Specialization: Renewable Energy Resources

Semester-III	
Course Code	**Course Name**
21MSP602T	Energy Harvesting And Storage Methods
21MSP603T	Solid State Solar and Thermal Energy Harvesting
21MSP604T	Wind, Hydro and Bioenergy Harvesting
21MSP618P	Renewable Energy Resources Laboratory
21MSP601	Project-I
	Semester-IV
	Project - II

M.Sc. Course					21MSP602T- ENERGY HARVESTING AND STORAGE METHODS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To introduce principles of energy conversion to useful form of energy for harvesting energy.
- To realize role of the thermal energy storage conversion devices, limitations and applications.
- To appreciate smart materials as electrochemical energy storage batteries and organic Li batteries
- To familiarize with Hydrogen generation, storage and application in fuel cells.

UNIT 1 ENERGY CONVERSION AND HARVESTING	10 Hrs.
Basics of energy: Different forms of energy, energy conversion process, indirect and direct, Energy conversion; Energy storage: Energy demand, energy storage methods; Energy and environment correlations: Environmental Impact Assessment and Life cycle analysis (LCA); Energy conservation: Audits, Planning and implementation.	
UNIT 2 THERMAL ENERGY STORAGE (TES)	**11 Hrs.**
Concepts of internal energy, entropy, enthalpy; Gas laws, Thermodynamic cycles, Irreversible and Reversible processes, Carnot cycle, Carnot engine; Heat engines and heat pumps/refrigeration, Psychometrics and use of psychrometric chart; Thermal energy and storage, Solar energy and TES, TES methods, Sensible TES, Latent TES, Cold TES, Seasonal TES; Environmental Impact: TES systems and Applications.	
UNIT 3 ELECTROCHEMICAL ENERGY & STORAGE	**11 Hrs.**
Concept of electrochemical energy, Batteries and supercapacitors: recent development; Advanced Li-ion: Positive and negative electrode materials for Li-ion technology; Capacitive Storage: Carbonated and Pseudo-capacitive materials, Electrolytes for supercapacitors; Eco-Compatible Storage: Ionothermal and Bioinspired synthesis, Organic electrodes for “green” Li-ion batteries; Smart materials.	
UNIT 4 HYDROGEN ENERGY	**13 Hrs.**
Hydrogen production (Electrolysis method, Thermo-chemical methods, Fossil fuel methods, solar energy methods), Hydrogen storage, Hydrogen transportation, Utilization of Hydrogen Gas, Safety and management, Hydrogen technology development. Design and principle of operation of a Fuel Cell (H_2, O_2 cell), Conversion efficiency of Fuel Cells, Applications of Fuel Cells.	
	Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify various microphysical concepts such as fluid dynamics, thermodynamic, classical mechanics involved in the power generation mechanism.

CO2 – Explain and assess the environmental impacts of thermal, electrochemical and solar energy harvesting and storage methods.

CO3 – Compare the efficiency and energy production from thermal, electrochemical and solar energy harvesting and storage methods.

CO4 – Explain operating mechanism of harvesting energy from thermal, electrochemical and solar storage methods.

CO5 – Apply the knowledge of site design, system optimization and technology selection for proposing power plant based on thermal, electrochemical and solar energy storage.

CO6 – Analyse the past, current and future state of development in hydrogen generation, storage and application in cells.

TEXT/REFERENCE BOOKS

1. Thermal Energy Storage: Systems and Applications, I. Dincer and M. A. Rosen, Wiley, 2nd Ed. 2010.
2. Solar Energy Priciples of Thermal Collection and Storage, S.P. Sukhatme,2nd Ed. TMH
3. Solar Engineering of Thermal Process, J.A. Duffie & W. A Beckman, 2nd Ed. John Wiley & sons.
4. Electrochemical Energy Storage, J. M. Tarascon and P. Simon, Wiley, 2015.
5. Solar energy, H. P. Garg and J Prakashi, TMH 1997
6. Introduction to Thermoelectricity, Julian Goldsmid, 2nd Edition, Springer-Verlag Berlin Heidelberg, 2016.
7. Solar Energy Utilization, G D Rai, Khanna Publishers, 1997.
8. Renewable Energy Source and Conversion Technology, N.K Bansal, M. Kleemanm & M. Melss, TMH.
9. Renewable Energy 2000, G.T. Wrixon, A.M.E. Rooney & W. Palz, Springer Verlag 1993.
10. Solar Power Plants, C.J. Winter, R.L. Sizmann & L.L Vant-Hull, Springer Verlag.

