Pt. Ravishankar Shukla University, Raipur

CURRICULUM & SYLLABUS

(Based on CBCS & LOCF)

M.Sc. in Renewable Energy Technology

(Program Code 0307)

Semester System

Session: 2024-25 & onwards

Approved by:	Board of Studies In Electronics	Academic Council
Date:		

03/09/2024

M.Sc. in Renewable Energy Technology

The Master of Science in Renewable Energy program is a comprehensive two-year, four-semester course specifically designed to equip students with a profound understanding of renewable energy concepts, technologies, and their applications, from fundamental principles to the cutting-edge innovations utilized in the field today. Throughout the program, students undergo extensive laboratory training, immersing themselves in course content and aligning with the current needs of industries and research and development (R&D) sectors.

With a focus on practical learning, the final semester of the program necessitates every student to engage in a significant project. This emphasis on hands-on experience aims to nurture strong laboratory skills, fostering the ability to undertake independent projects and fostering an entrepreneurial mindset among students.

Post Graduates from this curriculum are poised to become valuable assets, well-equipped to undertake state-of-the-art research within the field of renewable energy. The intent of the course structure is to develop skilled human resources, catering to the ever-evolving needs of the industry, R&D initiatives, and self-employment opportunities. Exposure to current technologies in practice and specialized training geared towards addressing industrial requirements form the backbone of this program.

03/09/2024

Program Outcomes:

Upon successful completion of the Master of Science in Electronics program, student will be able to:

PO1:	**KNOWLEDGE: Apply knowledge of mathematics and science in solving renewable energy-related problems.**
PO2:	**CRITICAL THINKING AND REASONING: To cultivates critical thinking and reasoning skills, enabling students to analyze complex energy systems, evaluate sustainable solutions, and innovate within the renewable energy sector.**
PO3:	**PROBLEM SOLVING: Demonstrate proficient problem-solving skills by applying advanced technical knowledge to identify, formulate, solve, and analyze problems in various disciplines of renewable energy.**
PO4:	**ADVANCED ANALYTICAL AND COMPUTATIONAL SKILLS: Equips students with advanced analytical and computational skills, enabling them to proficiently model, analyze, and optimize renewable energy systems for sustainable solutions.**
PO5:	**EFFECTIVE COMMUNICATION: Communicate effectively through oral, written reports, presentation and teaching means in the context of renewable energy.**
PO6:	**SOCIAL/INTERDISCIPLINARY INTERACTION: Cultivates socially and interdisciplinary adept professionals fostering collaboration between diverse fields, enabling holistic solutions to global energy challenges.**
PO7:	**SELF DIRECTED AND LIFE LONG LEARNING: Recognize the importance of lifelong learning and engage in continuous professional development in the field of renewable energy.**
PO8:	**EFFECTIVE CITIZENSHIP: Leadership and Innovation: Students will demonstrate effective citizenship by showcasing leadership and innovation in advancing sustainable energy solutions for global environmental challenges.**
PO9:	**ETHICS: Function effectively as a member of a multidisciplinary team, demonstrating ethics, integrity, and social responsibility in renewable energy projects.**
PO10:	**FURTHER EDUCATION OR EMPLOYMENT: Engage for further education, such as Ph.D. studies in related fields, or secure employment in various sectors including renewable energy firms, research institutions, government agencies, and consulting companies.**
PO11:	**GLOBAL PERSPECTIVE: Cultivates a global perspective by fostering a deep understanding of international renewable energy policies, technologies, and sustainable practices, enabling students to address worldwide energy challenges with cultural awareness and cross-border collaboration.**
PO12:	**PROJECT DESIGN & MANAGEMENT: Demonstrate knowledge and**

03/09/2024

	understanding of the Renewable Energy Technology and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PROGRAM SPECIFIC OUTCOMES (PSOs): At the end of the program, the student will be able to:

PSO1	**In-depth knowledge and the ability to elucidate detailed comprehension of the underlying principles, technologies, and applications of various branches of renewable energy.**
PSO2	**Exploring the interconnection between various renewable energy sources and their integration into existing energy system.**
PSO3	**Detailed coverage of topics such as renewable energy technologies, energy conversion systems, grid integration, energy storage, policy and regulations, and sustainable energy management.**
PSO4	**Hands-on experience in renewable energy system design, performance analysis, optimization, and modelling.**
PSO5	**The capability to conduct a short research project under supervision, incorporating techniques and methodologies of renewable energy.**

M.Sc. Renewable Energy Technology

Specification of Course	Semester	No. Of Courses	Credits
Core	**I-IV**	**17**	**70**
Elective	**I-IV**	**4**	**20**
Project work (Core)	**IV**	**01**	**10**
Total	**I-IV**	**22**	**100**
Additional Courses (Qualifying in nature, for student admitted in school of Studies only)			
Generic Elective	**II & III**	**02**	**04**
Skill Enhancement (Value Added Course)	**IV**	**01**	**02**
Indian Knowledge System (IKS)	**I**	**01**	**02**

03/09/2024

M.Sc. RENEWABLE ENEGY TECHNOLOGY

Semester	Course Nature	Course Code	Course Title	Course Type (T/P)	Hrs/ Week	Credits	Marks		
							CIA	ESE	Total
I	Core	RET 101	Solar Photovoltaic Technologies	T	5	5	30	70	100
	Core	RET 102	Numerical Methods and Computational Techniques	T	5	5	30	70	100
	Core	RET 103	Environmental Management	T	5	5	30	70	100
	Elective (Select any one)	RET 104	Simulation And Software	T	5	5	30	70	100
		RET 105	Indian And Global Energy Scenario	T	5	5	30	70	100
	Core	RET 106	Basic & Digital Electronics Laboratory	P	4	2	30	70	100
	Core	RET 107	Photovoltaic Laboratory	P	4	2	30	70	100
II	Core	RET 201	Solar Thermal Energy Conversion	T	5	5	30	70	100
	Core	RET 202	Instrumentation and Control In Energy Systems	T	5	5	30	70	100
	Core	RET 203	Fluid Mechanics and Thermodynamics	T	5	5	30	70	100
	Elective (Select	RET 204	Energy Auditing and Management	T	5	5	30	70	100

03/09/2024

	any one)	RET 205	Advanced Heat Transfer Technology	T	5	5	30	70	100
	Core	RET206	Solar Thermal Laboratory	P	6	3	30	70	100
		RET 207	Solar Concentrator Laboratory	P	4	2	30	70	100
III	Core	RET 301	Wind Energy	T	5	5	30	70	100
	Core	RET 302	E-Vehicles and Energy Storage	T	5	5	30	70	100
	Core	RET 303	Materials Science for Solar Applications	T	5	5	30	70	100
	Elective (Select any one)	RET 304	Energy Economics, Planning and Policies	T	5	5	30	70	100
		RET 305	Biomass Power Generation System	T	5	5	30	70	100
	Core	RET 306	Wind Energy Laboratory	P	4	2	30	70	100
	Core	RET 307	Renewable Energy Laboratory	P	4	2	30	70	100
	Core	RET 308	Internship (2 Weeks)	P	60 (in 2 week)	2	30 Seminar Presentation	70 Evaluation	100
IV	Core	RET 401	Energy Modelling and Project Management	T	5	5	30	70	100
	Core	RET 402	Solar Business Solutions	T	5	5	30	70	100
	Elective	RET	Hydrogen Energy and Fuel	T	5	5	30	70	100

03/09/2024

	(Select any one)	403	Cell Technology						
		RET 404	Alternative Energy systems	T	5	5	30	70	100
	Core	RET405	Project Work & Seminar	P	18	10	60	140	200

PROGRAMME STRUCTURE

Notes:

1. In place of Elective Course student can choose paper(s) from MOOC Courses (Swayam Portal) subjects to the following conditions:

    a. The chosen paper will be other than the papers offered in the current course structure

    b. The paper will be the PG level with a minimum of 12 weeks duration

    c. The list of courses on Swayam keeps changing, the departmental committee will finalize the list of MOOC courses for each semester.

    d. The paper(s) may be chosen from Swayam Portal on the recommendation of Head of the Department

2. The candidates who have joined the PG Programme in School of Studies (University Teaching Departments)/IRETM, shall undergo Generic Elective Courses (only qualifying in nature) offered by other departments/ SoS in Semester II and Semester III.

3. The candidates who have joined the PG Programme in IRETM/School of Studies (University Teaching Departments), shall undergo Skill Enhancement Course/Value Added Course (only qualifying in nature) in Semester I and Semester IV.

4. The candidates who have joined the PG Programme in IRETM, shall undergo Indian Knowledge System (only qualifying in nature) in Semester I.

5. **(a)** Two weeks Internship would be compulsory for PG students during their III semester (only qualifying in nature). Nature of Internship would be in-house (Inter-departmental/ Intra-departmental) or out of the house (Industry/Reputed academic Institution/Reputed Research labs in India)

    (b) Evaluation Process: Evaluation Process will be done by the parent department only. Students should submit their Internship certificate along with report.

    (c) Report format: Report should be comprised of Introduction, Literature Survey, Materials & Methods, Results, Conclusions , Future scope and references. Number of pages in report should be in between 40-50.

03/09/2024

6. 1 Credit = 15 hrs (Theory), 1 Credit = 30 hrs (Practical)

GENERIC ELECTIVE COURSES: (Offered to PG students of other Departments/ SoS only/IRETM)

Semester	Course Code	Course Title	Course Type (T/P)	Hrs/week	Credits	Marks		
						CIA	ESE	Total
II	RET501	Energy, Environment and Climate Change	T	2	2	30	70	100
III	RET502	Non-Conventional Energy Sources	T	2	2	30	70	100

SKILL ENHANCEMENT/VALUE ADDED COURSES: (Offered to the PG students of IRETM)

Semester	Course Code	Course Title	Course Type (T/P)	Hrs/ Week	Credits	Marks		
						CIA	ESE	Total
IV	RET601	Report Writing	P	2	2	30	70	100

INDIAN KNOWLEDGE SYSTEM : (Offered to the PG students of IRETM)

Semester	Course Code	Course Title	Course Type (T/P)	Hrs/ Week	Credits	Marks		
						CIA	ESE	Total
I	RET701	Indian Knowledge System (IKS)	T	2	2	30	70	100

03/09/2024

Programme Articulation Matrix:

Following matrix depicts the correlation between all the courses of the programme and Programme Outcomes ✓✖

Core Code	Pos												PSO				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
RETC101	✓	✓	✓	✓	×	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓
RETC102	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓
RETC103	✓	✓	✓	✓	✓	×	✓	×	×	✓	×	✓	✓	✓	✓	✓	✓
RETE104	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×	×
RETE105	✓	✓	✓	✓	×	✓	✓	✓	×	✓	✓	✓	✓	✓	×	✓	✓
RETL106	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	×	×
RETL107	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	×	✓	✓	×
RETC201	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	✓	×
RETC202	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
RETC203	✓	✓	✓	✓	×	✓	✓	×	✓	✓	×	✓	×	✓	✓	✓	✓
RETE204	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RETE205	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓
RETL206	✓	✓	✓	✓	×	×	×	✓	✓	✓	✓	✓	✓	×	×	✓	✓
RETL207	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓
RETC301	✓	✓	✓	✓	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓
RETC302	✓	✓	✓	✓	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
RETC303	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓
RETE304	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×
RETE305	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
RETL306	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	×	✓	✓	✓
RETL307	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓

03/09/2024

RETC401	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓
RETC402	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
RETE403	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
RETE404	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
RETP405	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

03/09/2024

DETAILED SYLLABUS

Semester -I

03/09/2024

M.Sc. (RET) Semester-I

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
CourseCode	CourseTitle		CourseType
RET101	SOLAR PHOTOVOLTAIC TECHNOLOGIES		Core
Credits	TotalNo.ofLectures-Tutorials-Practical(inhoursperweek):		
	L	T	P
5	5	1	
MaximumMarks	CIA		ESE
100	30		70

Course Outcomes (Semester - I)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Perform a solar resource assessment of a potential site. And estimate shadow formation, tilt angle and orientation of Photovoltaic panels.	R, U
2	Explain the operation of a Photovoltaic cell and PV module manufacturing methods.	R, U
3	Identify the different PV cell technologies used today and compare different PV cell technologies.	U, A
4	Learn basics of grid connected Solar Photovoltaic Power and types of inverters.	R, E
5	Design solar photovoltaic power plants for both grid-connected as well as Off-grid applications that comprise of an array of SPV modules, charge controller, batteries and inverter	A,E, C

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Learn about extraterrestrial solar radiation and its variations
2	Study electrical properties of semiconductors & characteristics of PV modules

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03/09/2024

3	**Learn about PV Cell technologies**
4	**Design Solar PV Plant**

COs-POs/PSOs Mapping for the course:

POs / COs	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	2	1	2	2	-	-	2	2	2	3	3	2	2	2
CO-2	3	3	3	2	1	2	2	-	-	2	2	2	3	3	2	2	2
CO-3	3	3	3	2	1	1	2	-	-	3	2	3	3	3	3	2	2
CO-4	3	3	3	3	1	3	2	-	-	3	3	3	3	3	3	2	3
CO-5	3	3	3	3	1	2	2	-	-	3	3	3	3	3	3	2	3

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Solar radiation resource, Extraterrestrial characteristics, Effect of Earth Atmosphere, Measurement and Estimation on horizontal and Tilted surfaces, Solar Radiation Geometry, Transparent and Opaque Materials, selective Coating. Applications of Solar PV - Lighting, refrigeration, telecommunications, aerospace, agriculture, fencing, water purification, navigation, offshore, etc.	15
02	Crystal Structure, Band Theory, intrinsic & Extrinsic Semiconductors, Carrier Transport phenomena in semi-conductors, Electrical Properties of Semiconductor, P-N Junction Physics, Thermoelectric and photo electric effect, photo conductivity, Homo junction & Hetero junction, Photo detector, solar cells, I-V and C-V characteristics, Conversion efficiency calculations, Losses in solar cells, Multi junction solar cells, quantum dots.	15
03	Types of solar cells, First, second and third generation solar cells, Mono crystalline and Poly crystalline solar cells, Thin film solar cells, Organic solar cells, Materials selection, Fabrication Techniques, Comparative study, Concentrated PV systems, Testing of Solar cells, Standardization and evaluation of solar cells.	15

03/09/2024

04	Grid connected Solar Photovoltaic Power Plants – Rooftop &Ground mount systems. SPV Modules and Arrays, Hotspots. Inverters – Characteristics of state-of-the-art Inverters, Types of Inverters – Central Inverters, String Inverters, Micro Inverters. Applications of Inverters - Grid-tie, Grid- interactive, Off-grid. Selection of Inverter. Maximum Power Point Tracker	**15**
05	Design of Grid-tie SPV power plants – Sizing the system, Optimal Layout of SPV Array, shading considerations, Wiring, Net metering. Installation of Grid-tie SPV power plants – Foundations, Module Mounting Structure, Wiring and connections, Inverter installation, Earthing, Lightning protection.	**15**

Text Book:

1. S. P. Sukhatme, Solar Energy Principles of Thermal Collections and Storage, 3rd Edition, Tata McGraw-Hill Education, 1996. ISBN: 9781259081965
2. V.V.N. Kishore (ed.), Renewable Energy Engineering and Technology, TERI Press, 2008.

Reference Books:

1. D. P. Kothari, K. C. Singal, Rakesh Ranjan, "Renewable Energy Sources and Emerging Technologies" 2nd Edition, PHI Learning Private Limited, 2012 ISBN: 9788120344709.
2. John Twidell and Tony Weir, "Renewable Energy Resources", 2 nd Edition, Taylor and Francis London, 2010 ISBN: 9780419253204
3. Alan L Fahrenbruch ; R H Bube, Fundamentals of Solar Cells, Academic Press, 1983.
4. S. A. Kalogirou, Solar Energy Engineering Processes and Systems, Elsevier.
5. S. R. Wenham, Applied Photovoltaics, 2nd Edition, Earth Scan.

03/09/2024

M.Sc. (RET) Semester-I

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
Course Code	Course Title		Course Type
RET102	Numerical Methods and Computational Techniques		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - I)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Master interpolation, finite differences, and empirical laws; apply differentiation and integration methods proficiently.**	R, U,An
2	**Solve Laplace's, Poisson's equations, one-dimensional heat equations; extend to two-dimensional heat equations and wave equations.**	Ap,An
3	**Explore Optimization Techniques, including linear programming, genetic algorithms, simulated annealing, and global optimization methods.**	U, Ap,An
4	**Attain MATLAB proficiency, covering variables, arrays, operators, expressions, loops, decisions, and program design skills.**	Ap, An
5	**Develop skills in program design, algorithmic thinking, and MATLAB for functions, data handling, plotting, GUI, and simulation.**	U,Ap,C

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	**Understand the advantages and limitations of each method and when to use them effectively**
2	**Study the accuracy and convergence properties of each integration method.**

03/09/2024

3	**Explore how to choose appropriate mathematical models to fit experimental data.**
4	**Study the solution of wave equations using numerical approaches and understand their applications in wave propagation problems.**

COs-POs/PSOs Mapping for the course:

POs / COs	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	1	1	2	-	-	3	1	2	3	2	1	1	2
CO-2	3	3	3	3	1	1	2	-	-	3	1	2	3	2	1	1	2
CO-3	3	3	3	3	1	1	3	1	1	3	1	3	3	2	1	2	3
CO-4	3	3	3	3	1	2	3	1	1	3	1	3	3	2	2	2	3
CO-5	3	3	3	3	2	2	3	1	1	3	1	3	3	2	2	2	3

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Interpolation, finite difference method, forward difference method, backward difference method, central difference method. Differentiation using forward, backward and central difference formulae. Integration using trapezoidal, Simpson's one-third and Simpson's three-eighth rule. Empirical laws and curve-fitting.	15
02	Solution of Laplace's equation, Poisson's equation. Solution of one-dimensional heat equation using Schmidt and Crank-Nicholson method; Solution of two-dimensional heat equation, Solution of wave equation.	15
03	Introduction to Optimization Techniques. Linear programming methods: Simplex method, Artificial variables and dual phase method. Introduction to genetic, simulated annealing and global optimization algorithms.	15
04	Introduction to MATLAB, variables and workspace, Arrays, vectors and matrix. Operators, expressions and statements, output, loops (for, each), decisions (if,else, elseif, while etc.).	15
05	Program design and algorithm development, MATLAB functions and data import export utilities, logical vectors. Introduction to graphics: basic 2D graphics, 3D plots, function M-files, graphical user interface, introduction to simulation.	15

Text Books:

03/09/2024

1. Balagurusamy E, Numerical Methods, Tata McGraw Hill, New Delhi.
2. Jain M K, Iyengar S R K, Jain R K, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Ltd. New Delhi.
3. S. Harman T L, Dabney J B, Richert N J, Advanced Engineering Mathematics with MATLAB.
4. Brain D Hahn, Daniel T Valentine, Essential MATLAB for Engineers and Scientists, Elsevier.
5. Redfern Darren, Colin Campbell, The MATLABS Handbook, Springer, New York

Reference Books:

1. Rajsekaran S, Numerical Methods in Science and Engineering, Wheeler, Allahabad.
2. Hilderbrand F B, Introduction to Numerical Analysis, Tata McGraw Hill, New Delhi.

03/09/2024

M.Sc. (RET) Semester-I

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
Course Code	Course Title		Course Type
RET103	ENVIRONMENTAL MANAGEMENT		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - I)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understand the foundational principles of environmental management and its participants.	R, U
2	Trace the evolution of EIA and comprehend its importance in forecasting environmental changes.	R, U
3	Acquire skills in conducting environmental audits, including waste and pollution prevention assessments.	U, A
4	Learn techniques for environmental monitoring, modeling, and remote sensing in environmental management.	R, E
5	Principles of Environmental design (ED) and economics.	A,E, C

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Learn about environmental laws and legislation applicable in the Indian context

03/09/2024

2	**Gain insights into EIA monitoring, auditing, and the review process for ensuring compliance**
3	**Gain knowledge of the stages, purposes, and applications of life cycle assessment (LCA) and Learn about the application of remote sensing in environmental management**
4	**Analyze the relationship between economics and the environment, including concepts of environmental valuation**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	2	3	2	3	1	3	2	-	-	3	-	2	2	2	2	3	3
CO-2	2	3	2	3	1	3	2	-	-	3	-	1	2	2	2	2	1
CO-3	2	2	2	3	1	3	2	-	-	2	-	3	3	2	2	2	1
CO-4	3	2	3	3	1	3	2	-	-	2	-	3	3	2	2	2	2
CO-5	2	2	2	3	1	3	2	-	-	2	-	2	2	2	2	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Principle, policy and legal aspects: Introduction of environmental management (EM), participants of EM, environmental ethics, environmental concerns in India, ecology and the environment, processes of ecosystem, environmental policies and program in India, environmental laws and legislation, legislation in Indian context.	15
02	Environmental impact assessment (EIA): Evolution of EIA, forecasting environmental changes, strategic environmental assessment (SEA), environmental clearance (EC) procedure in India, preliminary stages of EIA, steps of EIA, EIA monitoring and auditing, review of EIA report.	15

03/09/2024

03	Environmental auditing (EA) and life cycle assessment (LCA): Audit methodology, elements of audit process, waste audits and pollution prevention assessments, auditing of environmental management system (EMS), report preparation and review report. LCA-stages, purpose, application and case study of different products.	**15**
04	Environmental management techniques: Environmental monitoring & modeling, sensitivity analysis, remote sensing application in EM, environmental risk assessment.	**15**
05	Environmental design (ED) and economics: Principle, benefits and motivation of ED, ED for building, developmental planning, economics and environment, environmental valuation, economic natural resources.	**15**

Text Books:

1. Mary K., Theodore, Louis Theodore, Introduction to environmental management, CRC Press; 2nd edition, 2021.
2. T. V. Ramachandra, and Vijay Kulkarni, Environmental management" The Energy and Resources Institute, TERI, 2009.

Reference Books:

1. M. N. Rao, "Wastewater treatment" Oxford and IBH publishing Co. Pvt Ltd, 2007.

Christopher Sheldon, Environmental management systems

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03/09/2024

M.Sc. (RET) Semester-I

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
Course Code	Course Title		Course Type
RET104	SIMULATION AND SOFTWARE		Elective
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - I)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understand the Modeling and simulation of Solar Photovoltaic Systems, different MPPT algorithm, open loop control and close loop control.	U, Ap
2	Study and identify the simulation tool for analyze and simulate the Solar energy system, solar thermal and photovoltaic system.	R, U, An
3	Use the Transient System Simulation (TRNSYS) program for learning the Optimization techniques for photovoltaic system designing through PV system &System Advisor Model (SAM).	E, C, Ap,An
4	Understand the MATLAB software basics for designing, modeling, analysis and evaluation of Renewable Energy Systems	R,An,E,C
5	Use Simulink software for modeling and design of RE systems	Ap,An,E,C

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

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Learning Objectives (LO) :

LO No.	Learning Objectives
1	Learn techniques for modeling the electrical characteristics of PV cells and arrays
2	Learn how to analyze and interpret I-V and P-V curves to assess the performance of PV systems
3	Learn how to model and simulate various MPPT techniques, such as perturb and observe (P&O), incremental conductance, and hill climbing.
4	Explore available software tools for designing and simulating solar thermal and photovoltaic systems.
5	Introduction to Simulink and its applications in simulating dynamic systems, including solar energy systems

COs-POs/PSOs Mapping for the courses:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	1	3	2	-	-	3	2	3	3	3	2	-	-
CO-2	3	3	3	3	1	3	2	-	-	3	2	3	3	3	2	-	-
CO-3	3	3	3	3	1	3	2	-	-	3	2	3	3	3	2	-	-
CO-4	1	3	3	3	1	2	3	-	-	3	2	3	3	2	1	-	-
CO-5	3	3	3	3	2	1	3	-	-	3	2	3	3	2	1	-	-

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Modeling and simulation of Solar Photovoltaic Systems Mathematical modeling of PV array, analysis of I-V and P-V characteristics of PV, modeling and simulation of different MPPT algorithm, open loop control and close loop control.	15
02	Solar energy system designing and simulation software Solar	15

03/09/2024

	system designing: Available softwares for solar thermal and photovoltaic system designing and analysis; accuracy of simulation tool; selection of simulation tool based on system need and limitations.	
03	Transient System Simulation (TRNSYS) program: Simulation suite, building visual interface, Installing weather data, system description and modeling approach. Optimization techniques for photovoltaic system designing through PV system, System Advisor Model (SAM).	15
04	Introduction to MATLAB variables and workspace Arrays /vectors and matrix: Operators, Expressions and statements, output, loops (for, each), decisions (if, else, else if, while etc.); Program design and algorithm development, MATLAB functions, and data import export utilities, logical vectors	15
05	Introduction to graphics, basic 2D graphics, 3D Plots; function M, files, graphical user interface, Introduction to simulation. Introduction to Simulink, Applications of Simulink	15

Text Books:

1. Jyoti Prakash Srivastava, Step by Step Guide to Solar Simulation Software, 2021 Ed.
2. RudraPratap, Getting Started with MATLAB, OXFORD University Press, South Asia Ed 2010
3. S.N. Alam, S.S. Alam, Understanding MATLAB , TTK publication, CRC Press, Ed. 2013

Reference Books:

1. Jyoti Prakash , Simulating Solar Energy Systems, Notion Pw
2. PriyankaPatankar, MATLAB and Simulink In-Depth, Kindle ed. 2022
3. Mario Garcia-Sanz, Constantine H. Houpis, Wind Energy Systems, Ed. 1, 2012

03/09/2024

M.Sc. (RET) Semester-I

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
Course Code	Course Title		Course Type
RET105	INDIAN AND GLOBAL ENERGY SCENARIO		Elective
Credits	Total No. of Lectures-Tutorials-Practical (in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - I)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understand conventional (fossil fuels) and non-conventional (solar, wind, biomass) sources, their potential, and power generation methods.	R,U
2	Analyze economic and consumption growth, technology innovation, energy intensity, oil prices, and strategies like R&D, policies, and international collaboration.	R, An
3	Explore pollution from power generation, energy's impact on CO2 emissions, sustainable development of renewables, and policies for reducing environmental impact.	U, An
4	Address energy crisis, shift from carbon-rich to carbon-free tech, transition parameters, policy challenges in fossil fuels, renewables, power sector reforms, and energy conservation.	An, E
5	Study the role of regulations like the Energy Conservation Act and National Electricity Policy in shaping energy planning and development.	R, An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

03/09/2024

LO No.	Learning Objectives
1	**Differentiate between conventional (fossil fuels) and non-conventional (solar, wind, biomass) energy sources.**
2	**Evaluate the potential and challenges of various energy sources in the global and Indian context**
3	**Investigate the energy utilization patterns in India and their implications for social and economic development.**
4	**Understand the parameters influencing this transition and potential energy policy issues**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	1	2	2	1	2	2	3	1	2	2	3	2	2	1	2	2
CO-2	3	3	3	3	1	2	2	2	1	2	3	3	2	2	1	2	3
CO-3	3	3	3	2	1	2	2	2	1	3	3	3	2	1	1	2	3
CO-4	2	2	3	2	1	3	3	3	1	3	3	3	2	2	1	3	3
CO-5	1	2	2	2	1	3	3	3	1	3	3	3	2	2	1	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Energy resources – Conventional and non-conventional sources of energy - Fossil fuels, solar, wind and biomass sources. Global and Indian energy scenario - Potential and power generation.	15
02	World Energy Supply and Demand - Economic and energy consumption growth rate. Technology development and innovation. Global energy intensity - Oil prices and alternative sources. Strategies to achieve desired energy scenario – Research, development, demonstration and deployment, energy intensity	15

03/09/2024

	reduction, Government policies and International collaboration.	
03	Environmental Policy - Pollution - Power generation and utilization. Energy forecasting, impact on environment – CO2 emission reduction - Environmental policies. Sustainable development of renewable and non-renewable energy sources.	15
04	Future energy options - Energy crisis, transition from carbon rich and nuclear to carbon free technologies, parameters of transition. Energy policy issues - Fossil Fuels, renewable energy, power sector reforms, restructuring of energy supply sector, energy strategy for future. Energy conservation act and National electricity policy and plan.	15
05	Energy utilization pattern in India, Energy sector reforms, Role of energy in social and economic development, Modern energy production.	15

Text Books:

1. Tony Weir, John Twidell, "Renewable Energy Resources", 2nd Edition, Taylor and Francis Group, 2005.
2. Jose Goldenberg, Thomas Johansson, A. K. N. