Scheme of

POSTGRADUATE DEGREE COURSE

M.Tech. I to IV Semester

Renewable Energy Technology

(Effective from academic session: 2020-21)

Rajasthan Technical University, Kota

Akelgarh, Rawatbhata Road, Kota-324010

Teaching & Examination Scheme
M.Tech.: Renewable Energy Technology

1st Year –I Semester											
S N	**Course Type**	**Course Code**	**Course Name**	**Contact hrs/week**			**Marks**				**Cr**
				L	**T**	**P**	**Exm Hrs**	**IA**	**ETE**	**Total**	
1	PCC	1MRE1-01	Renewable Energy Sources	3	0	0	3	30	70	**100**	**3**
2	PCC	1MRE1-02	Solar Photovoltaics	3	0	0	3	30	70	**100**	**3**
3	PEC		**Elective-I:**	3	0	0	3	30	70	**100**	**3**
		1MRE2-11	a. Solar Heating & Cooling								
		1MRE2-12	b. Numerical Methods								
		1MRE2-13	c. Advanced Thermodynamics								
4	PEC		**Elective-II:**	3	0	0	3	30	70	**100**	**3**
		1MRE2-14	a. Energy Storage Technology								
		1MRE2-15	b. Optimization Techniques & Computer Applications								
		1MRE2-16	c. Advanced Heat Transfer								
5	MCC	1MCC3-21	Research Methodology & IPR	2	0	0	2	30	70	**100**	**2**
6	PCC	1MRE1-06	Renewable Technology Lab	0	0	4	4	60	40	**100**	**2**
7	PCC	1MRE1-07	Solar Photovoltaic Lab	0	0	4	4	60	40	**100**	**2**
8	SODECA	1MRE5-00	Social Outreach, Discipline & Extracurricular Activities							**100**	**2**
		TOTAL OF I SEMESTER		**14**	**0**	**8**		**270**	**430**	**800**	**20**

***L:** Lecture, **T:** Tutorial, **P:** Practical, **Cr:** Credits*
***ETE:** End Term Exam, **IA:** Internal Assessment*

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Teaching & Examination Scheme
M.Tech.: Renewable Energy Technology

1st Year – II Semester											
SN	Course Type	Course Code	Course Name	Contact hrs/week			Marks				Cr
				L	T	P	Exm Hrs	IA	ETE	Total	
1	PCC	2MRE1-01	Wind Energy Technology	3	0	0	3	30	70	**100**	**3**
2	PCC	2MRE1-02	Fuel Cell Technology	3	0	0	3	30	70	**100**	**3**
3	PEC		**Elective-III:**	3	0	0	3	30	70	**100**	**3**
		2MRE2-11	a. Geothermal Power Plants and Analysis								
		2MRE2-12	b. Green Buildings								
		2MRE2-13	c. Analysis of Power Plants								
4	PEC		**Elective-IV:**	3	0	0	3	30	70	**100**	**3**
		2MRE2-14	a. Solar Thermal Energy								
		2MRE2-15	b. Advanced Photovoltaic Technology								
		2MRE2-16	c. Solid Waste Management								
5	MCC	2MCC3-XX	Audit Course-I :	2	0	0					
6	PCC	2MRE1-06	Wind Energy Simulation Lab	0	0	4	4	60	40	**100**	**2**
7	PCC	2MRE1-07	Solar Energy Simulation Lab	0	0	4	4	60	40	**100**	**2**
8	REW	2MRE4-50	Mini Project with Seminar	0	0	4	4	60	40	**100**	**2**
9	SODECA	2MRE5-00	Social Outreach, Discipline & Extracurricular Activities							**100**	**2**
		TOTAL OF II SEMESTER		**14**	**0**	**12**		**300**	**400**	**800**	**20**

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Teaching & Examination Scheme
M.Tech.: Renewable Energy Technology

2nd Year – III Semester												
SN	**Course Type**	**Course Code**	**Course Name**	**Contact hrs/week**			**Marks**					**Cr**
				L	**T**	**P**	**Exm Hrs**	**IA**	**ETE**	**Total**		
1	PEC		**Elective-V:**	3	0	0	3	30	70	**100**		**3**
		3MRE2-11	a. Advanced Applications in Solar Energy Technology									
		3MRE2-12	b. Hydrogen Energy									
		3MRE2-13	c. Biofuel Technology & Mechanism									
2	MCC	3MCC3-XX	Open Elective:	3	0	0	3	30	70	**100**		**3**
3	MCC	3MCC3-XX	Audit Course-II	2	0	0						
4	REW	3MRE4-60	Dissertation Phase-I	0	0	20	4	240	160	**400**		**10**
		TOTAL OF III SEMESTER		**8**	**0**	**20**		**300**	**300**	**600**		**16**

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Teaching & Examination Scheme

M.Tech.: Renewable Energy Technology

2nd Year – IV Semester											
SN	**Course Type**	**Course Code**	**Course Name**	**Contact hrs/week**			**Marks**				**Cr**
				L	**T**	**P**	**Exm Hrs**	**IA**	**ETE**	**Total**	
1	REW	4MRE4-70	Dissertation Phase-II	0	0	32	4	360	240	**600**	**16**
		TOTAL OF IV SEMESTER		**0**	**0**	**32**		**360**	**240**	**600**	**16**

***L:** Lecture, **T:** Tutorial, **P:** Practical, **Cr:** Credits*
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Convener
BOS (Renewable Energy Technology)
RTU, Kota