M.Sc. Course					21MSP603T- Solid State Solar and Thermal Energy Harvesting					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To introduce fundamental and recent advances of energy harvesting from two of the most abundant sources, namely solar and thermal energies.
- To understand characteristics and design of common types of solar cells.
- To apply known approaches to increasing solar cell efficiency.
- To familiarize basic physical properties, Seebeck coefficient, electrical and thermal conductivities, and analysis through the Boltzmann transport formalism.

UNIT 1 FUNDAMENTALS OF PHOTOVOLTAICS	12 Hrs.
Solar resource, properties of sunlight, Light Absorption, Optical Losses, energy bands, doping, electric field, potential, Charge generation and Recombination, Basic Equations of Device Physics, drift current, diffusion current, P-N junction, Charge separation, 1-D device model, Commercial silicon solar cell technology, Current-voltage and quantum efficiency measurements and energy conversion efficiency analysis	
UNIT 2 ADVANCE PV CONCEPTS AND RELIABILITY	**12 Hrs.**
Commercial thin film photovoltaic technologies, Various solar cells introduction: including multijunction, multiple excitation generation, multibarrier, quantum dot, hot carrier, intermediate band, plasmonic, heterogenous, dye sensitized, and perovskite solar cells, Materials Properties Affecting Performance, Approaches to increasing solar cell efficiency. Modules, Systems, and Reliability.	
UNIT 3 THERMOELECTRICITY	**11 Hrs.**
Thermoelectric effect: Peltier effect, Seebeck effect, and Thomson effect, Physical properties of thermoelectric materials, Seebeck coefficient, electrical and thermal conductivities, the Boltzmann transport formalism, Carrier scattering time approximations in relation to dimensionality and the density of states, energy filtering, quantum confinement, size effects, band structure engineering, and phonon confinement, Thermoelectric generator (TEG) or Seebeck generator.	
UNIT 4 SOLAR PV POWER PLANTS	**10 Hrs.**
Energy yield forecast, irradiance on module plane, performance modeling, uncertainty in energy yield prediction, Plant Design: Technology selection, layouts, electrical design, sizing of invertors, cables, fuses and protection devices, optimizing system design and its construction Commissioning of plant: General recommendation, pre-connection acceptance testing, grid connection; Operation and maintenance of the power Plant.	
	Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Explain the operation of various solar cells including multijunction, multiple excitation generation, multibarrier, quantum dot, hot carrier, intermediate band, plasmonic, heterogenous, dye sensitized, and perovskite solar cells.

CO2 – Outline the parameters affecting the behaviour of various solar cells and thermoelectrics.

CO3 – Distinguish the underlying physics of electron and phonon transport in semiconductors.

CO4 – Identify the promising density of states, lattice structure, and phonon dispersion for efficient solar cell and thermoelectric energy conversion.

CO5 – Explain the microscopic origin of Peltier effect, Seebeck voltage, and Thomson effect.

CO6 – Evaluate the effectiveness of strategies for selecting solar PV technology.

TEXT/REFERENCE BOOKS

1. Semiconductor Devices, Physics and Technology, M. Sze and M. K. Lee, Wiley, 3rd edition, 2012.
2. The physics of solar cells, Jenny Nelson, Imperial College Press, 2003.
3. Solar Energy From Cells To Grid, Brijesh Tripathi , Manoj Kumar, CSMFL Publications, 2018.
4. Introduction to Thermoelectricity, Julian Goldsmid, 2nd Edition, Springer-Verlag Berlin Heidelberg, 2016.
5. Materials, Preparation, and Characterization in Thermoelectrics, David Michael Rowe, CRC Press, 1st edition, 2016.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: 10 questions of 2 marks each from all 4 units	35 Marks
Part B/Question: 8 questions of 10 marks each from all 4 units	65 Marks

M.Sc. Course					21MSP604T- Wind, Hydro and Bioenergy Harvesting					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To introduce principles of conversion to useful form of energy from wind, hydro and bioenergy resources.
- To emphasis the wind, hydro and bioenergy resource assessment and site selection techniques.
- To appreciate the power of osmotic energy harvesting along with wind, hydro and bioenergy.
- To realize role of the conversion devices, limitations, cost of energy generation and environmental issues during energy harvesting.

