CENTER OF EXCELLENCE FOR ENERGY AND ENVIRONMENTAL STUDIES

DEENBANDHU CHHOTU RAM UNIVERSITY OF SCIENCE AND TECHNOLOGY

MURTHAL: 131 039(SONEPAT)

SCHEME OF STUDIES & EXAMINATIONS

M. Tech Programme in Renewable Energy (RE)

1st YEAR (I - SEMESTER)

S.No.	Course No.	Course Name	L	T	P	Total Credit	Class Work	Theory Marks	Practical Marks	Total	Duration of Exam (Hours)
1	RE/ EEM-101	Renewable Energy Systems-I	3	0	0	3	25	75	-	100	3
2	RE-103	Heat Transfer and Process Integration	3	0	0	3	25	75	-	100	3
3	PE-1		3	0	0	3	25	75	-	100	3
4	PE-2		3	0	0	3	25	75	-	100	3
5	RE/EEM-117	Research Methodology and IPR	2	0	0	2	25	75	-	100	3
6	RE-105	Heat Transfer Lab	0	0	4	2	25	-	75	100	3
7	RE-107	Energy Research Laboratory-I	0	0	4	2	25	-	75	100	3
8	Audit-I	Audit-I	2	0	0	0	25	75	-	100	
Grand Total						18				800	

List o PE-1

1	RE/EEM-109	Solar Energy: Fundamentals, Devices and Systems
2	RE/EEM-111	Energy and Climate

List o PE-2

1	RE-113	Direct Energy Conversion
2	RE-115	Nuclear Energy

Audit course 1 & 2

1. English for Research Paper Writing
2. Disaster Management
3. Sanskrit for Technical Knowledge
4. Value Education
5. Constitution of India
6. Pedagogy Studies
7. Stress Management by Yoga
8. Personality Development through Life Enlightenment Skills

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MURTHAL: 131039 (SONEPAT)

SCHEME OF STUDIES & EXAMINATIONS

M. Tech Programme in Renewable Energy (RE)

1st YEAR (II - SEMESTER)

S.No.	Course No.	Course Name	L	T	P	Total Credit	Class Work	Theory Marks	Practical Marks	Total	Duration of Exam (Hours)
1	RE / EEM-102	Renewable Energy Systems-II	3	0	0	3	25	75	-	100	3
2	RE-104	Materials and Devices for Energy Applications	3	0	0	3	25	75	-	100	3
3	PE-1		3	0	0	3	25	75	-	100	3
4	PE-2		3	0	0	3	25	75	-	100	3
		Mini Project with seminar	2	0	0	2	25	75	-	100	3
5	RE-106	Energy Auditing and Simulation Laboratory	0	0	4	2	25	-	75	100	3
6	RE-108	Energy Research Laboratory-II	0	0	4	2	25	-	75	100	3
7	Audit-II	Audit-II	2	0	0	0	25	75	-	100	-
Grand Total						18				800	

List of PE-3

1	RE/EEM-110	Solar Photovoltaic Technology
2	RE-112	Energy Audit Procedures and Techniques

List of PE-4

1	RE/EEM-114	Solar passive heating and cooling
2	RE-116	Energy Conversion Systems

Audit course 1 & 2

1. English for Research Paper Writing
2. Disaster Management
3. Sanskrit for Technical Knowledge
4. Value Education
5. Constitution of India
6. Pedagogy Studies
7. Stress Management by Yoga
8. Personality Development through Life Enlightenment Skills

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SCHEME OF STUDIES & EXAMINATIONS

M. Tech Programme in Renewable Energy (RE)

IInd YEAR (III - SEMESTER)

S.No.	Course No.	Course Name	L	T	P	Total	Class Work	Theory Marks	Practical Marks	Total	Duration of Exam (Hours)
1	PE-5		3	0	0	3	25	75	-	100	3
2	OE		3	0	0	3	25	75	-	100	3
3	RE-209	Phase-I Dissertation	0	0	20	10	25	__	75	100	-
Grand Total						16	75	150	75	300	

List of PE-5

1	RE/EEM-201	Solar Energy Utilization
2	RE-203	Hydrogen Energy

List of OE

1	RE/EEM-205	Waste to Energy
2	RE-207	Green Building Technology

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MURTHAL: 131 039(SONEPAT)

SCHEME OF STUDIES & EXAMINATIONS

M. Tech Programme in Renewable Energy (RE)

IInd YEAR (IV - SEMESTER)

S.No.	Course No.	Course Name	L	T	P	Total	Class Work	Theory Marks	Practical Marks	Total	Duration of Exam (Hours)
1	RE-202	Phase-II Dissertation	0	0	32	16	25	-	75	100	-
Grand Total						16	25	-	75	100	

Total Credits: 18+18+16+16 = 68

RE/EEM-101: Renewable Energy Systems-I

M. Tech. - Renewable Energy (RE) 1st Year (I – Semester)

L	T	P/D	Credits			
3	--	--	3	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives :

To provide knowledge, understanding and application oriented skills on all renewable energy sources and relevant technologies towards their effective utilization for meeting energy demand. To introduce the various renewable sources of energy and modern applications. It includes solar thermal power, power from wind, biomass power and fuel cell. To provide the concepts of Interrelationship between energy and utilization of various resources of energy. The course will include latest technologies related to different power resources.

Unit I:
Solar Energy: Sun as Source of Energy, Availability of Solar Energy, Nature of Solar Energy, Solar Energy & Environment. Various Methods of using solar energy –Photothermal, Photovoltaic, Photosynthesis, Present & Future Scope of Solar energy.

Unit II:
Biomass: Origin of Biomass: Resources: Classification and characteristics; Techniques for biomass assessment; Biomass estimation, Thermochemical Conversion Different processes: Direct combustion, incineration, pyrolysis, gasification and liquefaction; Economics of thermochemical conversion.

Unit III:
Wind Energy: Basics & Power Analysis, Wind resource assessment, Power Conversion Technologies and applications, Wind machine types, classification, parameters. Wind, its structure, statistics, measurements, data presentation, power in the wind. Wind Power estimation techniques, Principles of Aerodynamics of wind turbine blade, various aspects of wind turbine design. Horizontal Axis Wind Turbine (HAWT), Vertical Axis Wind Turbine (VAWT) aerodynamics.

Unit IV:
Fuel Cell: Thermodynamics of fuel cells; free energy change and cell potentials; effects of temperature and pressure on cell potential; energy conversion efficiency; factors affecting conversion efficiency; polarization losses; important types of fuel cells, Principle of working, construction, electrode types; electrolytes for fuel cells; applications.

Course Outcomes:
The Course will create awareness among students about Non-Conventional sources of energy technologies and provide adequate inputs on a variety of

issues. After completion of this course, the students will know about all renewable energy sources like solar thermal power, power from wind, biomass power and fuel cell and relevant technologies. Now they have the ability to plan and perform a short scientific study and present the results in writing and orally.

Reference Books :

1. Biomass Renegerable Energy – D.O.hall and R.P. Overeed (John Wiley and Sons, New york, 1987)
2. Biomass for energy in the developing countries – D.O.Hall, G.W.barnard and P.A.Moss (Pergamon Press Ltd. 1982)
3. Thermo chemical processing of Biomass, Bridgurater A V.
4. Biomass as Fuel – L.P.White (Academic press1981)
5. Biomass Gasification Principles and Technology, Energy technology review No. 67, T.B. Read (Noyes Data Corp. , 1981)
6. Wind energy Conversion Systems – Freris L.L. (Prentice Hall1990)
7. Wind Turbine Technology: Fundamental concepts of wind turbine technology Spera D.A. (ASME Press, NY, 1994)
8. Wind Energy Systems – G.L. Johnson (Prentice Hall, 1985)
9. Wind Energy Explained – J.F.Manwell, J.G. McGowan and A.L. Rogers (John Wiley &Sons Ltd.)

