systems	3	1	0	**4**
	Numerical Methods and Computational Techniques	2	1	0	**3**
	I.C. Engines Lab.	0	0	2	**1**
	Measurement and instrumentation Lab.	0	0	2	**1**
	Conventional Power Generation Lab.	0	0	2	**1**
	Industrial visit to any Conventional Power Plant	0	0	0	**0**
Total Credits					**25**

Semester – V *Total credit requirement for this semester is 25.*					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Heat and Mass Transfer	3	1	0	**4**
	Refrigeration and Air Conditioning	3	1	0	**4**
	Electromagnetic Energy Conversion	3	1	0	**4**
	Power Electronics	3	1	0	**4**
	Open elective- I	3	0	0	**3**
	Open elective - II	3	0	0	**3**
	Refrigeration and Air Conditioning Lab.	0	0	2	**1**
	Electromagnetic Energy Conv. Lab.	0	0	2	**1**
	Power Electronics Lab.	0	0	2	**1**
Total Credits					**25**

Semester - VI					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Solar Thermal Technology	2	1	0	**3**
	Fuels and Combustion Technology	2	1	0	**3**
	Control System	2	1	0	**3**
	Electrical Power Systems	3	1	0	**4**
	Energy Management	3	1	0	**4**
	Machine Design for Energy Application	3	1	0	**4**
	Solar Thermal Technology Lab.	0	0	2	**1**
	Fuels and Combustion Technology Lab.	0	0	2	**1**
	Control System Lab.	0	0	2	**1**
	Electrical Power Systems Lab.	0	0	2	**1**
Total Credits					**25**

Semester VII					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Solar PV Technology	3	1	0	**4**
	Electrochemical Energy Conversion	3	1	0	**4**
	Wind Energy Technology	3	1	0	**4**
	Bio-Energy Systems	2	1	0	**3**
	Solar PV Technology Lab.	0	0	2	**1**
	Electrochemical Energy Conversion Lab.	0	0	2	**1**
	Wind Energy Technology Lab.	0	0	2	**1**
	Bio-Energy Systems Lab.	0	0	2	**1**
	Industrial training & Seminar#	0	0	0	**1**
	Project –I on Energy Innovation	0	0	8	**4**
Total Credits					**24**

 # The industrial training will take place during the vacation after 6th Semester and will be evaluated during 7th Semester.

Semester - VIII					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Energy System Modeling & Analysis	2	1	0	**3**
	Other Emerging Renewable Energy Resources	2	1	0	**3**
	Energy Auditing and Economics	2	1	0	**3**
	Energy, Environment and Climate Change	2	0	0	**2**
	Energy Efficient Building	3	0	0	**3**
	Project Management	2	0	0	**2**
	Project -I on Energy Innovation and Seminar-I	0	0	16	**8**
Total Credits					**24**

Semester - IX					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Human Values & Professional Ethics	3	0	0	**3**
	Elective-I	3	0	0	**3**
	Elective-II	3	0	0	**3**
	Pre-Dissertation Seminar	0	0	0	**5**
	Project-II Phase-I & Seminar	0	0	30	**10**
Total Credits					**24**

Semester - X					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Project-II Phase-II	0	0	40	**15**
	Post-Dissertation Seminar	0	0	0	**5**
	Grand VIVA	0	0	0	**4**
Total Credits					**24**

List of Electives

Open Elective *(Open electives offered by Centre for Energy Engineering for any students of the University)*					
Paper Code	**Paper Name**	**Credit Structure**			
		L	**T**	**P**	**C**
	Renewable Energy Resources	3	0	0	**3**
	Energy and Environment	3	0	0	**3**
	Energy and Society	3	0	0	**3**
	Direct Energy Conversion	3	0	0	**3**
	Basics of Energy Management	3	0	0	**3**
	Rural Energy Technology	3	0	0	**3**
Elective –I					
	Advanced Energy Storage	3	0	0	**3**
	Advanced PV Technology	3	0	0	**3**
	Nuclear Power Engineering	3	0	0	**3**
	Small Hydropower Systems	3	0	0	**3**
	Organic Photovoltaic Devices	3	0	0	**3**
	Alternative Fuels for Transportation	3	0	0	**3**
	Advanced Wind energy Systems	3	0	0	**3**
	Computer Aided Power System Analysis	3	0	0	**3**
	Advanced I.C. Engine	3	0	0	**3**
Elective – II					
	Power Generation Economics	3	0	0	**3**
	Grid Integration of Renewable Energy Sources	3	0	0	**3**
	Energy Efficient Lighting	3	0	0	**3**
	Hydrogen Energy	3	0	0	**3**
	Smart Grid & Hybrid Systems	3	0	0	**3**
	Energy and Sustainable Development	3	0	0	**3**
	Environmental Impact Assessment	3	0	0	**3**
	Waste to Energy	3	0	0	**3**

COURSE STRUCTURE & SYLLABI
for
Ph.D. COURSE WORK
in
Energy Engineering

knowledge to wisdom

Centre for Energy Engineering
Central University of Jharkhand
Brambe, Ranchi

Course Structure with paper code for PhD in Energy Engineering approved by Academic Council vide AC: 2016/13/026 dated 03-08-2016

GENERAL

- **Duration of Course Work : Minimum: One Semester (6 Months); Maximum: Three semesters (18 months)**
- **Total Credit Requirement: Minimum: 16;**
- **Performance Evaluation Components: Sessionals/assignment and end-term test.**

COMPULSORY COURSES

Course Code	Name of the Course	Credit Structure			
		L	**T**	**P**	**C**
EEN 911010	Research Methodology	4	0	0	**4**
ELECTIVE PAPERS (any three papers)					
EEN 918020	Introduction to Renewable Energy Resources and Technologies	4	0	0	**4**
EEN 918030	Solar Photovoltaics	4	0	0	**4**
EEN 918040	Solar Thermal Technology	4	0	0	**4**
EEN 918050	Micro Hydro Power Systems	4	0	0	**4**
EEN 918060	New Generation Photovoltaic Devices	4	0	0	**4**
EEN 918070	Hybrid Systems and Smart Grid	4	0	0	**4**
EEN 918080	Wind Energy Technology	4	0	0	**4**
EEN 918090	I.C. Engines for New Generation Fuels	4	0	0	**4**
EEN 918100	Renewable Energy Grid Integration	4	0	0	**4**
EEN 918110	Future Fuels for Transportation	4	0	0	**4**
EEN 918120	Hydrogen Energy	4	0	0	**4**
EEN 918130	Waste to Energy Conversion Technology	4	0	0	**4**
EEN 918140	Energy Management and Auditing	4	0	0	**4**
EEN 918150	Advanced Materials for Energy	4	0	0	**4**
EEN 918160	Experimental Techniques	4	0	0	**4**

Lecture (L) - Tutorial (T) - Practical (P) - Credit (C)

Compulsory Courses

EEN 911010: Research Methodology (4 0 0 4)

Unit-- I: Introduction to Research Methods

Philosophy of Science, Evolutionary Epistemology, Scientific Methods, Hypotheses Generation and Evaluation, Code of Research Ethics, Definition and Objectives of Research, Various Steps in Scientific Research, Types of Research: descriptive research, conceptual research, theoretical research, applied research –experimental research; Research Purposes, Research process, Criteria for good research, Problems encountered by Indian researchers.

(10)

Unit - II: Literature Review & Data Collection

Formulation of Research Task, Literature Review, Importance & Methods, Sources Quantification of Cause effect Relations, Research Design, Discussions, Field Study, Critical Analysis of Generated Facts, Hypothetical proposals for future development and testing, selection of Research task.

(12)

Unit - III: Statistical Modelling and Analysis

Mathematical modelling and simulation, Concepts of modeling, Classification of mathematical models, Modelling with, Ordinary differential equations, Difference equations, Partial differential equations, Graphs, Simulation, Process of formulation of model based on simulation.

(12)

Unit - IV: Research Reports

Interpretation and report writing, Techniques of interpretation, Precautions in interpretation, Significance of report writing, Differential steps in report writing, Layout of research report, Mechanics of writing research report, Layout and format, Style of writing, Typing, References, Tables, Figures, Conclusion Appendices.

(12)

Reference Books:

1. *J. W. Bames, Statistical Analysis for Engineers and Scientists, McGraw Hill, N. York, 1994.*
2. *Schank Fr., Theories of Engineering Experiments, Tata McGraw Hill Publication, 3rd edition*
3. *C. R. Kothari, Research Methodology, New Age Publishers, 2013.*
4. *K. L. Willktnsion, P. L.Bhandarkar Formulation of Hypothesis, Himalaya Publication, 2002.*
5. *D.R. Cooper, P.S. Schindler, Business Research Methods, 8/e, Tata McGraw-Hill Co. Ltd., 2006.*

ELECTIVE COURSES (any three Courses)

EEN 918020: Introduction to Renewable Energy Resources and Technologies (4 0 0 4)

Unit – I: Introduction:
Energy and its role in Sustainable Development and Social Transformation, Renewable and Non-Renewable Energy resources and their Availability, Global and National energy prospective, Global energy consumption and projected future demands, Energy cycle of the earth, Basics of Energy security and climate change, Various Renewable Energy resources and their prospects.
(6)

Unit - II: Solar Radiation and its Measurements
Introduction, Solar constant, Solar radiation outside the Earth's Atmosphere, Solar radiation at the earth's surface, Solar radiation geometry, Solar radiation measurements, Estimation of Average Solar radiation, Solar radiation on tilted Surfaces.
(6)

Unit - III: Solar Energy Conversions and Applications
Introduction, Solar energy conversion: direct and indirect, Physical principles of Solar radiation conversion. Photovoltaic Cell, Solar Thermal energy conversions, Types of collector: Flat-plate collectors, Concentrating collectors, Cylindrical Parabolic collector, Parabolic dish collector, central receiver collector. Applications: Solar water heating, Solar air heating, Solar distillation, Solar cooker, Solar drier, etc.
(8)

Unit - IV: Solar Energy Storage
Introduction, Importance of Energy storage, Types of Solar Energy storage system, Sensible heat storage system, Latent heat storage system, Chemical and Thermochemical storage, Solar pond storage: Introduction, Principle of operation, Description, Applications of Solar ponds, Other Solar pond concepts. Extraction of thermal energy from storage systems.
(8)

Unit - V: Wind Energy
Introduction, Basic principle of Wind energy conversion: Nature of the Wind, Power in the Wind, Wind data and Energy estimation, Site selection consideration, Basic components of a Wind Energy Conversion System (WECS), Classification of WECS, Advantages and disadvantages of WECS. Types of Wind Machine, Performance of Wind Machines, Generating systems, Wind energy storage, Application of Wind energy.
(6)

Unit - VI: Small Hydro-Energy
Introduction, Basic principle of Hydro-energy conversion, Types of Hydroelectric plants, Components of a hydroelectric scheme, Turbines and Generators for Hydroelectric power, Advantages and limitations of Hydroelectric power, Future prospects of Hydroelectric power.
(6)

Unit - VII: Other Renewable Energy Resources
Geothermal, Tidal energy, Wave energy, Bio-Energy: Biomass, Biomass gasifier, Biogas plant, Biofuel. Ocean thermal energy, Hydrogen energy.
(6)

Reference Books:

1. *B. Sørensen, Renewable Energy, Academic Press, fourth edition, 2010.*

2. *J. Twidell, T. Weir, Renewable Energy Resources, Taylor & Francis, 2nd edition, 2006.*
3. *J. A. Duffie and W. A. Beckman-Solar Engineering of Thermal Processes-John Wiley (1991).*
4. *L. L. Freris, Wind Energy Conversion systems, Prentice Hall, UK, 1990.*
5. *G. N. Tiwari, Solar Energy – Fundamentals Design, Modeling and Applications, Narosa Publishing House, New Delhi, 2002.*
6. *S. P. Sukhatme, J. K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 3rd edition, 2008.*
7. *G. Boyle, Renewable Energy: Power for a sustainable future, Oxford University Press, 2010.*
8. *D. P. Kothari, K. C. Singal, R. Ranjan, Renewable Energy Sources And Emerging Technologies, PHI Learning Pvt. Ltd., 2009.*

EEN 918030: Solar Photovoltaics (4 0 0 4)

Unit - I: **Solar Cell Basics and Materials**
Properties of Semiconductor: Intrinsic, extrinsic and compound semiconductor; Energy levels; Electrical conductivity; Determination of Fermi energy level; Probability of occupation of allowed states; Dynamics of energy density of allowed states; Density of electrons and holes; Carrier transport: Drift, diffusion, continuity equations; Absorption of light; Recombination process; Basic equations of semiconductor devices physics. (6)

Unit - II: **Solar Cell Physics**
p-n junction: homo and hetrojunctions, Metal-semiconductor interface; Dark and illumination characteristics; Figure of merits of solar cell; Efficiency limits; Variation of efficiency with band-gap and temperature, optimum bandgap, current and voltage dependence on illumination and temperature. Efficiency measurements; High efficiency cells. Loss mechanisms for real diodes, recombination, series and shunt resistance, interface states. Heterojunctions, Anderson model, current transport models, window layers. (8)

Unit – III: **Material Fabrication Technologies**
Preparation of metallurgical, electronic and solar grade Silicon; Production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) method, MBE, MOCVD, LPE, VPE. Thin film deposition methods: evaporation, sputtering, wet chemical, spray pyrolysis, and screen printing. (5)

Unit –IV: **Solar Cell Fabrication Technology**
Device Fabrication, Doping, alloying, diffusion and implantation, Procedure of masking, photolithography and etching, Device processing methods, Deposition of anti-reflection coatings, Dry and wet etching. Surface texturing and passivation techniques. Design of a complete silicon, GaAs, CdS, CdTe, InP solar cell; High efficiency III-V, II-VI multijunction solar cell; a-Si-H based solar cells; Quantum well solar cell, Organic solar cells, Thermo photovoltaic, Photovoltaic; Thermal(PV/T) hybrid systems. (6)

Unit-V: **Advanced Devices**
High efficiency crystalline silicon designs, III-V devices, high concentration, quantum wells devices, multijunction structures, Thin film solar cells, structures and fabrication, novel device designs, Organic photovoltaic cells, thermophotovoltaic devices, Multijunction tandem cells and concentrating systems. Efficiency limits. Approaches to low-cost thin-film and 3-dimensional photovoltaics. Terawatt low-cost wafer silicon photovoltaics. Introduction to multijunction concepts. Tandem structure. Junctions in Organic Solar Cells; Working and Efficiency limits (7)

Unit-VI: **Advance Characterization Methods**
Material characterization, X-ray diffraction, optical characterization, minority carrier lifetime and diffusion length measurement. Cell measurement, solar simulation, conversion efficiency

and spectral response. I-V-T and C-V-f measurements. Measurement and performance standards. (6)

Unit - VII: **PV Power Systems**
Centralized and decentralized SPV systems, Stand alone, hybrid and, grid connected system, System installation, Operation and Maintenance, Application of PV for lighting, Water pumping. Refrigeration, Telecommunication, Cathodic Protection etc., Solar PV Power Plant-Status-Case Studies, Hybridization Engineering, Hybrid systems, Grid integration. Building Integrated PV Systems, PV market analysis and Economics of SPV systems (6)

Unit-VIII: **Economics, Policy and Environment**
Economic Analysis: Economic theory, Production economics, Subsidies and tariff issues, financing mechanisms. Policy Issues: Market development, Government policies, Climate change issues, Environmental Impact Assessment, Module production, Energy analysis, Life cycle analysis, CO_2 emissions. (5)

Reference Books:

1. *Green, Martin. A., Solar Cells: Operating Principles, Technology and System Applications, Englewood Cliffs, N.J.; Sydney: Prentice Hall, 1992*
2. *C. S. Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, PHI Learning Pvt. Ltd., 2011.*
3. *S. R. Wenham, M. Green, M.E. Watt, R.Corkish), Applied Photovoltaics, Routledge; 3 edition, 2011.*
4. *Bhattacharya T. Terrestrial Solar Photovoltaic , Narosa Publishers Ltd, New Delhi, 1998*
5. *Fahrenbruch Alan L and Bube Richard H. Fundamentals of Solar Cells: PV Solar Energy Conversion, Academic Press, New York , 1983*
6. *Larry D Partain (ed.), Solar Cells and their Applications, John Wiley and Sons, Inc, New York, 1995.*
7. *H S Rauschenbach, Solar Cell Array Design Handbook, , Van Nostrand Reinfold, Company, New York, 1980.*
8. *Web link: http://www.pveducation.org/*

EEN 918040: Solar Thermal Technology (4 0 0 4)

Unit-I: **Solar Collectors**

Flat-plate and evacuated tubular collectors: Effective energy losses; Thermal analysis; Heat capacity effect; performance testing methods: Evacuated tubular collectors, Air flat-plate Collectors: Thermal analysis; Thermal drying

(5)

Unit-II: **Selective surfaces**
Selective surfaces: Ideal coating characteristics; Types and applications; Anti-reflective coating: Preparation and characterization.

(5)

Unit-III: **Concentrating collector systems**
Concentrating collector: Classification, design and performance parameters; Tracking systems;

Compound parabolic concentrators; parabolic trough concentrators; Concentrators with point focus; Solar furnaces

(6)

Unit-IV: **Solar Power Plants**

Solar power plants: Central receiver systems; Heliostats; Comparison of various designs: Parabolic trough systems; Rankine cycle; Parabolic Dish - Stirling System; Combined cycle

(6)

Unit-V: **Solar Thermal Applications**

Solar heating and cooling system: Liquid based solar heating system; Natural, forced and gravity flow, mathematical modeling, Vapour absorption refrigeration cycle; Water, ammonia and lithium bromide-water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling

(6)

Unit-VI: **Solar Energy Storage**

Solar thermal energy storage: Sensible storage; Latent heat storage; Thermo-chemical storage; High temperature storage, Designing thermal storage systems; Performances of solar collectors: ASHRAE code;

(6)

Unit-VII: **Solar System Design and Simulation**

Modeling of solar thermal system components and simulation; Design and sizing of solar heating systems: f–chart method, solar thermal system evaluation method; Simulation tool for solar heating and cooling applications; Introduction to TRNSYS simulation applications Solar energy for industrial process heat, Temperature requirements, consumption pattern; solar flat plate water heater and air heater for industrial process heat applications

(7)

Unit:VIII: **Solar Thermal Systems**

Solar thermal energy systems: Solar still; Solar cooker: Solar pond; Solar passive heating and cooling systems: Trombe wall; Greenhouse technology: Fundamentals, design, modeling and applications, ETC based water heating systems. (7)

Reference Books:

1. *J. A. Duffie, W. A. Beckman; Solar Engineering of Thermal Processes, Fourth Edition, Wiley,2013.*
2. *D. Y. Goswami, .F.Kreith, and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis , 1999.*
3. *G. N. Tiwari, Solar Energy, Fundamentals Design, Modeling and Applications, Narosa, 2002*
4. *H. P. Garg, Solar Thermal Energy Storage, D Reidel Publishing Co*
5. *B. Norton, Solar Thermal Energy Technology, Springer Verlag*
6. *S.A.Kalogirou, Solar Energy Engineering: Processes and Systems, Academic Press*
7. *G.Boyle, Renewable energy: power for a sustainable future, Third Edition*

EEN 918050: Micro Hydro Power Systems (4 0 0 4)

Unit-I: Basic Hydro Power Concepts

History of Hydro Power development , Importance of Hydro energy in the National Economy, Hydro Power Concepts , World and, Indian Hydro Energy Potential , Calculation of Hydro energy Potential of a Water Source, Hydro Power R & D Centres/ Institutions, Component Manufacturing Industry at International and National level

[10]

Unit-II: **Water Mills**

Designs of Traditional Water Mills Worldwide , Improved Water Mills : Turbines 1-5KW, , Relevance for hilly regions, Design considerations of a Water Mill System , MNRE Scheme, Present Status of Improved Water Mills

[6]