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Syllabus

M. Tech. (Renewable Energy Technology)

1MRE1-01: Renewable Energy Sources **M. Tech. (Renewable Energy Technology)** **Question Paper Pattern:** Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.	
Teaching Scheme: 3 hrs/week; **End Term Exam Maximum Marks: 70; Exam Hrs: 3**	
Syllabus Contents with Breakup of Number of Lecture Hours	**Hours**
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Energy Sources & Availability: Conventional, non-conventional, renewable, non-renewable sources of energy, prospects, perspectives, & advantages. Introduction to different types of non-conventional source of energy: solar, wind, biomass, Ocean Thermal Energy Conversion (OTEC), geothermal, hydrogen energy, fuel cells, MHD, thermionic power conversion, thermoelectric power conversion.	**8**
Unit 2: Solar Energy: Solar constant, solar radiation geometry, local solar time, day length, solar radiation measurement, radiation on inclined surface, solar radiation data, & solar charts.	**8**
Unit 3: Wind Energy: Wind as a source of energy, Characteristics of wind, wind data. Horizontal & vertical axis wind turbines.	**7**
Unit 4: Biomass Energy: Introduction to biomass, biofuels & their heat content, biomass conversion technologies. Aerobic & anaerobic digester, Factors affecting bio-digestion, biogas plants–types, description, utilisation of biogas, & use in I.C. engines. Biomass gasification: Gasifier types, direct thermal application of gasifiers. Advantages & problems in development of gasifiers.	**8**
Unit 5: Other Renewable Energy Sources: Geothermal Energy: Status & estimates, geothermal resources, geothermal systems & their characteristics. Hydrogen energy. Fuel Cells: Principle & classification, types, conversion, efficiency, polarization, & advantages. Magneto HydroDynamic (MHD) power conversion: Principle, types, closed & open cycle system, materials. Ocean Thermal Energy Conversion (OTEC). Tidal energy. Wave energy.	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. B. H. Khan, “Non-Conventional Energy Resources”.
2. Godfrey Boyle, “Renewable Energy”.
3. D. P. Kothari, K. C. Singhal, and Rakesh Ranjan, “Renewable Energy Sources and Emerging Technologies”.
4. S. P. Sukhatme and J. K. Nayak, “Solar Energy: Principles of Thermal Collection and Storage”.

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1MRE1-02: Solar Photovoltaics M. Tech. (Renewable Energy Technology) **Question Paper Pattern:** Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.	
Teaching Scheme: 3 hrs/week; **End Term Exam Maximum Marks: 70; Exam Hrs: 3**	
Syllabus Contents with Breakup of Number of Lecture Hours	**Hours**
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Photovoltaic effect: Principle of direct solar energy conversion into electricity in a solar cell. Semiconductor properties, energy levels, basic equations. Solar cell, p-n junction, structure. I-V characteristics of a PV module, maximum power point, cell efficiency, fill factor, effect of irradiation and temperature.	**8**
Unit 2: Commercial solar cells: Production process of single crystalline silicon cells, multicrystalline silicon cells, amorphous silicon, cadmium telluride, copper indium gallium diselenide cells, high efficiency solar cells. Design of solar PV systems and cost estimation.	**8**
Unit 3: Classification: Central Power Station System, Distributed PV System, Standalone PV system, Grid Interactive PV System, small system for consumer applications, hybrid solar PV system, concentrator solar photovoltaic. System components: PV arrays, inverters, batteries, charge controls, net-meters. PV array installation, operation, costs, reliability.	**8**
Unit 4: Building-integrated photovoltaic units, grid-interacting central power stations, stand-alone devices for distributed power supply in remote and rural areas, solar cars, aircraft, space solar power satellites, solar PV lantern, stand-alone PV system - Home lighting and other appliances, solar water pumping systems.	**8**
Unit 5: Socio-economic and environmental analysis of photovoltaic systems.	**7**
Total Lecture Hours	**40**

Suggested Readings:

1. Chetan Singh Solanki, “Solar Photovoltaic: Fundamentals, Technologies and Application”.
2. A. R. Jha, “Solar Cell Technology and Applications”.
3. John Balfour, Michael Shaw, and Sharlene Jarosek, “Introduction to Photovoltaics”.
4. Antonio Luque and Viacheslav Andreev, “Concentrator Photovoltaic”.

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1MRE2-11: Solar Heating and Cooling

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Potential and scope of solar heating and cooling, Types of solar heating and cooling systems, Solar collectors and storage systems for solar refrigeration and air-conditioning. Solar thermoelectric refrigeration and air-conditioning. Economics of heating and cooling systems.	**8**
Unit 2: Thermal comfort: Heat transmission in buildings - Bioclimatic classification. Passive heating concepts - Direct heat gain, indirect heat gain, isolated gain, and sunspaces. Passive cooling concepts - Evaporative cooling, radiative cooling, application of wind, water and earth for cooling, roof cooling, earth air-tunnel. Energy efficient landscape design - Concept of solar temperature and its significance, calculation of instantaneous heat gain through building envelope.	**8**
Unit 3: Flat plate collector: Liquid and air heating - Evacuated tubular collectors - Overall heat loss coefficient, heat capacity effect - Thermal analysis. Design of solar water heating systems, with natural and pump circulation, solar cookers. Solar dryers and applications. Thermal energy storage systems. Solar pond - Solar greenhouse.	**8**
Unit 4: Solar thermo-mechanical refrigeration system: Carnot refrigeration cycle, solar electric compression air conditioning, simple Rankine cycle air conditioning system.	**7**
Unit 5: Absorption refrigeration: Thermodynamic analysis – Energy and mass balance of Lithium bromide water absorption system, Aqua-ammonia absorption system, Calculations of COP and second law efficiency. Solar desiccant dehumidification.	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. Soteris A. Kalogirou, "Solar Energy Engineering: Processes and Systems".
2. J. A. Duffie and W. A. Beckman, "Solar Engineering of Thermal Process".
3. D. Yogi Goswami, "Principles of Solar Engineering".
4. H. P. Garg and J. Prakash, "Solar Energy: Fundamentals and Applications".

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1MRE2-12: Numerical Methods

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions.
All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	1
Unit 1: Approximations: Accuracy and precision, definitions of round off and truncation errors, error propagation.	5
Unit 2: Algebraic Equations: Formulation and solution of linear algebraic equations, Gauss elimination, LU decomposition, iteration methods (Gauss - Siedel), convergence of iteration methods, eigen values, and eigen vectors.	10
Unit 3: Interpolation Methods: Newton's divided difference, interpolation polynomials, and Lagrange interpolation polynomials.	8
Unit 4: Differentiation and Integration: High accuracy differentiation formulae, extrapolation, derivatives of unequally spaced data, Gauss quadrature, and integration.	8
Unit 5: Introduction to Optimization Methods: Local and global minima, Line searches, Steepest descent method, Conjugate gradient method, Quasi Newton method, Penalty function.	8
Total Lecture Hours	**40**

Suggested Readings:

1. A. Gourdin and M. Boumahrat, "Applied Numerical Methods".
2. S. K. Gupta, "Numerical Methods for Engineers".
3. S. S. Rao, "Engineering Optimization: Theory and Practice".