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-103: HEAT TRANSFER AND PROCESS INTEGRATION

M. Tech. - Renewable Energy (RE) 1st Year (I – Semester)

L	T	P/D	Credits			
3	--	--	3	**Class Work**	**:**	**25 Marks**
				Examination (Theory/Practical)	**:**	**75 Marks**
				Total	**:**	**100 Marks**
				Duration of Examination	**:**	**3 Hours**

Course Objectives :

Heat Transfer is possible by conduction, convection, radiation. The subject has a wide application. It is gaining importance continuously. The present one is a fundamental course which provides adequate concepts and prepares the students for undertaking calculations of heat transfer rate through different mechanisms. This is a bridge course for non mechanical engineering background students for Energy programme. To introduce the fundamental of thermodynamics required in thermal process, heat transfer and fluid mechanics.

Unit I

Basic Heat Transfer Concept and Terminology:

Basic Concepts Terminology, Heat Transfer Coefficients, Thermal Resistance, Equation, Steady State Conduction in simple geometries, Thermal; Contact Resistance ,Critical Thickness of Insulation, Multidimensional Steady State Heat Conduction (Shaper Factor), Types of Fins, Effectiveness and Efficiencies of Fins, Lumped Heat Capacity Analysis.

Unit II

Convection:

Similarity Principle, Mass moments and Energy Balance equations, Evaluation of Dimensionless Parameters, Forced Flow Convection (Laminar, Turbulent &Mixed) Thermal and Velocity Boundary Layer Thickness Convective Heat Transfer Coefficient ,Drag Coefficient for various geometrical figure, Free convection Verticals and Inclined Plates, Inclined Parallel Plates, Horizontal, Verticals, Cylinder and Sphere, Two Phase Convection :Phase Condensation on vertical and Single Tube, Bank of Tube Boiling.

Unit III

Boiling and Condensation

Basic concept **,** Simplified Relations for Boiling Heat Transfer with Water, The Heat Pipe.

Heat Exchangers

The Overall Heat-Transfer Coefficient, Fouling Factors, Types of Heat Exchangers, The Log Mean Temperature Difference, Effectiveness-NTU Method, Compact Heat Exchangers, Heat Exchangers Design Considerations.

Unit IV

Radiation

Blackbody Radiation, radiative properties, Atmospheric and solar radiation, Law of radiation, View Factor Algebra, Enclosures with Black Surfaces and Grey Surfaces, Radiosity. Numerical solutions of radiation network analysis.

Course Outcomes:

After doing this course student will know about the basics of heat transfer i.e. conduction, convection and radiation. The subject has a wide application in the industries, energy auditing and ECBC compliance in buildings. This is a fundamental course, now the students are prepared for calculations of heat transfer rate through different mechanisms.

Reference Books:

1. S.P. Shukatme, Heat Transfer, Orient Longman, New Delhi.
2. W.H. Giedt, Principles of Engineering Heat Transfer, D.Van Norstand Company Inc. (1961)
3. F. Kireth, Radiation Heat Transfer, International Text book Co., Semton, USA (1962).
4. Process Integration, Chapter of Energy Efficiency, By Eastop.
5. J.P. Holman – Heat Transfer
6 Cengel, Heat transfer, Tata Mc Graw Hill

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-105: HEAT TRANSFER LAB

M. Tech. - Renewable Energy(RE)1st Year (I – Semester)

L	T	P/D	Credits			
-	--	4	2	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives:

In order to supplement various topics related to energy aspects in class-room lectures, some laboratory experiments are needed as a part of curriculum development of energy studies programme for better understanding of the subjects. The experiments based on heat transfer principles are so designed so as to provide students enough stimulation for further investigation.

List of Experiments

1. Evaluation of UL, FR and η in Thermosyphonic mode of flow with fixed input parameters and at different radiation level.
2. Evaluation of UL, FR, η in Thermosyphonic mode of flow at different inlet water temperature and with fixed input parameters.
3. To determine and compare LMTD, Overall Heat transfer coefficient, efficiency and effectiveness of a heat exchanger in parallel flow and counter flow mode. (Water to water)
4. To determine and compare LMTD, Overall Heat transfer coefficient, efficiency and effectiveness of a heat exchanger in parallel flow and counter flow mode. (Water to air)
5. Evaluation of UL, FR, η and drawing of different curves in forced mode of flow at different flow rate.
6. Evaluation of UL, FR, η in forced mode of flow at different radiation level and at different inlet water temperature.
7. Evaluation of UL, FR, η in forced mode of flow at different wind speed.
8. Evaluation of UL, FR, η in forced mode of flow at different tilt angle and all other parameter as in forced mode experiment.

Course outcomes:

The students will be able to

1. Able to design and carry out a method of heat transfer analysis, including instrumental analysis.
2. Perform various heat transfer experiments through different modes like forced mode and thermosyphonic mode.
3. Now students easily understand the concept of heat transfer in their practical life also.

RE-107: ENERGY RESEARCH LABORATORY –I

M. Tech. - Renewable Energy(RE)1st Year (I – Semester)

L	T	P/D	Credits			
-	--	4	2	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives:

In order to supplement various topics related to energy aspects in class-room lectures, some laboratory experiments are needed as a part of curriculum development of energy studies programme for better understanding of the subjects. The experiments based on science/engineering principles are so designed so as to provide students enough stimulation for further investigation.

List of Experiments:

1. To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level.
2. To demonstrate the I-V and P-V characteristics of series and parallel combination of PV modules.
3. To show the effect of variation in tilt angle on PV module power.
4. To demonstrate the effect of shading on module output power.
5. To demonstrate the working of diode as Bypass diode and blocking diode.
6. To observe the open circuit voltage decay graph of a crystalline silicon solar cell.
7. To calculate the lifetime of the solar cell.
8. Understanding the concept of lifetime in solar cells.
9. Ability to calculate the lifetime of the solar cell.
10. To compare and analyse the performance of charge controllers.
11. To understand the different voltage rating applications.
12. Measurement of IV characteristics with change in illumination to analyse the deviation of operating points from Maximum power point.
13. To understand the PV system design and installation with tracking techniques and mechanisms.
14. Plot the Torque v/s Speed and Power v/s Speed characteristics of the turbine at different wind speed and load configuration.
15. Plot the torque v/s speed and power v/s speed characteristics of the turbine at different pitch angle and load configuration.

Course outcomes:

The students will be able to perform above mentioned experimental. The students are expected to learn the art and science of carrying out experimental research. At the end of the course a student should be able to design and carry out an experiment on his/her own. This is an important skill which anybody wanting to do experimental research is expected to possess.

RE/EEM-109: Solar Energy: Fundamentals, Devices and Systems

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks
				Duration of Examination	:	3 Hours

Course Objectives :

This course has objectives to elaborate PG students regarding current trends in solar architecture and following key concepts: Solar Radiation, Sun Angles, and Importance of Sun Angles for Building Fenestration/day lighting, Solar Passive Architecture, heat transfer in buildings, Natural Heating/Cooling concepts for Building, Refrigeration systems.

Unit I

Earth & Sun Relationship:

Earth & Sun Relation: Solar Angles, Day length, Angle of Incidence on Tilted Surface, Sun path Diagram. Available Solar Radiation: Extraterrestrial Characteristics, Effect of Earth Atmosphere, Measurement and Estimation on Horizontal and Tilted Surface, Solar Radiations Characteristics.