Unit-III**: Hydro Power Plants**

Design considerations of a Hydro Energy Power Plant ,Components of hydroelectric power plant, Various types of Turbines, hydro potential and exploitation in India, Micro hydal Power Projects , Major hydroelectric Power Plants in India, Hydro power fs in Western Himalayas, Environmental Impact of Large Hydro power Projects, Case studies

[12]

Unit-IV**: Economics, Policy, Organization, Regulations**

Economic and financial assessments, planning process, Economics of hydro policies and initiatives of Government for promotion of hydropower, organizations involved in hydropower development, Financing of hydropower projects, Legal issues, , Implications of hydropower development from privatization, Sustainable use of natural resources and its implications on project economy, Implications on project development from Environmental Impact Assessment [EIA processes, Design, cost estimates and cost benefit analysis, Economic risk- and sensitivity analyses, corporate social responsibility

[17]

Reference Books:

1. *G Brown, Hydro Electric Engineering: Vol. I, II, III, CBS Publication*
2. *P. S. Nigam, Hand Book of Hydro Electric Engineering, Nem Chand, 1985.*
3. *B .Honningsvåg, Hydropower in the New Millennium, Proceedings of the 4th International Conference on Hydropower Development, Hydropower '01, Bergen, Norway, Taylor and Francis, 20-22 June 2001*
4. *F. Koester, Hydroelectric Developments and Engineering: A Practical and Theoretical Treatise on the Development, Design, Construction, Equipment and Operation of Hydroelectric Transmission Plants, D. Van Nostrand Co., Original from the New York Public Library, 1909*
5. *B. R. Gupta, Generation Electrical Energy, S. Chand & Co., 6th edition, 2008*

EEN 918060: New Generation Photovoltaic Devices (4 0 0 4)

Unit-I: **Introduction**

Semiconductor physics: Carrier statistics and transport. Collection and quantum efficiency. Optics in solar energy conversion: antireflection coatings, concentration of light.

(3)

Unit-II: **Organic Semiconductor & Device**

Fundamentals of organic molecules, Electronic states in organic molecules and electronic properties, Bandgap and HOMO-LUMO Energy Levels, singlet vs. Triplet, Metal-organic and organic-organic interfaces, Physics of Organic Solids, Organic Semiconductors, Dielectrics, Comparative study between Organic & inorganic semiconductor, Conjugated polymers, Charge transport in organic semiconductors, Hopping & tunnelling model, p-type and n-type organic semiconductors, Application: Organic light emitting diodes, organic transistor, Photodetectors, memory, sensors Organic photovoltaic cells

(6)

Unit-II: **Organic Semiconductor Deposition Techniques**

Progress in growth techniques, Vacuum thermal evaporation, Organic vapor phase deposition,

Spin cast film fabrication, Vacuum evaporation, Spry coating, screen printing, Organic solar ink Effect of film morphology, Controlled growth heterojunction,

(6)

Unit-III: **Thin Film Characterization**

Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Miscroscopy (AFM), XRD, Cyclic Voltametry, Photocurrent and current-voltage characteristic, carrier lifetime measurement, Impedance Spectroscopy, Kelvin probe.

(6)

Unit-IV: **Organic Photovoltaic Cells**

Introduction, Donor and acceptor materials, low band gap polymer, Strategies for Band Gap Engineering, Charge injection and transport, Charge generation and recombination(geminate & non-geminate), Exciton formation: Frenkel, Wannier -Mott, Exciton diffusion length, Exciton dissociation, Organic Solar Cell Architectures: Single layer, Bilayer organic photovoltaic cells, Bulk heterojunction photovoltaic cells. Bulk Heterojunction Devices, Characterization of a Solar Cell Device, Critical Parameters for Solar Cell Efficiency, Stability, thin film Organic and multijunction solar cells, Tandem Solar cells, – principles and advances. Plastic Solar Cells: Mechanism, Architectures, Active layer deposition and annealing process, Solvent effects, Infrared polymer cells, Commercialization, Commercial status, Other third-generation solar cells

(8)

Unit-V: **Hybrid Solar Cell**

Organic –inorganic hybrid cells, Types of interfaces and structures, Fundamental challenge factors. Types of hybrid solar cells, Challenges as efficient carrier transport medium, Challenges as photoactive matrix layer

(3)

Unit-VI: **Dye-Sensitized Solar Cells (Grätzel cell)**

Operating principle of the dye-sensitized solar cell, theoretical issues of the dye cell operation : light absorption, charge separation, charge transport, recombination , interfacial kinetics. Materials of the dye-sensitized solar cell:. Substrates, nanoparticle electrodes, oxide semiconductors, sensitizer dyes. Electrolytes, counter-electrode catalysts, electrical contacts, sealing, and performance of the dye-sensitized solar cells: energy conversion efficiency, long term stability. Progress towards applications: cell and module architectures, DSSCs on plastic substrates, solid state DSSCs, industrial and commercial activities, cost estimates and comparison with other photovoltaic technologies

(5)

Unit-VII: **Stability and Degradation of Organic Photovoltaic Cells**

Degradation of photovoltaic devices performance due to air & humidity, encapsulation of the device to protection from air and humidity to achieve long lifetime. Current challenges and recent progress (4)

Unit-VIII: **Other emerging new generation solar cells**

Perovskite solar cell, Quantum dot (QD) solar cells, Multi-junction solar cells. (4)

Reference Books:

1. *H. Klauk, Organic Electronics Materials, Manufacturing and Applications, (Wiley- VCH), 2006*
2. *C. J. Brabec, V. Dyakonov, J. Parisi, N. S. Sariciftci, Oganic Photovoltaics: Concepts and Realization, 2003.*
3. *M. Pagliaro, G. Palmisano and R Ciriminna, Flexible Solar Cells Wiley-VCH, Weinheim, 2008.*
4. *K. Kalyanasundaram, Dye Sensitized Solar Cells, EPFL Press, 2010.*
5. *F. C. Krebs, Stability and Degradation of Organic and Polymer Solar Cells, John Wiley & Sons, 2012.*

6. *C.-Fuh Lin, W.-F. Su, C.-I Wu and I-Chun Cheng, Organic, Inorganic and Hybrid Solar Cells: Principles and Practice, Wiley-VCH, 2012.*
7. *N. S. Sariciftci and S-S. Sun Organic Photovoltaics, Taylor & Francis, 2005.*

EEN 918070: Hybrid Systems and Smart Grid (4 0 0 4)

Unit- I: **Introduction to Smart Grid**
Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient & Self-Healing Grid, Present development & International policies in Smart Grid. Case study of Smart Grid. CDM opportunities in Smart Grid.

[9]

Unit -II: **Smart Grid Technologies: Part 1**
Introduction to Smart Meters, Real Time Pricing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

Unit –III: **Smart Grid Technologies: Part 2**
Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

[9]

Unit –IV: **Micro grids and Distributed Energy Resources**
Concept of micro grid, need & applications of micro grid, formation of micro grid, Issues of interconnection, protection & control of micro grid, Captive power plants, Integration of renewable energy sources. Hybrid systems.

[8]

Unit –V: **Power Quality Management in Smart Grid**
Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

[10]

Reference Books:

1. *A. Keyhani, M. N. Marwali, M. Dai, Integration of Green and Renewable Energy in Electric Power Systems, Wiley, 2009.*
2. *C. W. Gellings, The Smart Grid: Enabling Energy Efficiency and Demand Response, CRC Press, 2009*
3. *J. Ekanayake, N. Jenkins, K. Liyanage, J. Wu, A. Yokoyama, Smart Grid: Technology and Applications, Wiley, 2012.*
4. *J. Claude Sabonnadière, N. Hadjsaïd, Smart Grids, Wiley Blackwell, 2012*
5. *T. Flick and J. Morehouse, Securing the Smart Grid, Elsevier Inc., 2010*
6. *P. S. Fox-Penner, Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities, 2010.*

EEN 918080: Wind Energy Technology (4 0 0 4)

Unit -I: **Introduction**

Wind Energy Fundamentals, Wind Measurements, Analysis and Energy Estimates Aerodynamics Theory.

[5]

Unit-II: **Wind Turbines Technology**

Wind turbines types: Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control , Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator

[7]

Unit-III: **Wind Turbine Technology & Components of WTG**

Gear Coupled Generator Type [Const. Speed], Direct Coupled Generator Type [Variable Speed Variable Frequency]: Multipole Synchronous / PMG Generators.

[8]

Unit-IV: **Gear Coupled Generator Wind Turbine Components and their construction**

Electronics Sensors, Encoder, Resolvers, Wind Measurement : Anemometer & Wind Vane, Grid Sysnchronisation System, Soft Starter, Switchgear [ACB/VCB], Transformer, Cables and assembly, Compensation Panel, Programmable Logic Control, UPS, Yaw & Pitch System : AC Drives, Safety Chain Circuits, Generator Rotor Resistor controller (Flexi Slip), Differential Protection Relay for Generator, Battery, Super Capacitor Charger & Batteries, Super Capacitor for Pitch System, Transient Suppressor, Lightning Arrestors, Oscillation & Vibration sensing.

[7]

Unit-V: **Direct Rotor Coupled Generator (Multipole) [Variable Speed ,Variable Freq.]**

Excited Rotor Synch.Generator, PMG Generator, Control Rectifier, Capacitor Banks, Step Up / Boost Converter (DC-DC Step Up), Grid Tied Inverter, Power Management. Grid Monitoring Unit (Voltage and Current), Transformer, Safety Chain Circuits Doubly Fed Induction Generator and Power Control

[7]

Unit -V: **Modern Wind Turbine Control & Monitoring System**

Details of Pitch System & Control Algorithms, Protections used & Safety Consideration in Wind turbines, Wind Turbine Monitoring with Error codes, SCADA & Databases: Remote Monitoring and Generation Reports, Operation & Maitenance for Product Life Cycle, Balancing technique (Rotor & Blade), FACTS control & LVRT & New trends for new Grid Codes.

[7]

Unit-VI: **Concept of Wind Farms and project cycle**

Project planning, Site selection, Project execution, Operation and maintenance Environmental concerns: Pollution free power; Noise; birds; Aesthetics; Radio waves interference; Rainfall

[7]

Unit -VII: **Cost Economics**

Wind resource assessment and R & D costs, Fixed and variable costs, Value of wind energy, Life cycle costing and cash flow of wind power projects, Wind project owners / developers, Wind energy market

[6]

Reference Books:

1. *L. L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.*
2. *D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press, 1994.*
3. *T. Burton, Handbook of Wind Energy, John Wiley and Sons, 2nd edition, 2011.*
4. *G.L. Johnson, Wind Energy Systems, Printice Hall Inc, New Jersy, 1985*
5. *E. Hau, Wind Turbines- Fundamentals: Technologies, Application, Economics, Springer - Verlag Berlin -Heidelbeg, 2000.*
6. *D. N. V- Riso Guidelines for Design of Wind Turbines, 2nd Edition, Riso NationalLaboratory, Denmark, 2002.*
7. *M. O.L. Hansen, Aerodynamics of Wind Turbine, James and James (Science Publishers) Ltd, London, 2000 .*

8. *A. Mani, Wind Energy Data for India, 1992.*
9. *C-Wet : Wind Energy Resources Survey in India VI*
10. *S. Rangrajan : Wind Energy Resources Survey in India V, 1990.*
11. *Prepared by WISE: Wind Power in India (5000MW BY 2015).*

EEN 918090: I.C. Engines for New Generation Fuels (4 0 0 4)

Unit- I: **Spark Ignition Engines**
Air-fuel ratio requirements and calculations, Design of carburetor –fuel jet size and venture size, Stages of combustion-normal and abnormal combustion, Factors affecting knock, Combustion chambers, Introduction to thermodynamic analysis of SI Engine combustion process, flame structure and speed, cycle variation in combustion (9)

Unit–II: **Compression Ignition Engines**
Stages of combustion-normal and abnormal combustion – Factors affecting knock, Direct and Indirect injection systems, Combustion chambers, Turbo charging, Introduction to Thermodynamic Analysis of CI Engine Combustion process; phenomenological model of CI engine compression, analysis of cylinder pressure data, fuel spray behavior, mixing control combustion (9)

Unit – III: **Engine Exhaust Emission Control**
Formation of NOX , HC/CO mechanism , Smoke and Particulate emissions, Green House Effect, Methods of controlling emissions , Three way catalytic converter and Particulate Trap, Emission (HC,CO, NO and NOX ,) measuring equipments, Smoke and Particulate measurement, Indian Driving Cycles and emission norms. (9)

Unit-IV: **Modeling real engine flow and Combustion process**
Modeling real engine flow and Combustion process (4)

Unit-V: **Alternate Fuels**
Alcohols, Vegetable oils and bio-diesel, Bio-gas, Natural Gas, Liquefied Petroleum Gas, Hydrogen, Properties, Suitability, Engine Modifications, Performance, Combustion and Emission Characteristics of SI and CI Engines using these alternate fuels. (5)

Unit- VI: **Recent Trends**
Homogeneous Charge Compression Ignition Engine, Lean Burn Engine, Stratified Charge Engine, Surface Ignition Engine, Four Valve and Overhead cam Engines,Electronic Engine Management, Common Rail Direct Injection Diesel Engine, Gasoline Direct Injection Engine, Data Acquisition System –pressure pick up, charge amplifier PC for Combustion and Heat release analysis in Engines. (9)

Reference Books:

1. *H. Heisler, 'Advanced Engine Technology," SAE International Publications, USA,1998.*
2. *V. Ganesan," Internal Combustion Engines" , Third Edition, Tata Mcgraw-Hill ,2007.*
3. *J. B. Heywood," Internal Combustion Engine Fundamentals", Tata McGraw-Hill, 1988.*
4. *D. J. Patterson and N. A. Henein, "Emissions from combustion engines and their control," Ann Arbor Science publishers Inc, USA, 1978.*
5. *H. N. Gupta, "Fundamentals of Internal Combustion Engines" ,Prentice Hall of India, 2006.*
6. *U. Adler ," Automotive Electric / Electronic Systems, Published by Robert Bosh, GmbH,1995.*

EEN 918100: Renewable Energy Grid Integration (4 0 0 4)

Unit-I: **Introduction**
The state of Renewable Energy generation, and the challenges of integrating these sources into the grid.

[6]

Unit-II: **Power systems & Power electronic converters**
Basic concepts, system operation, Power electronic converters: switches, diodes, basic converter topologies.

[7]

Unit –III: **Generation and Storing technologies**
Photovoltaic and Thermo-solar Power generation, Wind power generation, Biomass Power generation overview, Hydroelectric power generation, Hydrogen Technologies Power Storing: Battery types, Ultracapacitors based energy storage systems, Flywheel. Electric Vehicles.

[8]

Unit-IV: **Control Techniques and Renewable Energy Integration systems**
AC/DC Drives Control, Predictive direct power control of systems connected into the Grid, Technological aspects of power electronic systems connection to the grid, Active Network Devices, Control and FACTS Technology, Micro-Grids.

[7]

Unit-V: **Power Grid Analysis and Studies**
Electric Systems Modelling, Power Supply Quality, Optimization and Grid Planning

[8]

Unit-VI: **Smart Grids**
Smart Grids Programming, Protective Devices, Case of Study: Distributed Generation Protection, Smart grids

[7]

Unit-VI: **Standards and Electric Markets**
Electric Market: The electric sector: structures and models, Economics in distributed generation. Remuneration, Regulation comparison with other international electric markets Experiences, Regulation of the electric sector impact on distributed generation, New activities regulation proposals. Standards: State of the art, Power supply quality generic standards, Renewable energies specific standards

[9]

Reference books:

1. *E. F. Fuchs, Power Conversion of Renewable Energy Systems, Springer,2011.*
2. *F. P. Sioshansi, Smart Grid: Integrating Renewable, Distributed & Efficient Energy, Academic Press, 2011.*
3. *Q.-C. Zhong, T. Hornik Control of Power Inverters in Renewable Energy and Smart Grid Integration, Wiley, John & Sons, Incorporated, 2012.*
4. *J. Manwell, J. F. Manwell, Wind Energy Explained: Theory, Design and Application,2009.*
5. *R. Ramesh, Renewable energy technologies by Publication, Narose publishing house, 1997.*
6. *A. Keyhani, Design of Smart Power Grid Renewable Energy Systems, 2011.*

EEN 918110: Future Fuels for Transportation (4 0 0 4)

Unit-I: **Introduction**
An introduction to hydrocarbon fuels–their availability and effect on environment, Gasoline and diesel self ignition characteristics of the fuel, Octane number, Cetane number, Alternative fuels - liquid and gaseous fuels, Physico-chemical characteristics

[7]

Unit-II: **Alternative liquid fuels Production & Utilization**
Alternative liquid fuels, Alcohol fuels: Ethanol & methanol, Fuel composition, Fuel induction techniques, Fumigation, Emission of oxygenates, Applications to engines and automotive conversions

[8]

Unit-III**: Biodiesel Production & Utilization**
Biodiesel formulation techniques, Transesterification, Application in diesel engines, DME (Dimethyl ether), properties fuel injection consideration general introduction to LPG and LNG.

[7]

Unit-IV: **Compressed Natural Gas Production & Utilization**
Compressed natural gas components, mixtures and kits, fuel supply system and emission studies and control.

[8]

Unit-V: **Hydrogen Production, Storage & Utilization**
Hydrogen production methods, Hydrogen storage methods, Hydrogen combustion characteristics, Flashback control techniques, Safety aspects and system development, NOx

[8]

Unit-VI: **Biogas, DME & DEE**
DME (Dimethyl ether), properties fuel injection consideration general introduction to LPG and LNG, Biogas, Producer gas and their characteristics system development for engine application, DEE.

[8]

Reference Books:

1. *R. L. Bechtold, Alternate Fuels – Transportation Fuels for Today and Tomorrow, Society of Automotive Engineers (SAE) – 2002.*
2. *J. B. Haywood, Internal Combustion Engine Fundamentals, McGraw-Hill Book Company, 1988.*
3. *S.S. Thipse, Alternative Fuels; Concepts, Technologies and Developments, Publisher: Jaico Book Distributers, 2011.*

EEN 918120: Hydrogen Energy (4 0 0 4)

Unit-I: **Introduction**
Hydrogen pathways introduction: current uses, General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen and Hydrogen production power plants

[7]

Unit-II: **Hydrogen Production Processes**
Thermal: Steam Reformation and Oxidative Steam Reforming, Thermo chemical Water Splitting, Gasification, Pyrolysis, Nuclear thermo catalytic and partial oxidation methods. **Electrochemical**: Electrolysis, Photo electro chemical. **Biological**: Photo Biological, Anaerobic Digestion, Fermentative Micro-organisms.

[8]

Unit-III: **Hydrogen Storage**
Physical and chemical properties, General storage methods, compressed storage: Composite cylinders: Glass micro sphere storage: Zeolites, Metal hydride storage, chemical hydride storage and cryogenic storage. Metal hydrides, metallic alloy hydrides, chemical hydride storage and cryogenic storage, Carbon nano-tubes, sea as source of deuterium

[10]

Unit-IV**: Hydrogen Purification**

Catalytic Purification (Water-Gas Shift, Selective CO Oxidation, Methanation), Separation Methods (Pressure Swing Adsorption)

[7]

Unit-V: **Hydrogen Utilization**

Overview of Hydrogen utilization: I.C. Engines, gas turbines, hydrogen burners, power plant, refineries, domestic and marine applications. Hydrogen fuel quality, performance, COV, emission and combustion characteristics of Spark Ignition engines for hydrogen, back firing, knocking, volumetric efficiency, hydrogen manifold and direct injection, fumigation, NOx controlling techniques, dual fuel engine, durability studies, field trials, emissions and climate change.

[7]

Unit-VI: **Hydrogen Safety**

Safety barrier diagram, risk analysis, safety in handling and refueling station, safety in vehicular and stationary applications, fire detecting system, safety management, and simulation of crash tests.