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1MRE2-13: Advanced Thermodynamics M. Tech. (Renewable Energy Technology) **Question Paper Pattern:** Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.	
Teaching Scheme: 3 hrs/week; **End Term Exam Maximum Marks: 70; Exam Hrs: 3**	
Syllabus Contents with Breakup of Number of Lecture Hours	**Hours**
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Review of basic thermodynamic principles; entropy; availability; irreversibility; first and second law analysis of steady and unsteady systems.	**8**
Unit 2: General thermodynamics relations; Fundamentals of partial derivatives; relations for specific heats; internal energy, enthalpy, and entropy; Joule-Thompson coefficient; Clapeyron equation.	**8**
Unit 3: Multi component systems; Review of equation of state for ideal and real gases; thermodynamic surfaces; gaseous mixtures; fugacity; ideal solutions.	**8**
Unit 4: Multi component phase equilibrium; Criteria of equilibrium; stability; heterogeneous equilibrium; Gibbs Phase rule.	**7**
Unit 5: Thermodynamics of chemical reaction (combustion); internal energy and enthalpy - first law analysis and second law analysis; basic relations involving partial pressures; third law of thermodynamics; chemical equilibrium and chemical potential equilibrium constants.	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. Yunus Cengel and Boles, "Thermodynamics: An Engineering Approach".
2. P. K. Nag, "Engineering Thermodynamics".
3. Richard Edwin Sonntag, Claus Borgnakke, and Gordon John Van Wylen, "Fundamentals of Thermodynamics".

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1MRE2-14: Energy Storage Technology M. Tech. (Renewable Energy Technology) **Question Paper Pattern:** Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.	
Teaching Scheme: 3 hrs/week; **End Term Exam Maximum Marks: 70; Exam Hrs: 3**	
Syllabus Contents with Breakup of Number of Lecture Hours	**Hours**
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Introduction of energy storage technology, requirement for energy storage, Current status, Future prospect of storage.	**5**
Unit 2: Mechanical energy storage systems: Flywheel energy storage (FES), pumped hydropower storage (PHS), and compressed-air energy storage (CAES). Comparison and application of state-of-arts including principle, function and deployments. Technical characteristics in terms of power rating and discharge time, storage duration, energy efficiency, energy density, cycle life and life time etc.	**9**
Unit 3: Electrochemical energy storage: Battery, Fuel Cell, and Capacitor. Comparison and application of state-of-arts including principle, function and deployments. Technical characteristics of various electrochemical energy storage systems. Capacitor-battery hybrid systems.	**9**
Unit 4: Hydrogen energy: Hydrogen economy, Hydrogen production, Hydrogen Transportation, and Hydrogen storage methods.	**6**
Unit 5: Thermal energy storage: Sensible heat storage (SHS), latent heat storage (LHS) or phase-change materials (PCMs), and thermo-chemical energy storage (TCES). Comparison and technical characteristics. Hybrid PCMs energy storage.	**10**
Total Lecture Hours	**40**

Suggested Readings:

1. B. H. Khan, "Non-Conventional Energy Resources".
2. Godfrey Boyle, "Renewable Energy".
3. D. P. Kothari, K. C. Singhal, and Rakesh Ranjan, "Renewable Energy Sources and Emerging Technologies".
4. S. P. Sukhatme and J. K. Nayak, "Solar Energy: Principles of Thermal Collection and Storage".

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1MRE2-15: Optimization Techniques and Computer Applications **M. Tech. (Renewable Energy Technology)** **Question Paper Pattern:** Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.	
Teaching Scheme: 3 hrs/week; **End Term Exam Maximum Marks: 70; Exam Hrs: 3**	
Syllabus Contents with Breakup of Number of Lecture Hours	**Hours**
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Introduction to Optimization: Classification and formulation of optimization problem.	**7**
Unit 2: Classical Optimization Methods: Single variable optimization, Multivariable optimization with no constraints, Multivariable optimization with equality constraints: Solution by Direct Substitution, Solution by the Method of Constrained Variation, & Solution by the Method of Lagrange Multipliers. Multivariable Optimization with Inequality Constraints: Kuhn–Tucker Conditions, Constraint Qualification.	**8**
Unit 3: One-Dimensional Minimization Methods: Unimodal Function, Elimination Methods: Unrestricted Search (Search with Fixed Step Size, Search with Accelerated Step Size), Exhaustive Search, Dichotomous Search, Interval Halving Method, Fibonacci Method, Golden Section Method.	**8**
Unit 4: Unconstrained Optimization Techniques: Indirect search (Descent) methods- Gradient of a Function, Steepest Descent (Cauchy) Method, Conjugate Gradient (Fletcher–Reeves) Method, & Newton's Method.	**8**
Unit 5: Constrained Optimization Techniques: Indirect Methods-Basic Approach of the Penalty Function Method, Interior Penalty Function Method, Exterior Penalty Function Method, Checking the Convergence of Constrained Optimization Problems: Testing the Kuhn–Tucker Conditions. Modern Method of Optimization: Neural-Network Based Optimization.	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. S. S. Rao, "Engineering Optimization: Theory and Practice".
2. J. S. Arora, "Introduction to Optimum Design".
3. R. Saravanan, "Manufacturing Optimization through Intelligent Techniques".