Unit II

Thermal Energy Storage: Sensible Storage (Water, pebble bed and ground storage), Latent Heat Storage.

Thermal Energy Systems

Solar Water Heating System: Components, Natural Flow, Forced Flow and Load
Solar Air Heating Systems: Space Heating, Solar Drying, Load Estimation.
Solar desalination system: Design and type, Solar still, performance analysis.

Unit III

Solar Refrigeration and Desiccant

Cooling : Vapor Absorption Refrigeration cycle, Water ammonia and Lithium bromide – water absorption refrigeration systems, Solar Operated Refrigeration Systems, Solar Desiccant cooling .

Unit IV

Solar Power Generator

Solar Thermal Power Generation : Basic Operating and applications, Parabolic trough Systems, Parboloidal Dish Systems, Heliostat system, Central Receiver Power Plants, Solar Furnace.

Course outcomes:

This will enable them to understand the solar architecture and following key concepts: Solar Radiation, Sun Angles, and Importance of Sun Angles for Building Fenestration/day lighting, thermal energy storage and devices, Solar Passive Architecture, Solar Refrigeration and Desiccant and Solar Power Generator.

Recommended Books:

1. Duffle and Beckman, Solar Thermal Engineering Process, John Wiley & Sons, New York
2. J.S. Hsieh, Solar Energy, Prentice Hall Inc. New Jerssey
3. A.B. Meinel and M.B. Meinel, Applied Solar Energy, Addison – Wiley Pub. Co., Reading
4. P.J. Lunde, Solar Thermal Engineering, John Wiley & Sons, New York
5. N.C. Harris, C.E. Miller and I.E. Thomas, Solar Energy Systems Design, John Wiley & Sons, New York
6. H.P. Garg, Advanced in Solar Energy Technology, D. Reidel Publishing Co., Drdricht.
7. S.P. Sukhatme, Solar Energy, Tata McGrew Hill Company Ltd., New Delhi
8. M.A. Greaen "Solar Cells – Operating Principles, Technology, and System Applications", 1983 Prentice Hall, Inc. New Jersey.
9. Markvart, Solar Electricity, John Wiley
10. F. Kreith and J.F. Kreider, Principles of Solar Engineering Hemisphere Publishing Coro.
11. G.N. Tiwari and S. Suneja, Solar Thermal Engineering Systems, Narosa Publishing House.
12. W H Blass, F. Pfisterer – Advance in Solar Energy Technology.
13. Mathur and Methaf - Solar Energy.

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-111: Energy and Climate

M. Tech. - Renewable Energy (RE) Elective

L	T	P/D	Credits			
3	--	--	3	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives:

To provide knowledge, understanding and application oriented skills on energy – environment interaction, environmental emissions from various energy resource technology combinations and their impact on ecosystems as well as various measures and initiatives for emissions mitigation. The course also fosters an understanding of fundamental environmental issues with a focus on resource conservation and management for future use. To sensitize students towards environmental concerns and issues, and make them able to apply their knowledge for sustainable development

Unit I

Energy and us: Energy terms; Current energy scenario (World, US, India); Fossil energy Vs renewable sources; Electricity; Future projections; Externalities of energy use, Carbon Cycle: Natural systems, autotrophs, heterotrophs, energy flows, pre-industrial humanity; Photosynthesis- efficiency of natural ecosystems, forests and various crops; Respiration, combustion and other oxidation processes.

Unit II

Climate Science Research: Climate history; Greenhouse gas effect; Anthropogenic climate change; Role of different gases; Global problem; Integrated assessment models; Impacts and adaptation; Uncertainties.

Unit III

Carbon Sequestration: Biological pathways; Physico-chemical methods; CO_2 capture from large point sources; Pre-, post- and oxy-combustion technology; Transport, storage and monitoring; Feasibility, economics and public perceptions.

Unit IV

Climate Policy: Kyoto protocol; UNFCCC; IPCC; Geopolitics of GHG control; Carbon market - CDM and other emission trading mechanisms; Non-CO_2 GHGs; Relevance for India.

Course outcomes:

Student will be able to explain the concepts of Interrelationship between energy, ecology and environment, environmental issues related to harnessing and utilization of various sources of energy and related environmental degradation. Understand the special engineering challenges of using each of these sources of energy efficiently and environmentally effectively. Students will be able to understand the problems related to environment at global level like GHG emissions, Kyoto protocol, CDM etc.

Reference Books:

1. Energies: V Smil, MIT Press, Cambridge, 1999.
2. Global Warming: J Houghton, Cambridge University Press, New York, 1997
3. Various reports published by IPCC: http://www.ipcc.ch/, 1990 onwards
4. IPCC Special Report on Carbon Dioxide Capture and Storage: B Metz et al (Eds), Cambridge University Press, NY, 2005.
5. CDM Country Guide for INDIA: Institute for Global Environmental Strategies (Ed), Ministry of the Environment, Japan, 2005.
6. Global Environmental Issues:F Harris (Ed),John Wiley,Chichester, 2004.
7. Carbon Capture and Sequestration: Integrating Technology, Monitoring, and Regulation edited by E J Wilson and D Gerard, Blackwell Publishing, Ames, Iowa, USA, 2007
8. Energy and the environment: J A Fay and D S Golomb, Oxford University Press, New York, 2002.
9. Introduction to Engineering and the Environment: E S Rubin, McGraw Hill, New York, 2001

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE/EEM-113: Direct Energy Conversion

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks
				Duration of Examination	:	3 Hours

Course Objectives:

To provide adequate inputs on a variety of issues relating to direct energy conversion systems. Introduction to principles and operation of devices that convert thermal, chemical, and electromagnetic energy directly into electricity. This course will also discuss about the basics of semiconductor materials and devices for photovoltaic applications.

Unit I

Survey of energy conversion problem. Basic science of energy conversion, 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, Physics of semiconductor junctions for photovoltaic

Unit II

Fabrication and evaluation of various solar cells. Application of solar cells in photo voltaic power generation systems. Batteries: Thermodynamic analysis, design and analysis of batteries, Other modes of direct energy conversion.

Unit III

Technology and physics of thermo-electric generators. Thermo-electric materials and optimization studies, Basic concepts and design consideration of MHD generators. Cycle analysis of MHD systems. Thermionic power conversion and plasma.

Unit IV

Introduction to the principles and operation of fuel cells, stack configurations and fuel cell systems. Fuel cell system design, optimization and economics. Overview of fuel cell technology. Thermodynamics of fuel cells, introduction to electrochemical kinetics, transport-related phenomena and conservation equations for reacting multicomponent systems. Environmental effect.

Course outcomes:

After doing this course students will know about energy conversion problems, basic science of energy conversion, energy conversion process, indirect and direct energy conversion; fabrication and evaluation of various solar cells; design and analysis of batteries; technology and physics of thermo-electric and MHD generators and basic concept of other chemical to energy conversion devices.

Reference Books:

1. Direct Energy Conversion : W.R.Corliss
2. Aspects of Energy Conversion : I.M.Blair and B.O.Jones
3. Principles of Energy Conversion : A.W.Culp (McGraw-Hill International)
4. Energy conversion principles : Begamudre , Rakoshdas
5. Semiconductor Devices by Nauro Zamluto, Mc Graw Hill 1989 (Int. Ed.)
6. Solid State Electronic Devices. III ed. By B. G. Streetman, Prentice Hall India Pvt. Ltd., N.D, 1991.
7. Solar Cells by Martin Green, Pergamon press.
8. Solar Energy Thermal processes: Duffie & Buckman, Wiley & Sons, New York.
9.Solar Energy by S.P. Sukhatme, Tata Mc Graw Hill, New Delhi.
10.Solar Energy: H P Garg & J P Prakash.
11. Non-Conventional Sources of Energy- G D Rai
12. Energy Technology- S. Rao (Khanna Publications)

Note: **Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.**

RE-115: Nuclear Energy

M. Tech. - Renewable Energy(RE)Elective

L	T	P/D	Credits			
3	--	--	3	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives :

Due to the rapidly growing energy needs of the country, India has made definite moves towards exercising the nuclear option for large-scale energy generation in the coming years. To further the needs of the country in this direction a National Fusion Program has also been set up within the country. In view of these developments, it is appropriate that a course on basic nuclear energy be available for students interested in large scale energy options both for India and globally. The course treats the basics of both nuclear fission and fusion, and energy generation using these methods; it is suitable for students from interdisciplinary background. To impart knowledge about nuclear deformations, properties and nuclear models for understanding of related reaction dynamics.

Unit I

Basics of Nuclear Fission and Fusion processes, Advantages and Disadvantages, Fuels for Nuclear energy, Nuclear Energy in relevance India. Current status

Unit II

Nuclear Fusion reactions, Difficulties in the fusion reactions, Fuel Ignition temperature, Lawson criterion, confinement problems.

Unit III

Laser-driven fusion, magnetic confinement, equilibrium and stability, cross-field transport, Important heating schemes. Tokamak and magnetic mirror, reactor concepts.

Unit IV

Nuclear fission reactor and nuclear fusion reactor. Nuclear radiation detector. Current status.

Course outcomes:

Student will familiarize with the basic possibilities for energy production by fission and fusion reactions. Students will know the necessary technological elements of fusion reactors and areas of current problems in their development. Student will develop the understanding of the energy conversion systems for nuclear power plants, the advantages/disadvantages (including overall environmental effects) of each type of present plants, and those of the new Generation IV concepts. After doing this course the students are expected to have basic understanding of nuclear fusion process and the schemes to achieve this.

Reference/Text books:

1. Energy Technology-S. Rao (Khanna Publications)
2. Nuclear Energy Now: - Alan M. Herbst and George W. Hopley
3. Plasma Physics and Controlled Nuclear Fusion-Miyamoto, Kenro (Springer)
4. Nuclear Principles in Engineering-Jevremovic, Tatjana (Springer)
5. Nuclear Energy: An Introduction to the Concepts, Systems, And Applications of Nuclear Processes-Raymond LeRoy Murray
6. Nuclear Fusion- Keishiro Niu and K. Sugiura (2009)
7. Plasma Physics and Fusion Energy by Jeffrey P. Freidberg

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE/EEM-117: RESEARCH METHODOLOGY AND IPR

M. Tech. - Renewable Energy (RE) 1st Year (I – Semester)

L	T	P/D	Credits			
3	--	--	3	**Class Work**	**:**	**25 Marks**
				Examination (Theory/Practical)	**:**	**75 Marks**
				Total	**:**	**100 Marks**
				Duration of Examination	**:**	**3 Hours**

Course Objectives:

1. To understand some basic concepts of research and its methodologies
2. To identify appropriate research topics
3. To select and define appropriate research problem and parameters
4. To prepare a project proposal (to undertake a project)
5. To organize and conduct research (advanced project) in a more appropriate manner
6. To write a research report and thesis
7. To write a research proposal (grants)
8. The main objective of the IPR is to make the students aware of their rights for the protection of their invention done in their project work.
9. To get registration in our country and foreign countries of their invention, designs and thesis or theory written by the students during their project work and for this they must have knowledge of patents, copy right, trademarks, designs and information Technology Act.
10. Further teacher will have to demonstrate with products and ask the student to identify the different types of IPR's.

Unit 1:

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Unit 2:

Effective literature studies approaches, analysis, Plagiarism, Research ethics, Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Unit 3:

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Unit 4:

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications, New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Course Outcomes:

At the end of this course, students will be able to:

1. Understand research problem formulation.
2. Analyze research related information
3. Follow research ethics
4. Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
5. Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.
6. Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

Reference Books :

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.
7. Asimov, "Introduction to Design", Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

<u>Note:</u> Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE/EEM-102: Renewable Energy Systems-II

M. Tech. - Renewable Energy(RE) 1st Year (II – Semester)

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks
				Duration of Examination	:	3 Hours

Course Objectives:

To provide knowledge, understanding and application oriented skills on all renewable energy sources and relevant technologies towards their effective utilization for meeting energy demand. The Course will create awareness among students about Non-Conventional sources of energy technologies and provide adequate inputs on a variety of issues. The objective of this course is to study the potential of power generation from renewable and quantify its impact on carbon dioxide mitigation. It includes geothermal, tidal Energy, hydrogen energy, hydel energy and nuclear power. Some of the advanced countries around the world are harnessing this power. The course will include latest technologies related to different power resources.

Unit I:
Geothermal, Tide and Wave Energy: Availability of Geothermal Energy-size and Distribution, Recovery of Geothermal Energy, Various Types of Systems to use Geothermal Energy, Direct heat applications, Power Generation using Geothermal Heat, Sustainability of Geothermal Source, Status of Geothermal Technology, Economics of Geothermal Energy.

Unit II:
Hydrogen Energy: Hydrogen as a renewable energy source, Sources of Hydrogen, Fuel for Vehicles. Hydrogen Production: Direct electrolysis of water, thermal decomposition of water, biological and biochemical methods of hydrogen production. Storage of Hydrogen: different methods and metal hydrides etc.

Unit III:
Hydel Energy: Hydro power: Potential, Hydropower Generation and Distribution, Mini and Microhydel Power (MHP) Generation: Classification of hydel plants, Concept of micro hydel, merits, MHP plants: Components, design and layout, Turbines, efficiency, Status in India. Integrated Energy systems and their cost benefit analysis.

Unit IV:
Nuclear Energy: Potential of Nuclear Energy, Nuclear Energy Technologies – Fuel enrichment, Different Types of Nuclear Reactors, Nuclear Waste Disposal, and Nuclear Fusion.

Course Outcomes:
The Course will create awareness among students about Non-Conventional sources of energy technologies and provide adequate inputs on a variety of issues. After completion of this course, the students will know about all renewable energy sources like geothermal, tidal Energy, hydrogen energy, hydel energy and nuclear power and relevant technologies. Now they have the ability to plan and perform a short scientific study and present the results in writing and orally.

Reference Books :

1. Renewable Sources of Energy and Conversion Systems: N.K.Bansal and M.K.Kleeman.
2. Principles of Thermal Process : Duffie Beckman.
3. Solar Energy Handbook: Kreith and Kreider (McGrawHill)
4. Solar Cell : Marteen A. Green
5. Solar Hydrogen Energy Systems T. Ohta (Ed.) (Pergamon Press)
6. Hydrogen Technology for Energy – D.A.Maths (Noyes Data Corp.)
7. Handbook : Batteries and Fuel cell – Linden (Mc.Graw Hill)

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-104: Materials and Devices for Energy Applications

M. Tech. - Renewable Energy(RE)1st Year (II – Semester)

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks
				Duration of Examination	:	3 Hours

Course Objectives:

The development of novel materials and processes requires deep knowledge of physical foundations of materials. The central objective of the course is to provide basic understanding of physics and technology behind thin film growth. Possible applications demonstrating novel material designs and case studies in technological areas of current interest will be discussed. The aim of this course is to provide the knowledge on the physics of nanostructure materials, materials growth aspects important for size control and size selection and application of nanoscale materials for energy harvesting. The aim of this course is to provide the knowledge on the Experimental methods used by researchers to understand the properties of materials.

Unit I

Device fabrication technologies: diffusion, oxidation, photolithography, sputtering, physical vapor deposition, chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), hot wire CVD (HWCVD), etc.

Unit II

Introduction to material characterization: Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), X-ray diffraction (XRD), Raman spectroscopy, Atomic force microscopy (AFM), Spectral response of solar cells, quantum efficiency analysis, dark conductivity, I-V characterization.

Unit III

Basics of Semiconductors Physics: Intrinsic and Extrinsic Semiconductor, Direct and indirect transition, inter-relation between absorption coefficients and band gap recombination of carriers. Basics of Photovoltaic Technology: Types of Solar cells, crystalline silicon deposition techniques, description and principle of working of single crystal, polycrystalline and amorphous silicon solar cells.

Unit IV

Materials and devices for energy storage; Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNTs for hydrogen storage, CNT-polymer composites etc. Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells.

Course outcomes:

This course will discuss some of the important concepts, which are key to understand and modify the properties of different types of materials. The course lays foundation for advanced courses in engineering aspects of materials and their applications. This course will provide the knowledge on the Experimental methods used by researchers to understand the properties of materials.

Texts/Reference Books:

1. Solar cells: Operating principles, technology and system applications, by Martin A. Green, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.
2. Seminconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
3. Solid State electronic devices, Ben G. Streetman, , Prentice-Hall of India Pvt. Ltd., New delhi 1995.
4. Carbon nanotubes and related structures: New material for twenty-first century, P. J. F. Harris, Cambridge University Press, 1999.
5. Thin-film crystalline silicon solar cells: Physics and technology, R. Brendel, Wiley-VCH, Weinheim, 2003.
6. Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial college press, 2001.
7. Organic photovoltaics: Concepts and realization, C. Barbec, V. Dyakonov, J. Parisi, N. S. Saricifttci, Springer-Verlag 2003.
8. Fuel cell and their applications, K. Kordesch, G. Simader, VCH, Weinheim, Germany, 1996.
9. Battery technology handbook, edited by H.A. Kiehne, Marcel Dekker, New York, 1989
10. Solar Energy (Tata McGraw Hill, N. Delhi) by S. P. Sukhatme
11. Solar cell Devices (Academic Press, New York) by Fonash

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-106: Energy Auditing and Simulation Laboratory

M. Tech. - Renewable Energy(RE)1st Year (II – Semester)

L	T	P/D	Credits			
-	--	4	2	**Class Work**	:	**20 Marks**
				Examination (Theory/Practical)	:	**30 Marks**
				Total	:	**50 Marks**
				Duration of Examination	:	**3 Hours**

Objectives of the Laboratory:

- Attract more M.Tech/ Ph.D Students to carry out their experiments in the field of energy use analysis and Thesis work and to publish high quality research papers in the National /International Journals.
- Provide facility for conducting the energy conservation, quality and auditing of Residential,Commercial,Official Buildings and Industries etc.
- Develop more and more Socio-economic / Industrial /Public relationship.
- Improve teaching, training and learning facilities of Engineers from industry and otherTechnical Institutes.
- Promote demand driven R& D with suitable added facilities

List of experiments

1. Introduction to energy simulation tools.
2. Modelling techniques, validation of simulation model.
3. Use of application software (TRANSYS, PVSyst, RETSCREEN, HOMER etc.) For energy system analysis.
4. Simulation for energy efficiency of buildings.
5. Simulation of major energy experiments using real time data acquired through data acquisition system
6. Modeling of energy systems and investigation of dynamic behaviour: concept of input, parameters, output, errors, tools for validation.
7. Solar Radiation Data Monitoring and Analysis.
8. To study various renewable energy source options (Solar PV) installed in the DCRUST campus and write report.
9. Software - Modelling software like ProE, Gambit, ANSYS etc Analysis software like ANSYS, Fluent, CFX, etc Equation solving software like MATLAB, Engg equation solver
10. Energy audit of a small scale industry/institute and submit report with recommendation.
11. Energy audit of HVAC or Compressed air or Boiler and steam system and submit report with recommendations.
12. Carry out the Energy audit of Electrical system.
13. Electrical tariff calculations

Outcomes: Learner will be able to…

1. Simulation and Modelling of typical energy system.
2. Summarize and explain need for energy management, economics and auditing
3. Describe importance of and analyze efficiency in thermal and electrical utilities
4. Assess need of waste heat recovery and cogeneration

RE-108: Energy Research Laboratory -II

M. Tech. - Renewable Energy(RE)1st Year (II – Semester)

L	T	P/D	Credits			
-	--	4	2	**Class Work**	:	**20 Marks**
				Examination (Theory/Practical)	:	**30 Marks**
				Total	:	**50 Marks**
				Duration of Examination	:	**3 Hours**

Objectives:

In order to supplement various topics related to energy aspects in class-room lectures, some laboratory experiments are needed as a part of curriculum development of energy studies programme for better understanding of the subjects. The experiments based on science/engineering principles are so designed so as to provide students enough stimulation for further investigation. Acquainting the students on the SOP adopted for quantification of various parameters. To inculcate the habit of analyzing the numbers resulting from experimentation. To create awareness on actual performance limits of renewable energy gadgets/ industrial utilities

List of experiments

1. To draw the charging and discharging characteristics of battery.
2. Workout power flow calculations of standalone PV system of DC load with battery.
3. Workout power flow calculations of standalone PV system of AC load with battery.
4. Workout power flow calculations of standalone PV system of DC and AC load with battery.
5. Performance analysis of PWM and MPPT type charge controllers.
   (a) Change in operating point of modules with and without MPPT with variation in load.
   (b) Comparison between charging points of battery with and without MPPT.
6. To convert and observe various DC voltages 17.5, 35, 70 V to 24, 48 & 96 V respectively using DC step up converters.
7. To convert and observe various DC voltages 17.5, 35, 70 V to 6, 12, 24 V respectively using DC step down converters.
8. To convert various DC voltages to 230 V single phase AC.
9. To analyse the efficiency of step up and step down converter and DC to AC converter at different power.
10. Measurement of IV characteristics at different temperature levels to extract temperature parameters of the modules(without fans)
11. Measurement of IV characteristics with change in illumination to analyse the deviation of operating points from Maximum power point.

12. Measurement of Quantum efficiency of solar cell for different wavelengths of light and obtain quantum efficiency curve. User can also measure Internal and external quantum efficiency measurements.
13. Measurement and comparison of spectral response for different wave lengths of light and obtain spectral response curve.
14. Determine the Performance (UL, FR, η) of the Parabolic Trough collector with varying flow rate of fluid (Water).
15. Determine the Performance (UL, FR, η) of the Parabolic Trough collector with different inlet water temperature.

Outcomes: Learners will be able to ……

1. Understand the behavioral effect of battery under AC & DC loading.
2. Draw the V-I characteristics of PV modules and to analyse the effect of MPPT and PMW on the output of PV modules.
3. Draw the performance curves for various solar thermal system and can understand the impact of various parameters on the performance of the systems.
4. Develop new systems.
5. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

RE/EEM-110: Solar Photovoltaic Technology

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks
				Duration of Examination	:	3 Hours

Course Objectives :

The Course will be introducing the students to all the aspects of PV technology. To develop basic understanding related to fabrication ad characterization of different types of solar cells. To know state of art in the field of solar cells materials and solar cells. To provide the introduction of solar photovoltaic system design and solar photovoltaic system testing.

Unit I

Solar Cells

Conversion of Solar energy into Electricity - Photovoltaic Effect, Equivalent Circuit of the Solar Cell, Analysis of PV Cells: Dark and illumination characteristics, Figure of merits of solar cell, Efficiency limits, Variation of efficiency with band-gap and temperature, Efficiency measurements, Effect of temperature on Cell performance, Thermo photovoltaic effect, Types of solar cells, Recent developments in Solar Cells.

Unit II

Fabrication Technology for Solar Cells

Si solar cells, CdTe solar cells, Cu(In,Ga)Se2, GaAs solar cells, Organic solar Cells, Perovskite solar cells, High efficiency multi-junction solar cell. Technologies for the fabrication of thin film cells: Thermal evaporation, CVD, CSS etc.

Unit III

Solar Photovoltaic System Design

Solar cell array system analysis and performance prediction, Shadow analysis: Reliability, Solar cell array design concepts, PV system design, Design process and optimization: Detailed array design, Voltage regulation, Maximum tracking, Quick sizing method, Array protection.

Unit IV

Solar Photo Voltaic System Testing

Sun Simulator, Testing and performance assessment of Solar PV generator, Electronic Control and Regulation, Power Conditioning, Converters and inverter, Concentrating system, System design and configuration.

Course outcome:

This course will enable student to understand solar cells, fabrication technologies for solar cells, solar photovoltaic system design and solar photovoltaic system testing. This will enable students to understand the requirements for PV materials and PV systems for different applications. After completing this course student will have theoretical knowledge about fabrication of solar cells, device physics of solar cells, design and development of PV modules, arrays etc.

Text Books/ References:

1. AL Fahrenbruch and RH Bube, Fundamentals of Solar Cells: PV Solar Energy Conversion, Academic Press, New York, 1983

2. T Bhattacharya, Terrestrial Solar Photovoltaic, Narosa Publishers Ltd, New Delhi LD Partain (ed), Solar Cells and their Applications, John Wiley and Sons, Inc, New York, 1995

3. RH Bube, Photovoltaic Materials, Imperial College Press, 1998

4. HS Rauschenbach, Solar Cell Array Design Handbook, Van Nostrand Reinfold Company, New York, 1980

5. R Messenger and J Vnetre, Photovoltaic Systems Engineering, CRC Press Stand Alone PV Systems: A Handbook of Recommended Design Practices, Report No SAND 87-7023, Sandia National Lab USA

6. F Kreith and JF Kreider, Principles of Solar Engineering, McGraw-Hill (1978)

7. J Twidell and T Weir, Renewable Energy Resources, Taylor and Francis (Ed), New York, USA, 2006

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE 112: Energy Audit Procedures and Techniques

M. Tech. - Renewable Energy(RE)Elective

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks
				Duration of Examination	:	3 Hours

Course Objectives:

1. To introduce to students the global energy management in building, energy efficient technology.
2. To develop student the ability to do simple energy audit
3. Study the working of various thermal systems and energy saving opportunities
4. Study electrical energy management, cogeneration and waste heat recovery

Unit I

Energy Audit Methodology & Recent Trends: Current Practices, Integration of two or more systems, Switching of Energy Sources, Economics of implementation of energy optimisation projects, it's constraints, barriers and limitations, Report-writing, preparations and presentations of energy audit reports, Post monitoring of energy conservation projects, MIS ,Case-studies / Report studies of Energy Audits. Guidelines for writing energy audit report, data presentation in report, findings recommendations, impact of renewable energy on energy audit recommendations. Case studies of implemented energy cost optimization projects in electrical utilities as well as thermal utilities.

Unit II

Electrical Distribution and Utilisation: Electrical Systems, Transformers loss reductions, parallel operations, T & D losses, P.F. improvements, Demand Side management (DSM), Load Management, Harmonics & its improvements, Energy efficient motors and Soft starters, Automatic power factor Controllers, Variable speed drivers, Electronic Lighting ballasts for Lighting, LED Lighting, Trends and Approaches.

Unit III

Thermal Systems: Boilers- performance evaluation, Loss analysis, Water treatment and its impact on boiler losses, integration of different systems in boiler operation. Advances in boiler technologies, FBC and PFBC boilers, Heat recovery Boilers- it's limitations and constraints. Furnaces- Types and classifications, applications, economics and quality aspects, heat distributions, draft controles, waste heat recovering options, Furnaces refractories- types and sections. Thermic Fluid heaters, need and applications, Heat recovery and its limitations. Insulators- Hot and Cold applications, Economic thickness of insulation, Heat saving and application criteria. Steam Utilization- Properties, steam distribution and losses, steam trapping, Condensate, Flash steam recovery.

Unit IV

Cogeneration: Integrated analysis of steam base co-gen system, Gas turbine combine cycle operation, IC engine base co-generation and tri-generation, extraction turbines and steam cycle of co-generation.

Course Outcomes:

1. Enhance professional practice to meet the global standards with ethical and social responsibility.
2. Solve industrial, social and environmental problems with modern engineering tools
3. Develop skills to work in teams, think intellectually and pursue life long learning.

Reference Books:

1. Energy Management: W.R.Murphy, G.Mckay (Butterworths).
2. Energy Management Principles: C.B.Smith (Pergamon Press)
3. Efficient Use of Energy: I.G.C.Dryden (Butterworth Scientific)
4. Energy Economics A.V.Desai (Wieley Eastern)
5. Industrial Energy Conservation: D.A. Reay (Pergammon Press)
6. Energy Management Handbook – W.C. Turner (John Wiley and Sons, A WileyInterscience publication)
7. Industrial Energy Management and Utilization –L.C. Witte, P.S. Schmidt, D.R. Brown (Hemisphere Publication, Washington, 1988)
8. Industrial Energy Conservation Manuals, MIT Press, Mass, 1982
9. Energy Conservation guide book Patrick/Patrick/Fardo (Prentice hall1993)
10. Handbook on Energy efficiency.
11. ASHRAEE Energy Use (4 Volumes), 12. CIBSI –guide –Users Manual (U.K.) 13. CRC Handbook on Energy Efficiency – CRC Press

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE/EEM-114: Solar Passive Heating and Cooling

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives :

This course has objectives to elaborate PG students regarding current trends in solar architecture and following key concepts: Solar Radiation, Sun Angles, and Importance of Sun Angles for Building Fenestration/day lighting, Solar Passive Architecture, Natural Heating/Cooling concepts for Building, Earth to Air Heat Exchanger, passive heating, passive cooling and solar ventilation.

Unit I

Heating and cooling load of buildings: elements of heating and cooling load, load reduction approaches, building energy codes, thermal mass.

Unit II

Solar geometry and exposure: sun path diagram, shading analysis, graphical design tools, solar control issues.

Unit III

Passive heating: Direct and indirect solar passive heating systems; solarium, trombe wall, trans-wall.

Passive cooling systems: thermal mass, courtyard effect, wind tower design, earth air tunnel system, evaporative cooling, radiative cooling.

Unit IV

Solar ventilation: stack effect, solar chimney for ventilation, absorber design, stack design, issues in opening design.

Course outcomes:

This will enable them to understand the solar architecture and following key concepts: Solar geometry, sun path diagram, heat transfer in buildings, Solar Passive Architecture, Flat plate collectors, Earth to Air Heat Exchanger, passive heating, passive cooling and green buildings.

Recommended Books:

1. M.S.Sodha, N.K. Banaal, P.K.Bansal, A.Rumaar and M.A.S. Malik, Solar Passive: Building Science and Design, Pergamon Preen (1986).
2. Jamee; L. Threlked, Thermal Environment Engineering, Prentice Hall, INC-, Raglevood Cliffs, New Jersey (1970)
3. T.A. Markus and R.N. Morris, Building, Climate and Energy Spottwoode Ballantype Ltd-, London U.K. (1980)
4. Solar Thermal Energy Storage, H. P. Garg et.al, D. Reidel Publishing Company (1985)
5. Instructions to Energy Auditors, Vol. - I & Vol. - II –National Technical Information Services U. S. Deptt. Of Commerce Springfield, VA 22161.
6. BEE Volume I –Second Edition 2005
7. G.G. Ranjan: Optimizing Energy Efficiencies in Industry, Edition-2003 McGraw Hill

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-116: Energy Conversion Systems

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives:

The purpose of this course is to critically examine the technology of energy systems that will be acceptable in a world faced with global warming, local pollution. The focus is on thermal systems and devices used in various industries for power generations, production cooling and transportation. Both the devices and the overall systems are analyzed

Unit I

Conventional & Renewable Energy Sources: prospecting, extraction and resource assessment and their peculiar characteristics. Direct use of primary energy sources, Conversion of primary into secondary energy sources such as Electricity, Hydrogen, Nuclear energy etc. Energy Conversion through fission and fusion, Nuclear power generation etc.

Unit II

Thermal energy using fossil fuels. Conversion of Thermal Energy to Mechanical energy & Power. Turbines: Steam turbines, Hydraulic turbines.

Unit III

Boilers Types, combustion in boilers, performance evaluation, analysis of losses, feed water treatment, blow down. FBC Boilers: Introduction, mechanism of fluidized bed combustion, advantages, types of FBC boilers, operational features, retrofitting FBC system to conventional boilers. HVAC, Refrigeration and Air Conditioning: Vapor compressor refrigeration cycle, refrigerants, coefficient of performance, capacity, factors affecting refrigeration and air conditioning system performance, Vapor absorption refrigeration systems: Working principle, type and comparison with vapor compressor system.

Unit IV

Sterling Engines, Steam Engine, Internal Combustion systems and external combustion system, Overview of different types of turbines.

Mechanical Engineering and Overview: Basic Engineering concepts and design considerations, Governing regulations and codes and standards, Strength of Materials, mechanical properties of materials, mechanics of materials Torque and Power: Basic theory,

Shafts, Flywheels etc. Power Transmission: Concepts of Belts Drives, Gearing, Coupling etc. Bearing and Lubricants as Energy Saving Measures Electromechanical energy: Electric to mechanical energy conversion, Electric Motors.

Course Outcomes:

1. The student will become adept in the comparative analysis of various energy conversion systems. The comparisons will include cost, social acceptability as well as environmental consequences.

2. The student will be able to apply engineering analysis techniques to the emerging energy technologies of the 21 st century (e.g. wind turbines, combined cycle power plants), and to understand the context in which the design of energy systems takes place.

Reference Books:

1. Direct Energy Conversion : W.R.Corliss
2. Aspects of Energy Conversion : I.M.Blair and B.O.Jones
3. Principles of Energy Conversion : A.W.Culp (McGrawHill International
4. Energy conversion principles : Begamudre , Rakoshdas
5. Fuel Economy Handbook, NIFES,
6. Industrial Furnaces (Vol I & II) and M.H. Mawhinney, (John Wiley Publications)
7. Refractories – F.H. Nortan,(John Wiley Publication.)
8. Refractories and their Uses – Kenneth Shaw, (Applied Science Publishers Ltd.)
9. Refractory Material G.B. Rotherberg , (Noyes data Coorp. N.I)
10. The storage and handling of Petroleum liquid (John R. Hughes, Charles Griffin & Co. Ltd.)
11. Fuels and fuel TechnologyWilfred Francis, (Pergamon press)
12. Domestic and commercial oil Burners Charles H. Burkhadt (McGraw Hill Publication)
13. The efficient use of steam – Oliver Lyle, (HMSO London)
14. Boilers – Types, Characteristics and functions – Carl D. Shields (Mcgraw Hill book)
15. The Efficient use of steam generation – General editor – P.M.Goodall
16. Principles of Refrigeration R.J. Dossat (Wiley Estern Limited.)
17. Stoichiometry – Bhatt, Vora (Tata Mc.Graw Hill) 18. Practical Heat Recovery – Boyen J.L. (John Wiley, New York, USA1976)

Note: Eight (8) questions are to be set – uniformly distributed over the entire content of the course syllabus. Students shall have to attempt any five (5) of those questions.

RE-209: Phase-I Dissertation

M. Tech. - Renewable Energy (RE) 1st Year (I – Semester)

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks

Course Objectives:

1. To prepare student for specialized training on IC Engines, Thermal Engineering, Solar Energy, Hydrogen Energy, Gas Sensing and Photocatalytic Activity, Renewable Energy etc.

2. To make familiar with basic concepts of research and its methodologies

Outcome of Course:

After completion of the Phase-I Dissertation student will be able to:

1. To identify appropriate research topics

2. To understand research problem and parameters

3. To understand a project proposal

4. To understand how to conduct research

5. To understand basics of research report

RE/EEM-201: Solar Energy Utilization

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	**Class Work**	**:**	**25 Marks**
				Examination (Theory/Practical)	**:**	**75 Marks**
				Total	**:**	**100 Marks**
				Duration of Examination	**:**	**3 Hours**

Course Objectives:

This course has objectives to elaborate PG students regarding current trends in solar architecture and following key concepts: Solar Radiation, Sun Angles, and Importance of Sun Angles for Building Fenestration/day lighting, heat transfer in buildings, Solar Passive Architecture, Flat plate collectors, Earth to Air Heat Exchanger, passive heating, passive cooling and green buildings.

Unit I

Thermal comfort, Sun's motion, Building orientation and design, Thumb rules.

Unit II

Heat transfer in buildings, Thermal storage, Conversion of heat into mechanical energy, Active heating and cooling of buildings, Passive heating and cooling of buildings.

Unit III

Flat plate collectors: liquid and air type. Theory of flat plate collectors, advanced collectors, Solar water heating, solar dryers, solar stills, solar cooling and refrigeration.

Unit IV

Adoption to sustainable resources, process and Technologies. Green Buildings, Intelligent Buildings, Rating of Buildings, Efficient Use of Buildings, Solar Passive Architecture. Eco-housing concepts and National and International norms. Illustrative passive buildings.

Course outcomes:

After doing this course students will be familiar with state of art and up to date knowledge in the field of solar architecture and following key concepts: Solar Radiation, Sun Angles, and Importance of Sun Angles for Building Fenestration/day lighting. Students will be familiar with sustainable aspects related to green building technology.

Recommended References:

1. Tiwari G.N. Solar Energy. CRC Press, New York (2002).
2. M.S. Sodha, N.K. Bansal, P.K. Bansal, A. Kumar, and M.A.S.Malik, *Solar Passive Building,* Science and Design, Pergamon Press, New York (1986).
3. Solar Energy of Thermal Processes, Second Edition, 1991, by JA Duffie and WA Beckman, John Wiley & Sons Inc.
4. Solar Energy, First Edition, 2002, by GN Tiwari, Narosa Publishing House.
5. Principals of Solar Engineering, Second Edition, 2000, by DY Goswami, F Krieth & JF Krieder, Taylor and Francis Inc.

Note: Eight (8) questions are to be set – uniformly distributed over the entire content of the course syllabus. Students shall have to attempt any five (5) of those questions.

RE-203: Hydrogen Energy

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	Class Work	:	25 Marks
				Examination (Theory/Practical)	:	75 Marks
				Total	:	100 Marks
				Duration of Examination	:	3 Hours

Course Objectives:

To teach fundamentals of hydrogen energy as energy systems, production processes, storage, utilization, and safety that is necessary for taking some important elective subjects as well as to increase the potential for job opportunities in automotive industries and hydrogen production & its infrastructure development related sectors as about 40% energy is being consumed by automotive sectors.

Unit I

Hydrogen Energy: Need and Relevance in relation to depletion of fossil fuels and environmental considerations.
Hydrogen Production: Photo-electrolysis, Fossil, Biological Process & Bio Fuels, Benefits and barriers of different production methods.

Unit II

Hydrogen Storage technologies: compressed storage, liquid state storage, solid state storage, different materials for storage – metal hydrides, high surface area materials, complex and chemical hydrides, hydrogen storage system – design and materials aspects. Advantages and disadvantage of different storage methods.
Metal Hydrides: Benefits, PC isotherms, Hydrogen storage methods.

Unit III

Fundamentals of Hydrogen storage in different materials: Carbon nanostructures, Magnesium hydrides, Intermetallics and other materials.

Unit IV

Hydrogen Fuel Cells: Principle and workings systems, Applications, Safety & Standards. Application of Hydrogen/Hydrides as fuel in Engines, Socio-Economic Aspects. Comparative future viability analysis, Hydrogen economics, Public acceptability of hydrogen, Policy implications and Current status.

Course outcome:

After doing this course students will familiar with state of art and up to date knowledge in the field of hydrogen energy and its all aspects like production, storage, transportation and utilizations. Students will be familiar with safety aspects related to use of hydrogen energy as future energy carrier.

Books/References:

1. Energy Technology- S. Rao (Khanna Publications)
2. Renewable Energy Sources and Emerging Technologies- D. P. Kothari (PHI Publisher)
3. Metal Hydrides-MVC Sastri (Narosa Publisher)
4. Solar Hydrogen Energy Systems -T. Ohta (Ed.) (Pergamon Press) 1979
5. Hydrogen Technology for Energy – D.A.Maths (Noyes Data Corp.) 1976
6. Handbook : Batteries and Fuel cell – linden (McGraw Hill)- 1984
7. Solid State Hydrogen Storage- Edited by Gavin Walker(CRC Publication)

Note: Eight (8) questions are to be set – uniformly distributed over the entire content of the course syllabus. Students shall have to attempt any five (5) of those questions.

RE-205: Waste to Energy

M. Tech. - Renewable Energy(RE) Open Elective

L	T	P/D	Credits			
3	--	--	3	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives:

To give an idea about different biomass and other solid waste materials as energy source and their processing and utilization for recovery of energy and other valuable products. A comprehensive knowledge of how wastes are utilized for recovery of value would be immensely useful for the students from all fields.

Unit I
Sun as Source of Energy, Availability of Solar Energy, Nature of Solar Energy, Solar Energy & Environment. Various Methods of using solar energy –Photothermal, Photovoltaic, Photosynthesis, Present & Future Scope of Solar energy.

Unit-II
Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste, MSW

Unit-III: Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification, Biomass conversion processes, Thermo chemical conversion, Direct combustion, Types of biogas Plants, Applications.

Unit-IV
Thermo-chemical Conversion: Pyrolysis, Combustion, Gasification, Liquification. Bio-Chemical Conversion: Aerobic and Anaerobic conversion, Fermentation etc. Bio-fuels: Importance, Production and applications. Bio-fuels: Types of Bio-fuels, Production processes and technologies, Bio fuel applications, Ethanol as a fuel for I.C. engines, Relevance with Indian Economy.

Course Outcomes:

In these days of energy crisis and environmental deterioration, students will understand the concept of energy by waste products. It is being used globally to generate electricity and provide industrial and domestic applications. Students will also enable to understand the environmental issues related to harnessing and utilization of various sources of energy and related environmental degradation.

References:

1. Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-207: Green Building Technology

M. Tech. - Renewable Energy(RE) Elective

L	T	P/D	Credits			
3	--	--	3	**Class Work**	:	**25 Marks**
				Examination (Theory/Practical)	:	**75 Marks**
				Total	:	**100 Marks**
				Duration of Examination	:	**3 Hours**

Course Objectives:

There is very good scope for saving energy, by using it judiciously. During these days of saving the environment, energy conservation plays a vital role. The government of India has passed Energy Conservation Act-2003 and Energy Conservation Building Code (ECBC-2007), in this regard. This course has objectives to elaborate PG students regarding current trends in solar architecture and following key concepts: Thermal comfort, Typical Designs of Selected Buildings in various Climatic Zones, LEED, GRIHA, Concept of Net zero energy building, net zero community.

Unit I

Energy use in Buildings, Factors effecting Energy use, Energy Conservation options. External Factors – Climate, Building Orientation, Shading, types of shading devices, Sustainable site, water, energy, material and indoor environment issues for green buildings

Unit II

Thermal Comfort**,** Criteria and various Parameters, Psychometric Chart, Thermal Indices, Requirements of Different use Buildings, Air Quality control Equipments, Typical Designs of Selected Buildings in various Climatic Zones.

Unit III

Thumb Rules for Design of Building systems, Concept of green buildings features of green building rating systems in India: LEED, GRIHA, Concept of Net zero energy building, net zero community.

Unit IV

Modeling of Building, Correlation methods - solar load ratio, load collector ratio, thermal time constant method, and Analytical methods - thermal circuit analysis, The periodic solutions - thermal modeling of AC / Non AC buildings, software application. ASHRAE Methods and standards for estimates of Heating and cooling and Ventilation.

Course Outcomes:

After doing this course student will know about the basics of saving energy. They will also understand the Energy Conservation Act-2003 and Energy Conservation Building Code (ECBC-2007), in this regard. This course also enable them to understand the current trends in solar architecture and following key concepts: Thermal comfort, Typical Designs of Selected Buildings in various Climatic Zones, LEED, GRIHA, Concept of Net zero energy building, net zero community.

Recommended Books:

1. M.S.Sodha, N.K. Banaal, P.K.Bansal, A.Rumaar and M.A.S. Malik, Solar Passive: Building Science and Design, Pergamon Preen (1986).
2. Jamee; L. Threlked, Thermal Environment Engineering, Prentice Hall, INC-, Raglevood Cliffs, New Jersey (1970)
3. T.A. Markus and R.N. Morris, Building, Climate and Energy Spottwoode Ballantype Ltd-, London U.K. (1980)
4. Solar Thermal Energy Storage, H. P. Garg et.al, D. Reidel Publishing Company (1985)
5. Instructions to Energy Auditors, Vol. - I & Vol. - II –National Technical Information Services U. S. Deptt. Of Commerce Springfield, VA 22161.
6. BEE Volume I –Second Edition 2005
7. G.G. Ranjan: Optimizing Energy Efficiencies in Industry, Edition-2003 McGraw Hill.

Note: Eight (8) questions are to be set selecting two from each unit. Students shall have to attempt any five (5) selecting at least one from each unit.

RE-202: Phase-II Dissertation

M. Tech. - Renewable Energy (RE) 2nd t Year (IV – Semester)

L	T	P/D	Credits			
3	**--**	**--**	**3**	**Class Work**	**:**	**25 Marks**
				Examination (Theory/Practical)	**:**	**75 Marks**
				Total	**:**	**100 Marks**

Course Objectives:

1. To provide specialized training on IC Engines, Thermal Engineering, Solar Energy, Hydrogen Energy, Gas Sensing and Photo catalytic Activity, Renewable Energy etc.
2. To understand some basic concepts of research and its methodologies

Outcome of Course:

After completion of the Phase-II Dissertation student will be able to:

1. To identify appropriate research topics.
2. To select and define appropriate research problem and parameters.
3. To prepare a project proposal (to undertake a project).
4. To organize and conduct research (advanced project) in a more appropriate manner.
5. To write a research report and thesis.
6. To write a research proposal (grants).