[7]

Reference Books:

1. *M. Ball and M. Wietschel, "The Hydrogen Economy Opportunities and Challenges", Cambridge University Press, 2009.*
2. *P. Hoffmann, B. Dorgan, Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet, The MIT Press; revised, 2012.*
3. *J. O. M. Bockris, Energy options : real economics and the solar hydrogen system, Halsted Press and London publisher, 1980.*
4. *D. A. Rand, R. M. Dell, Hydrogen Energy: Challenges and Prospects, RSC Publishing, 2008.*
5. *J. Rifkin, The Hydrogen Economy. Penguin Putnam Inc., 2002.*
6. *G. Holland, J. Provenzano, The Hydrogen Age, The: Empowering a Clean-Energy Future, 2007.*

EEN 918130: Waste to Energy Conversion Technology

(4 0 0 4)

Unit-I: **Solid waste**

Definitions - Sources, Types, Compositions, Properties of Solid Waste - Municipal Solid Waste - Physical, Chemical and Biological Property - Collection - Transfer Stations – Waste Minimization and Recycling of Municipal Waste. (8)

Unit-II: **Waste Treatment**

Size Reduction - Aerobic Composting - Incineration - Furnace Type & Design, Medical / Pharmaceutical Waste Incineration - Environmental Impacts - Measures of Mitigate Environmental Effects due to Incineration (8)

Unit-III: **Waste Disposal**

Land Fill Method of Solid Waste Disposal - Land Fill Classficaition, Types, Methods & Siting Consideration - Layout & Preliminary Design of Land Fills - Composition, Characteristics, Generation, Movement and Control of Landfill Leachate & Gases – Environmental Monitoring System for Land Fill Gases (10)

Unit-IV: **Hazardous Waste Management**

Definition & Identification of Hazardous Waste - Sources and Nature of Hazardous Waste - Impact on Environment - Hazardous Waste Control - Minimization and Recycling - Assessment

of Hazardous Waste Sites - Disposal of Hazardous Waste, Underground Storage Tanks Construction, Installation & Closure. (9)

Unit-V: **Energy Generation from Waste**
Types - Biochemical Conversion - Sources of Energy Generation - Industrial Waste, Agro Residues - Anaerobic Digestion - Biogas Production - Types of Biogas Plant Thermochemical Conversion - Sources of Energy Generation - Gasification - Types of Gasifiers - Briquetting - Industrial Applications of Gasifiers - Utilization and Advantages of Briquetting - Environment Benefits of Biochemical and Thermochemical Conversion (8)

Reference Books:

1. *Parker, Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier, Applied Science, London, 1985.*
2. *Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Printice Hall, 2000.*
3. *M. Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997.*
4. *G. Rich, et.al., Hazardous Waste Management Technology, Podvan Publishers, 1987.*
5. *A. D. Bhide, B. B. Sundaresan, Solid Waste Management in Developing Countries, INSDOC New Delhi, 1983.*

EEN 918140: Energy Management and Auditing (4 0 0 4)

Unit-I: **Introduction**
Energy Scenario - Principles and Impeartives of Energy Conservation. Energy Consumption Pattern, Resource Availability, Role of Energy Managers in Industries. Energy Audit-Purpose, Methodology with respect to process. Industries - Power plants, Boilers etc, Characteristic method Employed in Certain Energy Intensive Industries; Discount rate, Payback period, Internal rate of return, life cycle costing. (5)

Unit –II: **Total Energy systems**
Concept of Total Energy, Advantages & Limitations, Total Energy system & Application - Various Possible Schemes Employing Steam Turbines Movers Used in Total Energy Systems -Potential & Economics of Total Energy Systems (4)

Unit -III: **Thermal Energy Management**
Energy conservation in boilers, steam turbines and industrial heating systems; Application of FBC; Cogeneration and waste heat recovery; Thermal insulation; Heat exchangers and heat pumps; Building Energy Management. (5)

Unit -IV: **Electrical Energy Management**
Potential Areas for Electrical Energy Conservation in Various Industries-Energy Management opportunities in Electrical Heating, Lighting system, Cable selection, Energy Efficient Motors - Factors involved in Determination of Motor Efficiency Adjustable AC Drives, Applications & its use variable speed Drives/Belt Drives Importance of Energy Management, Energy Economics - Discount Rate, Payback Period, Internal Rate of Return, Life Cycle Costing. (6)

Unit –V: **Co-generation**

Advantages of Cogeneration Technology. Cogeneration Application in various industries like Cement, Sugar Mill, Paper Mill etc. Sizing of waste heat boilers, Performance calculations, Part load characteristics selection of Co-generation Technologies. Financial considerations. Operating and Investments - Costs of Cogeneration. (5)

Unit -VI: **Waste Heat Recovery**

Recuperators, Regenerators, economizers, Plate Heat Exchangers, Waste Heat Boilers. Classification, Location, Service Conditions, Design Considerations, Unfired combined Cycle - supplementary fired combined cycle, fired combined cycle applications in Industries. Fluidised bed heat exchangers, heat pipe exchangers, heat pumps, thermic fluid heaters selection of waste heat recovery technologies, financial considerations, operations and investment costs of waste heat recovery. (6)

Unit-VII: **Energy Audit**

Types and Methodology; Energy Audit Reporting Format; Understanding Energy Costs; Benchmarking and Energy Performance; Matching Energy Usage to Requirement; Maximizing System Efficiency; Fuel and Energy Substitution; Energy Audit Instruments; Duties and responsibilities of energy auditors. (4)

Unit-VIII: **Material and Energy Balance**

Basic Principles; The Sankey Diagram and its Use; Material Balances; Energy Balances; Method for Preparing Process Flow Chart; Facility as an Energy System; How to Carryout Material and Energy (M & E) Balance. (4)

Unit-IX: **Energy Action Planning**

Key elements; Force field analysis; Energy policy purpose, perspective, contents, formulation, ratification; Organizing the management: location of energy management, top management support, managerial function, accountability; Motivation of employees: Information system designing, barriers, strategies; Marketing and communicating: Training and planning. (3)

Unit-X: **Energy Monitoring & Targeting**

Definition; Elements of Monitoring & Targeting System; A Rationale for Monitoring, Targeting and Reporting; Data and Information Analysis; Relating Energy Consumption and Production; CUSUM; Case Study. (3)

Reference Books:

1. *C. H. Butler, Cogeneration, McGraw Hill Book Co., 1984.*
2. *J. H. Horlock, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford, 1987.*
3. *S. Sengupta et.al., Waste Heat Utilization and Management, Hemisphere, Washington, 1983.*
4. *De Nevers, Noel., Air Polllution Control Engineering, McGrawHill, New York,1995.*
5. *CB Smith, Enegy Management Principles, Pergamon Press, NewYork, 1981*
6. *Hamies, Energy Auditing and Conservation; Methods, Measurements, Management & Case study, Hemisphere, Washington, 1980.*
7. *P.R. Trivedi, K.R. Jolka, Energy Managemnent, Commonwealth Publication, New Delhi, 1997.*
8. *L. C. Witte, Industrial Energy Management & Utilization, Hemisphere Publishers, Washington, 1988.*
9. *R.M.E. Diamant, Total Energy, Pergamon, Oxford, 1970.*
10. *Y. Y. Hamies, Energy Auditing and Conservation; Methods, Measurements, Management & Case study, Hemisphere, Washington, 1980.*

11. *Bureau of Energy Efficiency ; Study material for Energy Managers and Auditors Examination: Paper I to IV, 2003.*

EEN 918150: Advanced Materials for Energy (4 0 0 4)

Unit-I*:* **Introduction**

Review of 1st and 2nd law, statistical distribution; Review of heat transfer; Fourier law; Newton's law of cooling; Planck's blackbody radiation law, Stefan-Boltzmann law; *Energy states in matter:* Electron band structure; Phonon spectrum of solids; Density of states; Carrier density (8)

Unit-II: **Characterization of Materials**

Optical, thermal, electrical, electrical and structural characterization (5)

Unit-III: **Energy Harvesting Materials/structures**

Black Selective coating; Anti-reflection coating/layer; Concentrators: Refractive, reflecting materials/surfaces (4)

Unit-IV: **Materials for Energy Conversion Devices**

Thermoelectric effect and thermoelectric devices: Seebeck effect; Peltier effect; Thomson effect; Thermoelectric figure of merit; *Kinetic formulation of thermoelectricity;* Coupled electron heat transport; Electron engineering; Phonon engineering; *Current thermoelectric materials:* Classical thermoelectric materials; Commercial materials: oxides, half-Heusler; Nanostructures; Complex materials

Photovoltaics: Evolution of new generation devices and materials; New Generation photovoltaic materials

Chemical Energy Conversion: Fuel Cells

Mechanical Energy Conversion: Piezoelectric nanogenerators; Self-powered nanodevices/nanosystems and thermoelectrics

Energy Efficient Lighting: Optoelectronic devices for efficient energy usage including light emitting diodes and photodetectors (16)

Unit-V: **Energy/Fuel Storage Materials**

Thermal: Sensible Thermal, Latent Thermal, Thermochemical; *Electrochemical*: Batteries and supercapacitors; *Chemical Storage Materials*: Hydrogen, Hydrogen storage; Biofuel storage; *Chemical Energy Generation/synthesis:* Hydrogen generation; Carbon valorization; Biofuel synthesis (4)

Unit-VI: **Green Energy and Environment Sensors Materials**

Temperature, Pressure, Humidity, Carbon emission sensors (3)

Unit-VII: **Modelling of Energy Materials**

Introduction to computational methods and approaches; Modelling materials for energy generation applications: solar energy; Modelling materials for storage applications: batteries and hydrogen; Modelling materials for energy conversion applications: fuel cells, heterogeneous catalysis and solid-state lighting; Nanostructures for energy applications (6)

Reference Books:

1. *L. H. Van Vlack, Elements of Materials Science and Engineering, Addison-Wesley, New York, 1989.*
2. *William D. Callister , David G. Rethwisch, Materials Science and Engineering: An Introduction, John Wiley, New York, 2010 (8th Edition).*

3. *Duncan W. Bruce, Dermot O'Hare, Richard I. Walton, Energy Materials (Inorganic Materials Series), John Wiley and Sons, UK, 2011.*
4. *D. S. Ginley et al, Fundamentals of Materials for Energy and Environmental Sustainability, Cambridge University Press, 2011.*
5. *R. Catlow, A. Sokol, A. Walsh, Computational Approaches to Energy Materials, John Wiley and Sons, 2013.*

EEN 918160: Experimental Techniques (4 0 0 4)

Unit-I: Production and measurements of Low pressure: Rotary, absorption, oil diffusion, Gauges, Pirani, Penning, leak detection. (9)

Unit-II: **Spectroscopic techniques**
Spectrometer (IR and UV–visible), Fourier transform-infrared (FT-IR), FT-NMR, ESR, UV-Visible, luminescence, Mass, thermal stability (TGA, DTA, DSC, DMA), PL. (9)

Unit -III: **X-Ray crystallography**
Scattering and Absorption of X-rays, neutrons and electrons, X-ray methods for orienting crystals, applications of XRD, crystal structure analysis, measurement of intensities of Xray reflection.
Auger Electron spectroscopy (AES): Basic Principle, methodology and Instrumentation,. Applications of AES in Composition analysis and depth profiling.
X-ray photoelectron spectroscopy (XPS) or ESCA: Principle, Instrumentation, Methodology, Quantitative analysis and Applications. (10)

Unit -IV: **Surface structure and composition analysis techniques**
Scanning electron Microscopy (SEM): Principle, Instrumentation, Methodology and Applications, field emission Electron microscopy (FESEM).
Transmission Electron Microscopy (TEM): Principle, Instrumentation, Methodology for plain view and cross-sectional analysis, Applications in structural analysis, HRTEM.
Atomic Force Microscopy (AFM): Basic principle, Methodology, typical applications in structural analysis.
EPX, AES, SIMS, EELS, SEM, TEM, STM, LEED, Ellipsometry (10)

Unit-V: **Software Analysis**
MATLAB, AutoCAD, Design expert, TRANSIS, PV Syst, DFT calculation software. (10)

Reference Books:

1. *D.P. Woodruff, T. A. Delchar, Experimental Techniques of Surface Science , Cambridge University Press, 2nd edition, 2010.*
2. *N. W. Ashcroft and N. Mermin, Solid State Physics, 1976.*
3. *S. R. Elliot, Amorphous Materials, Longman, 1984.*
4. *L. C. Feldman and J.W. Mayer, Fundamentals of Surfaces and Thin Films Analysis, New York: North Holland-Elsevier, 1986.*
5. *M. M. Woolfson, An Introduction of X-ray Crystallography, Cambridge University Press, 2nd edition, 1997.*
6. *W.K. Chu, Rutherford Backscattering Spectrometry Characterization of Materials, new York, Academic press, 1978.*

7. *G. Haugstad, Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications, wiley, 2012.*
8. *C. J. Chen, Introduction to Scanning Tunneling Microscopy: Second Edition, 2007*
9. *D. J. Higham, N. J. Higham, MATLAB Guide, Society for Industrial and Applied Mathematics; 2nd edition, 2005.*
10. *D. Sholl, J. A. Steckel, Density Functional Theory: A Practical Introduction, Wiley-Blackwell; 1st edition 2009.*
11. *G. Omura, B. C. Benton, Mastering AutoCAD 2015 and AutoCAD LT 2015, Autodesk Official Press, 2014.*

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