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1MRE2-16: Advanced Heat Transfer

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions.
All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	1
Unit 1: Review of the basic laws of conduction, convection, and radiation.	5
Unit 2: Conduction (a): One dimensional steady state conduction with variable thermal conductivity and with internal distributed heat source; local heat source in non-adiabatic plate. Extended surfaces-review; optimum fin of rectangular profile; straight fins of triangular and parabolic profiles; optimum profile; circumferential fin of rectangular profile.	10
Unit 3: Conduction (b): Unsteady state conduction; sudden changes in the surface temperatures of infinite plate, cylinders and spheres; solutions using Groeber's and Heisler's charts for plates, cylinders, and spheres suddenly immersed in fluids.	8
Unit 4: Convection: Heat transfer in laminar flow; free convection between parallel plates; forced internal flow through circular tubes, fully developed flow; velocity and thermal entry lengths solutions with constant wall temperature and with constant heat flux; forced external flow over a flat plate.	10
Unit 5: Radiation: Review of radiation principles; diffuse surfaces and the Lambert's Cosine law. Radiation through non-absorbing media; Hottel's method of successive reflections. Radiation through absorbing media; logarithmic decrement of radiation.	6
Total Lecture Hours	**40**

Suggested Readings:

1. J.P. Holman and S. Bhattacharyya, “Heat Transfer”.
2. F. P. Incropera and D. P. Dewitt, “Fundamentals of Heat and Mass Transfer”.
3. R. C. Sachdeva, “Fundamentals of Engineering Heat and Mass Transfer”.
4. S. P. Venkateshan, “Heat Transfer”.

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1MCC3-21: Research Methodology & IPR

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 2 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 2

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	1
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.	7
Unit 2: Effective literature studies approaches, analysis. Plagiarism, Research ethics,	5
Unit 3: Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee	5
Unit 4: Nature of Intellectual Property: Patents, Designs, Trade Marks, 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.	5
Unit 5: 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.	5
Total Lecture Hours	**28**

Suggested Readings:

1. Stuart Melville and Wayne Goddard, “Research methodology: An introduction for science and engineering students”.
2. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”.
3. Ranjit Kumar, “Research Methodology: A Step by Step Guide for beginners”.
4. C. R. Kothari, “Research Methodology: Methods and Techniques”.
5. Neeraj Pandey and Khushdeep Dharni, “Intellectual Property Rights”.

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1MRE1-06: Renewable Technology Lab

M. Tech. (Renewable Energy Technology)

Teaching Scheme: 4 hrs/week;

End Term Exam Maximum Marks: 40; Exam Hrs: 4

The experiments may be designed based on the course of "Renewable Energy Sources". Suggested list of experiments are as follows:

1. Study of energy systems: Conventional & Non-conventional.
2. Measurement of wind speed and wind direction using anemometer and wind vane.
3. Estimation of solar radiation: Pyranometer and pyrheliometer.
4. Study of biomass briquetting technique.
5. Study of a biomass gasifier.
6. Study of biogas appliances.
7. Wind energy experimental set up.

1MRE1-07: Solar Photovoltaic Lab

M. Tech. (Renewable Energy Technology)

Teaching Scheme: 4 hrs/week;

End Term Exam Maximum Marks: 40; Exam Hrs: 4

The experiments may be designed based on the course of "Solar Photovoltaics". Suggested list of experiments are as follows:

1. Study of solar photovoltaic module.
2. To demonstrate the I-V and P-V characteristics of PV Module.
3. To demonstrate the I-V and P-V characteristics of PV module with varying insolation and temperature level.
4. To show the effect of variation in tilt angle on PV module power.
5. To demonstrate the effect of shading on PV module output power.
6. Determination of maximum power point and fill factor of a solar photovoltaic module.
7. Analysis of working of solar photovoltaic water pumping system.
8. Analysis of working of grid connected rooftop solar photovoltaic power system.
9. Analysis of working of solar PV based street lighting system.

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2MRE1-01: Wind Energy Technology

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	1
Unit 1: Wind Resource Assessment: Modern wind energy and its origins**.** Modern wind turbines: Horizontal axis wind turbines, other wind turbine concepts. Wind characteristics and resources: General characteristics of wind resource, mechanics of wind motion. Wind data analysis and resource estimation: available power in the wind, turbulence intensity, wind speed probability density functions, effect of terrain on wind, & wind turbine power curve. Present status of wind energy in India, Wind measurements and instrumentations: Wind speed & wind direction.	8
Unit 2: Aerodynamics of Horizontal-Axis Wind Turbines: One-dimensional momentum theory and Betz limit, Ideal horizontal axis wind turbine with wake rotation, Airfoils and general concepts of Aerodynamics: lift, drag, lift versus drag machines. Momentum theory and Blade Element Theory.	8
Unit 3: Electrical Aspects of Wind Turbines: Synchronous generators, Induction generators. Fixed-speed generator systems: Synchronous generator directly coupled to the grid, Induction generator directly coupled to the grid, Variable-slip induction generator, & Multi-speed generator systems. Variable speed generator systems with inverter: Synchronous generator with inverter, Induction generator with over-synchronous cascade, & Double-Fed Induction Generator. Directly rotor-driven variable-speed generators: Synchronous generator with electric excitation & Generators with permanent magnets.	8
Unit 4: Wind Turbine Siting, System Design, and Integration: Wind turbine siting. Installation and operation issues. Wind farms. Wind turbines and wind farms in electrical grids. Offshore wind farms. Hybrid wind systems.	8
Unit 5: Environmental Aspects & Impacts: Avian interaction with wind turbines. Visual impact of wind turbines. Wind turbine noise. Electromagnetic interference effects. Land-use environmental impacts. Other environmental considerations.	7
Total Lecture Hours	**40**

Suggested Readings:

1. J. F. Manwell, J. G. McGowan, and A. L. Rogers, "Wind energy explained: Theory, Design and Application".
2. E. Hau, "Wind Turbines: Fundamentals, Technologies, Application, Economics".
3. T. Burton, D. Sharpe, N. Jenkins, & E. Bossanyi, "Wind Energy Handbook".