UNIT 1 WIND ENERGY HARVESTING	11 Hrs.
Introduction: Factors influencing wind, Wind resource assessment, Weibull distribution; Betz limit, Wind energy conversion systems: classification, applications, power, torque and speed characteristics; General theories of wind machines, Basic laws and concepts of aerodynamics, Description and performance of the horizontal–axis wind machines, Blade design, The generation of electricity by wind machines, case studies.	
UNIT 2 HYDRO ENERGY HARVESTING	**11 Hrs.**
Hydrology, Resource assessment, Potential of hydropower in India, Classification of Hydropower Plants, Overview of micro mini and small hydro, Site selection and civil works, Penstocks and turbines, Speed and voltage regulation, Investment issues, load management and tariff collection, Distribution and marketing issues, case studies, Wind and hydro based stand-alone / hybrid power systems.	
UNIT 3 OSMOTIC POWER HARVESTING	**11 Hrs.**
Introduction: Diffusion, Principle of Osmosis, Types of osmotic power generation: Pressure retarded osmosis (PRO) and Reversed electro dialysis (RED) fresh and saline water availability, Salinity and Temperature gradient, Osmotic power generation: Pre-treatment, membrane stacks, pumps, pipes and turbines; Areas of application and Potential locations for an osmotic power plant, Capacity of an Osmotic power plant: Net energy production, Main infrastructure.	
UNIT 4 BIOENERGY HARVESTING	**12 Hrs.**
Introduction to bioenergy; biomass harvesting; availability and assessment of biomass for bioenergy applications; characterization and classification of biomass feedstock (physico-chemical properties, ultimate, proximate, compositional, calorific value, thermogravimetric, differential thermal and ash fusion temperature analyses); classification of biomass feedstock: first, second and third generation biofuels; hybrid biofuels, Different pre-treatment processes of biomass; different production routes for biomass conversion to biofuels.	
	Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify various microphysical concepts such as fluid dynamics, thermodynamic, classical mechanics involved in the power generation mechanism.

CO2 - Determine the various impacts of wind, hydro, osmotic and bioenergy harvesting on the environment and sustainable development.

CO3 – Compare the efficiency and energy production from wind, hydro, osmotic pressure and bio energy resources.

CO4 – Explain the design and analyse the basic operating mechanism of harvesting energy from wind, hydro, osmotic pressure and bio energy resources.

CO5 – Apply the knowledge of site selection and case studies for proposing power plant based on wind, hydro, osmotic or bioenergy resources.

CO6 – Analyze the past, current and future state of development in wind, hydro, osmotic pressure and bio energy harvesting.

TEXT/REFERENCE BOOKS

1. Wind Energy: Renewable Energy, V. Nelson, CRC Press, 2009.
2. Manwell J. F., McGowan J. G. and Rogers A. L., Wind Energy Explained – Theory, Design and Application John Wiley & Sons, Ltd., 2002.
3. Biomass to Renewable Energy Processes, J. C. Jay, Taylor and Francis, CRC Press, 2018.
4. Understanding Clean Energy and Fuels from Biomass, H. S. Mukunda, Wiley India, 2011.
5. Renewable Energy Resources, Twidell, John, and Tony Weir, Taylor and Francis, 2005.
6. Bio-inspired Nanocomposite Membranes for Osmotic Energy Harvesting, Cheng Chen, et al., Joule 4, 247–261, January 15, 2020.
7. Blue Energy and Its Potential: The Membrane Based Energy Harvesting, Shubham Lanjewar, et al., Advances in Membrane Technologies, 2020.
8. Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes, Harvey A., Brown A. and Hettiarachi P., ITDG, 1993.
9. Renewable Energy Source and Conversion Technology, N.K Bansal, M. Kleemanm & M. Melss, TMH.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: 10 questions of 2 marks each from all 4 units	20 Marks
Part B/Question: 8 questions of 10 marks each from all 4 units	80 Marks

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<tr><th colspan="5">M.Sc. Course</th><th colspan="6">21MSP618P- Renewable Energy Resources Laboratory</th></tr>
<tr><th colspan="5">Teaching Scheme</th><th colspan="6">Examination Scheme</th></tr>
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COURSE OBJECTIVES

- To understand the working of various renewable energy systems in techniques conducting scientific experiments and observations.
- To gain practical knowledge in the field of renewable energy resources through experiments.
- To understand basics concepts of renewable energy generation and utilization.

List of experiments

1. Solar radiation measurements for solar energy experiments.
2. Flywheel experiment to learn about gravitational potential energy, generated electrical energy and rotational kinetic energy.
3. Solar pathfinder experiment to determine the criteria for true north, declination angle, sun path diagram and finding out the best location for maximum percentage of solar energy available at a specific location throughout the year.
4. To study the effect of concentrating sunlight on the output from a solar cell.
5. To study the storage of the energy produced from a PV cell in a tank of water.
6. To study the energy storage potential of compressed air.
7. To study the effect of fan speed on the power output of a wind turbine.
8. To determine the temperature change of the water in a solar collector.
9. To study the operation of photo-voltaic panels using variable light source.
10. To study areal characteristics of solar panel.
11. Wind turbine experiment to determine the specific wind power, wind frequency, different types of turbines and their advantages and disadvantages.
12. Thermoelectricity experiment to study the Seebeck effect, the Peltier effect and thermal capacitors.
13. Fuel cell experiment to study about inner workings of a hydrogen fuel cell as a power source and its advantages and disadvantages.
14. Hydroelectricity experiment to study the process of calculating gravitational potential energy using a hydroelectric turbine.
15. Demonstration of heat transfer from one fluid to another through a solid wall using shell and tube exchanger and energy balance and efficiency calculations.
16. Quantitative assessment of biofuel/biomass using digital bomb calorimeter.
17. Measurements of Density, Viscosity, Flash-point, Fire-point Pour-point, ASTM distillation of liquid biofuels.

COURSE OUTCOMES

On completion of the course, the students will be able to

CO1 - Apply and analyse the concepts of renewable energy generation.

CO2 - Understand the use of solar energy for thermal and electrical energy generation.
CO3 - Demonstrate and implement the concept of hydro energy generation and storage.
CO4 - Investigate the effect of solar light concentration on solar panel output.

CO5 - Examine various electrical and electronic components useful for energy generation and storage.

CO6 - Examine the output electrical characteristics of renewable energy systems.

TEXT/REFERENCE BOOKS

1. Wind Energy: Renewable Energy, V. Nelson, CRC Press, 2009.
2. Manwell J. F., McGowan J. G. and Rogers A. L., Wind Energy Explained – Theory, Design and Application John Wiley & Sons, Ltd., 2002.
3. Biomass to Renewable Energy Processes, J. C. Jay, Taylor and Francis, CRC Press, 2018.
4. Solar Energy Principles of Thermal Collection and Storage, S.P. Sukhatme,2nd Ed. TMH
5. Solar Engineering of Thermal Process, J.A. Duffie & W. A Beckman, 2nd Ed. John Wiley & sons.
6. Electrochemical Energy Storage, J. M. Tarascon and P. Simon, Wiley, 2015.
7. Semiconductor Devices, Physics and Technology, M. Sze and M. K. Lee, Wiley, 3rd edition, 2012.
8. The physics of solar cells, Jenny Nelson, Imperial College Press, 2003.
9. Solar Energy from Cells To Grid, Brijesh Tripathi, Manoj Kumar, CSMFL Publications, 2018.

Evaluation

Max. Marks: 100

Continuous evaluation	50 marks
End semester examination, Viva-voce & project presentation	50 marks