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2MRE1-02: Fuel Cell Technology

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Introduction: Fuel cells basics, relevance and importance. Stack design, gas supply, and cooling, classification of fuel cells. Electrochemistry basis of fuel cells. Efficiency and open circuit voltage. Influence of pressure and gas concentration: Nernst Equation, hydrogen partial pressure. Voltage-current behaviour of fuel cell, Fuel-cell irreversibility. Activation losses- Tafel equation, Internal current and fuel crossover, ohmic losses, mass-transportation losses. Hydrogen processing and Storage: Processing from Alcohols, Hydrocarbons and other sources. Hydrogen as an engine fuel, methods of hydrogen storage.	**8**
Unit 2: Alkaline Fuel Cell (AFC): Description, working principle, components, general performance characteristics, operating temperature and pressure. Ammonia as AFC fuel.	**7**
Unit 3: Phosphoric Acid Fuel Cell (PAFC): System design: Fuel processing, fuel utilization. Principles of Operation: electrolyte, electrode, catalyst, stack construction, stack cooling & manifolding. Performance: operating pressure & temperature, effects of carbon monoxide and sulphur.	**8**
Unit 4: High Temperature Fuel Cells: Solid Oxide Fuel Cell (SOFC): History, benefits and limitations, cell components, Cathode and Anode materials, fuel, configuration and performance. Environmental impact of SOFC. Application and future of SOFC. Molten Carbonate Fuel Cell (MCFC): General principle, cell components, mechanisms of electrode reactions, Influence of pressure & temperature, status of MCFC.	**8**
Unit 5: Proton-Exchange Membrane Fuel Cell (PEMFC): Principles of operation, Electrodes & electrodes structure, components. Water management, cooling and air supply. Introduction to Direct Methanol Fuel Cell (DMFC).	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. Andrew L. Dicks and David A. J. Rand, "Fuel Cell Systems Explained".
2. B. Viswanathan and M. Aulice Scibioh, "Fuel Cells: Principles and Applications".

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2MRE2-11: Geothermal Power Plants and Analysis

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Introduction: Earth structure**,** Thermal structure of the Earth, Heat flow and temperature distribution within Lithosphere. Volcanoes, earthquakes & plate tectonics. Types of Geothermal systems: Vapour dominated, Hot water, Geopressured, Hot Dry Rock, & Magma.	**8**
Unit 2: Analysis of Geothermal Resources: Calculations for hot dry rock system: (a) Heat energy content; and (b) Energy extraction. Calculations for hot aquifer system: (a) Heat energy content; and (b) Energy extraction.	**7**
Unit 3: Geothermal power generating systems: Single-flash steam power plants, Double-flash steam power plant, Dry-steam power plant, Binary Cycle Power Plant. Solar-Geothermal Hybrid Plants: Solar-geothermal binary plant with superheating of the binary working fluid, Solar-geothermal double-flash plant.	**8**
Unit 4: Environmental impact of geothermal power plant: Environmental Advantages of Geothermal Plants: Gaseous Emissions, Land Usage, Solids Discharge, Water Usage, & Water Pollution. Environmental Challenges of Geothermal Plants: Land Subsidence, Induced Seismicity, Induced Landslides, Noise Pollution, Disturbance of Natural Hydrothermal Manifestations, Disturbance of Wildlife Habitat, Vegetation and Scenic Views, Catastrophic Events, & Thermal Pollution.	**8**
Unit 5: Geothermal power plant case studies: Worldwide status of geothermal power plant development. Geothermal Energy in India. Larderello Dry-Steam Power Plants (Tuscany, Italy). The Geysers Dry-Steam Power Plants (California, USA).	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. Harsh K. Gupta and Sukanta Roy, "Geothermal Energy: An Alternative Resource for the 21st Century".
2. B. H. Khan, "Non-Conventional Energy Resources".
3. Ronald Dipippo, "Geothermal Power Plants: Principles, Applications, Case Studies, and Environmental Impact".

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2MRE2-12: Green Buildings

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions.
All questions carry equal marks.

Teaching Scheme: 3 hrs/week;
End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	1
Unit 1: Introduction: Environmental implications of buildings energy, carbon emissions, water use, waste disposal; Building materials: sources, methods of production and environmental implications. Embodied Energy in Building Materials: Transportation Energy for Building Materials; Maintenance Energy for Buildings.	8
Unit 2: Comforts in Building: Thermal Comfort in Buildings-Issues; Heat Transfer Characteristic of Building Materials and Building Techniques. Incidence of Solar Heat on Buildings-Implications of Geographical Locations. Utility of Solar energy in buildings: Concepts of Solar Passive Cooling and Heating of Buildings. Low Energy Cooling. Case studies of Solar Passive Cooled and Heated Buildings.	8
Unit 3: Green Building Techniques: Concepts of Green Composites. Water Utilisation in Buildings, Low Energy Approaches to Water Management. Management of Solid Wastes. Management of Sewage. Urban Environment and Green Buildings. Green Cover and Built Environment. Provisions for Rain Water Harvesting, Solar PV systems, Solar Water Heaters.	8
Unit 4: Green Building Rating Systems: Features of green building rating systems in India: Indian Green Building Council (IGBC), Green Rating for Integrated Habitat Assessment (GRIHA), & LEED (Leadership in Energy and Environmental Design) etc. Sustainable site, water, energy, material, and indoor environment issues for green buildings; Intent and documentation for credits/points for green rating systems; Difference in evaluation and documentation for new construction and existing buildings. Green home rating, green factory rating, green neighbourhood concept.	8
Unit 5: Concept of Net Zero Energy Building, Costs of green buildings. Energy Conservation Building Code: requirements of code, applicability, compliance options: prescriptive, trade-off, whole building performance routes for compliance.	7
Total Lecture Hours	**40**

Suggested Readings:

1. Mili Majumdar, "Energy-efficient buildings in India".
2. K. S. Jagadish , B.V. Venkatarama Reddy , and K. S. Nanjunda Rao , "Alternative Building Materials & Technologies".
3. Ursula Eicker, "Low energy cooling for sustainable buildings".
4. Jerry Yudelson, "Green Building through Integrated Design".
5. Osman Attmann, "Green Architecture: Advanced Technologies & Materials".

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2MRE2-13: Analysis of Power Plants **M. Tech. (Renewable Energy Technology)** **Question Paper Pattern:** Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.	
Teaching Scheme: 3 hrs/week; **End Term Exam Maximum Marks: 70; Exam Hrs: 3**	
Syllabus Contents with Breakup of Number of Lecture Hours	**Hours**
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Introduction: Power and energy, sources of energy, review of thermodynamic cycles related to power plant. Load estimation, load curves, various terms and factors involved in power plant calculations. Effect of variable load on power plant operation, Selection of power plant units. Power plant economics and selection. Effect of plant type on: costs, rates, fixed elements, energy elements, customer elements, and investor's profit; depreciation and replacement. Economics in plant selection, other considerations in plant selection.	**8**
Unit 2: Steam Power Plant: General layout of steam power plant, Power plant boilers including critical and super critical boilers. Fluidized bed boilers, boilers mountings and accessories, Different systems such as coal handling system, pulverisers and coal burners, combustion system, draft, ash handling system, Dust collection system, Feed water treatment and condenser and cooling towers and cooling ponds, Turbine auxiliary systems such as governing, feed heating, reheating, flange heating and gland leakage. Operation and maintenance of steam power plant, heat balance and efficiency, Site selection of a steam power plant.	**8**
Unit 3: Hydroelectric and Non-conventional Power Plants: Hydroelectric power plants, classification, typical layout and components, Types of turbine- Pelton, Francis, Kaplan, Propeller, Deriaz and Bulb turbines. Performance of turbines and comparison. Principles of wind, tidal, solar PV, solar thermal, geothermal, biogas, and fuel cell power plants.	**8**
Unit 4: Diesel and Gas Turbine Power Plants: General layout of Diesel and Gas Turbine power plants, Performance of Diesel and Gas Turbine power plants, comparison with other types of power plants.	**7**
Unit 5: Nuclear power plant: Layout and subsystems of nuclear power plants, Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANDU Reactor, Pressurized Heavy Water Reactor (PHWR), Fast Breeder Reactors (FBR), gas cooled and liquid metal cooled reactors, safety measures for nuclear power plants.	**8**
Total Lecture Hours	**40**
Suggested Readings: **1.** P. K. Nag, "Power Plant Engineering". **2.** M. M. El Wakil, "Power Plant Technolog	

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2MRE2-14: Solar Thermal Energy M. Tech. (Renewable Energy Technology) **Question Paper Pattern:** Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.	
Teaching Scheme: 3 hrs/week; **End Term Exam Maximum Marks: 70; Exam Hrs: 3**	
Syllabus Contents with Breakup of Number of Lecture Hours	**Hours**
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: **Solar Radiation:** Solar radiation outside the earth atmosphere and at earth surface. Instruments for measuring solar radiation and sunshine. Solar Radiation Geometry, sunrise, sunset, day length, Local Apparent Time. Empirical equations for predicting the availability of solar radiation: Monthly average daily global radiation, monthly average daily diffuse radiation, monthly average hourly global radiation, monthly average hourly diffuse radiation. Hourly global, beam, and diffuse radiation under cloudless skies. Solar radiation on tilted surfaces.	**8**
Unit 2: Liquid Flat-Plate Collectors (FPC): Introduction of FPC, Performance analysis, Transmissivity of the cover system: Transmissivity based on reflection-refraction, absorption, and for diffuse radiation. Transmissivity-Absorptivity product. Overall loss coefficient. Effects of various parameters on performance (Selective surfaces, Number of covers, Spacing, Effect of shading, collector tilt, Fluid inlet temperature, Cover transmissivity, Dust on the top cover). Testing procedures of FPC. Alternatives to FPC (Evacuated Tube Collectors).	**8**
Unit 3: Solar Air Heaters: Introduction, various types of solar air heaters, Testing procedures. Matrix air heater. Plastic air heater. Inflatable-tunnel plastic solar heater.	**7**
Unit 4: Concentrating Collectors: Concentrating collectors for medium and high temperature applications. Line-focusing and point-focusing concentrators: Cylindrical parabolic collector, compound parabolic collector (CPC), paraboloid dish collector, Central Receiver Collector (heliostat field with central receiver), Linear Fresnel lens collector, Circular Fresnel lens concentration.	**8**
Unit 5: Thermal Energy Storage & Applications of Solar Energy: Introduction to three basic methods for storing thermal energy. Sensible heat storage in liquids & solids, Thermal Stratification. Latent Heat Storage. Thermochemical Storage. Applications: Solar water heaters, Solar pond, its principle of working, and solar-pond electric-power plant. Solar furnaces. Solar Cookers. Solar Chimney Plant. Solar greenhouses. Solar passive space heating and cooling systems. Solar Industrial Heating Systems.	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. John A. Duffie and William A. Beckman, "Solar Engineering of Thermal Processes".
2. B. H. Khan, "Non-Conventional Energy Resources".
3. H. P. Garg and J. Prakash, "Solar Energy: Fundamentals and applications".
4. Sukhatme & Nayak, "Solar Energy: Principles of thermal collection & storage".

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2MRE2-15: Advanced Photovoltaic Technology

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Overview of different types of solar cells/panels. Photovoltaic industries in India and World. International certification of solar panels and Indian scenario.	**7**
Unit 2: Wafer based silicon solar cells and its market trend. Cost breakup of wafer based solar panels, future trends. Concentrator solar cells, reflector and lens based versions. Performance in Indian climatic conditions. Low, medium and high concentration, combined thermal and concentration PV system.	**8**
Unit 3: Semi-transparent solar cells and related materials, applications in buildings (BIPV), thin film and wafer based versions, appearance and structure of thin film solar cells, Flexible solar cells.	**8**
Unit 4: Multi-junction solar cells, its working principles. Hetero-junction with intrinsic thin layer (HIT) solar cells, structure and working principle, comparison with conventional bulk solar cells.	**8**
Unit 5: Polymer, organic, dye sensitized, and quantum dot solar cells, structure, working principle, present applications, near future trends.	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. Chetan Singh Solanki., “Solar Photovoltaic: Fundamentals, Technologies and Application”.
2. A. R. Jha, “Solar Cell Technology and Applications”.
3. John Balfour, Michael Shaw, and Sharlene Jarosek., “Introduction to Photovoltaics”.
4. Antonio Luque and Viacheslav Andreev, “Concentrator Photovoltaic”.

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2MRE2-16: Solid Waste Management

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;
End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	1
Unit 1: Fundamentals of Solid Waste Management: Definition of solid wastes –types of solid wastes –Sources -Industrial, mining, agricultural, and domestic –Characteristics. Solid waste Problems -impact on environmental health –Concepts of waste reduction, recycling and reuse. **Collection and Transport of Municipal Solid Waste:** Determination of composition of MSW –storage and handling of solid waste –Future changes in waste composition. Waste collection systems, analysis of collection system –alternative techniques for collection system. Need for transfer operation, transport means and methods, transfer station types and design requirements.	8
Unit 2: Processing of Solid Waste and Energy recovery: Unit operations for separation and processing, Materials Recovery facilities, Waste transformation through combustion and aerobic composting, anaerobic methods for materials recovery and treatment –Energy recovery –Incinerators	7
Unit 3: Disposal of Solid wastes: Land farming, deep well injections. Landfills: Design and operation including: site selection, Geo-environmental investigations , engineered sites, liners and covers, leachate control and treatment, gas recovery and control, including utilization of recovered gas (energy), and landfill monitoring and reclamation.	8
Unit 4: Integrated Waste Management: Requirements and technical solution designated waste landfill remediation, Integrated waste management facilities. TCLP (Toxicity Characteristic Leaching Procedure) tests and leachate studies. Economics of the onsite v/s offsite waste management options. Natural attenuation process and its mechanisms. Hazardous waste –legislations –RCRA process –superfund process –toxicological principles –dose response –toxic effects –toxic response-Various industrial hazardous waste (textiles, tanneries, electroplating, distilleries etc.) disposal and handling methods-case studies.	8
Unit 5: Biomedical, Radiation Risk Assessment, and E-Waste Management: Biomedical waste: Definition, sources, classification-infectious wastes –handling –storing and disposal of medical wastes –collection, segregation, treatment and disposal. Principles of radiation protection–quantifying and combining risks–uncertainty assessments–site specific considerations. E-Waste characteristics, generation, collection, transport, and disposal.	8
Total Lecture Hours	**40**

Suggested Readings:

1. William A. Worrell and P. Aarne Vesilind, "Solid waste Engineering".
2. George Tchobanoglous, Hilary Theisen, and Samuel A. Vigil, "Integrated Solid Waste Management: Engineering principles and management issues".

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2MRE1-06: Wind Energy Simulation Lab **M.Tech. (Renewable Energy Technology)**
Teaching Scheme: 4 hrs/week; **End Term Exam Maximum Marks: 40; Exam Hrs: 4**
The experiments may be designed based on the course of "Wind Energy Technology". Suggested list of experiments are as follows: 1. Study of wind energy conversion devices. 2. Designing of a grid connected wind farm using software. 3. Field visit of students to a grid connected wind farm. 4. Analysis of small wind turbines and hybrid system. 5. Wind resource assessment techniques. 6. Electrical aspects of wind turbine generators.

2MRE1-07: Solar Energy Simulation Lab **M. Tech. (Renewable Energy Technology)**
Teaching Scheme: 4 hrs/week; **End Term Exam Maximum Marks: 40; Exam Hrs: 4**
The experiments may be designed based on the course of "Solar Energy". **Suggested list of experiments are as follows:** 1. Study of flat plate collector and evacuated tube collector. 2. Study of a box type solar cooker and calculation of its thermal efficiency. 3. Study of natural convection type solar water heater. 4. Study of natural convection type solar dryer. 5. Study and simulation of smart energy homes. 6. Simulation of grid connected 1 MW solar photovoltaic power plant using PVSyst software. 7. Field visit to grid connected rooftop solar photovoltaic power plant. 8. Simulation of hybrid solar PV system.

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3MRE2-11: Advanced Applications in Solar Energy Technology

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	1
Unit 1: Introduction to advanced solar energy applications. Thermal comfort; Sun motion. Solar water heating: Water heating systems; Freezing, boiling & scaling. Auxiliary energy; Forced-circulation systems. Natural-circulation systems; Integral collector storage systems. Water heating in space heating and cooling systems; Swimming pool heating. Hot water industrial process heat system.	7
Unit 2: Solar based Building Heating & Cooling: Passive Heating of Buildings: Direct Gain, Thermal storage wall, Sunspaces, Thermal storage roof, Convective loop. Passive cooling of buildings: Shading, ventilation, evaporation, radiation cooling, ground coupling, dehumidification. Building heating-Hybrid methods: Solar active heating of buildings: General aspects, Components of solar heating system (solar collector, thermal storage system, Auxiliary heat supply system, control systems). Three ways of solar space heating: solar air systems, solar liquid systems, and solar heat pump systems.	8
Unit 3: Solar Refrigeration and Air conditioning: Carnot refrigeration cycle. Solar absorption cooling: Principle of absorption cooling, Basics of absorption cooling, LiBr-H_2O absorption system, H_2O-NH_3 absorption system, Intermittent absorption refrigeration system. Solar Vapour Compression Refrigeration. Solar Desiccant Cooling: Triethylene glycol open-cycle air conditioning system using solar air heating collectors for regeneration, LiCl-H_2O open-cycle cooling system. Ventilation desiccant cycle and Recirculation desiccant cycle. Solar thermoelectric refrigeration and air-conditioning.	8
Unit 4: Solar Drying of Food & Solar Desalination: Basics of solar drying. Types of solar dryers: Natural convection or Direct type solar dryers. Forced circulation type dryers: Hybrid dryer, Bin type grain dryer, solar timber drying. Hot air industrial process heat system. Solar Desalination: Simple solar still, Basics of solar still, material problems in solar still, Performance prediction of Basin-Type still. Wick type solar still. Multi-stage solar still. Active solar still. Future material advancements.	8
Unit 5: Solar Photovoltaic Power Applications: Rooftop Solar PV Systems: Introduction, system components, typical schematic diagram of rooftop solar PV systems, costing, net-metering of rooftop grid connected system, system performance analysis (Performance Ratio and Levelized Cost of Electricity). Solar PV water pumping system. Solar PV battery charging system. Solar PV street lighting system. Floating solar PV systems.	8
Total Lecture Hours	**40**

Suggested Readings:

1. Chetan S. Solanki., “Solar Photovoltaic: Fundamentals, Technologies and Application”.
2. S. P. Sukhatme and J. K. Nayak, “Solar Energy: Principles of Thermal Collection and Storage”.
3. J. A. Duffie and W. A. Beckman, “Solar Engineering of Thermal Process”.
4. H. P. Garg and J. Prakash, “Solar Energy: Fundamentals and Applications”.

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3MRE2-12: Hydrogen Energy

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions.
All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Introduction of Hydrogen Energy Systems: Hydrogen pathways introduction – current uses, General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and Hydrogen production power plants. Fuel properties of hydrogen.	**8**
Unit 2: Hydrogen Production Processes: **Thermal**-Steam Reformation – Thermo chemical Water Splitting – Gasification – Pyrolysis, Nuclear thermo catalytic and partial oxidation methods. **Electrochemical** – Electrolysis – Photo electro chemical. **Biological** – Anaerobic Digestion – Fermentative Micro-organisms. **Renewable Sources**: Hydrogen production methods using solar energy and wind energy.	**8**
Unit 3: 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.	**8**
Unit 4: 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, NO_x controlling techniques, dual fuel engine, durability studies, field trials, emissions and climate change.	**8**
Unit 5: 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**
Total Lecture Hours	**40**

Suggested Readings:

1. Michael Ball and Martin Wietschel, "The Hydrogen Economy: Opportunities and Challenges".
2. M. K. G. Babu and K. A. Subramanian, "Alternative Transportation Fuels: Utilization in Combustion Engines".
3. Krishnan Rajeshwar, Robert McConnell, and Stuart Licht, "Solar Hydrogen Generation: Toward a Renewable Energy Future".
Ram B. Gupta, "Hydrogen Fuel: Production, Transport, and Storage".

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3MRE2-13: Biofuel Technology & Mechanism

M. Tech. (Renewable Energy Technology)

Question Paper Pattern: Attempt any **Five** questions out of **Seven** questions. All questions carry equal marks.

Teaching Scheme: 3 hrs/week;

End Term Exam Maximum Marks: 70; Exam Hrs: 3

Syllabus Contents with Breakup of Number of Lecture Hours	Hours
Introduction: Objectives, scope, and outcomes of the course.	**1**
Unit 1: Biofuel Technology: Introduction, potential of biofuels in the energy scenario of India, Biofuels in relation to environment, ecology, agriculture, health and sanitation, Factors enhancing/inhibiting biofuel production.	**7**
Unit 2: Bio-chemical and Microbial Aspects of Biogas: Biogas mechanism, enhancement of biogas production by different additives (Chemicals, organic substances, enzymes), pre-treatment process, etc. Scrubbing process, bottling, need for bottling of biogas, liquefaction of biogas. Various uses of biogas and its merits and demerits.	**8**
Unit 3: Biogas Plants and Applications: Types of biogas plants, design of a biogas plant (cow dung and organic waste) and structural strength, selection of site and size, construction technique, material requirement, recent advances in high rate bio-methanation reactors design and material, night soil linked biogas plant. Cold condition biogas plant design concept, cost and financial viability. Principles of dual fuel biogas engines, its limitations, biogas appliances including thermal and cooking efficiency test.	**8**
Unit 4: Production and Applications of Biodiesel: Trans-esterification reaction and process, Raw materials and pre-treatment, Environmental conditions and operational process, Separation and purification stages, Qualities of biodiesel and associated regulations, properties of biodiesel, application in diesel engines and environmental effects, economic impact of biodiesel.	**8**
Unit 5: Alcohols and other Biofuels: Types of feedstock for alcohols and other biofuels and their availability. Types of alcohols (methanol, ethanol, butanol, etc.) and other oxygenated biofuels, their production methods, applications, advantages and limitations. Physico-chemical properties of biofuels. Combustion characteristics of biofuels in spark ignition and compression ignition engines.	**8**
Total Lecture Hours	**40**

Suggested Readings:

1. K. C. Khandelwal and S. S. Mahdi, "Biogas Technology: A Practical Handbook".
2. N. S. Rathore and A. K. Kurchania, "Biomethanation Technology".
3. A. N. Mathur and N. S. Rathore, "Biogas: Production management and utilization".
4. Liangwei Deng, Yi Liu, and Wenguo Wang, "Biogas Technology".
5. Wim Soetaert and Erick J. Vandamme, "Biofuels".
6. Caye M. Drapcho and Terry H. Walker, "Biofuels Engineering Process Technology".
7. Ahindra Nag, "Biofuels Refining and Performance".

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3MRE4-60: Dissertation Phase-I

M. Tech. (Renewable Energy Technology)

Teaching Scheme: 20 hrs/week;

Guidelines:

- The Dissertation Work will start in semester III and should preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solution and must preferably bring out the individual contribution.
- Seminar should be based on the area in which the candidate has undertaken the dissertation work as per the common instructions for all branches of M. Tech. The examination shall consist of the preparation of report consisting of a detailed problem statement and a literature review. The preliminary results (if available) of the problem may also be discussed in the report. The work has to be presented in front of the examiners panel set by the Head of Department.
- Candidate will have the right to select the M. Tech. dissertation supervisor based on their research interest. As this course is interdisciplinary in nature, candidate may also chose supervisor from academic departments other than where this course is being run. Candidate will submit an application along with consent of supervisor chosen by the candidate to the Head of Department. Head of Department will assign that supervisor to the candidate based on the application. If candidate is not able to select supervisor by himself, than only Head of Department will allot supervisor to that student. The candidate has to be in regular (daily) contact with his supervisor and the topic of dissertation must be from renewable energy area which is mutually decided by the supervisor and the candidate.

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4MRE4-70: Dissertation Phase-II

M. Tech. (Renewable Energy Technology)

Teaching Scheme: 32 hrs/week;

Guidelines:

- It is a continuation of Project work started in semester III. Student has to submit the thesis in prescribed format and also present a seminar. The dissertation should be presented in standard format as provided by the university. The candidate has to prepare a detailed thesis consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) of solution and results and discussion. The thesis must bring out the conclusions of the work and future scope for the study.
- Candidate will have the right to select the M. Tech. dissertation supervisor based on their research interest. As this course is interdisciplinary in nature, candidate may also chose supervisor from academic departments other than where this course is being run. Candidate will submit an application along with consent of supervisor chosen by the candidate to the Head of Department. Head of Department will assign that supervisor to the candidate based on the application. If candidate is not able to select supervisor by himself, than only Head of Department will allot supervisor to that student. The candidate has to be in regular (daily) contact with his supervisor and the topic of dissertation must be from renewable energy area which is mutually decided by the supervisor and the candidate.

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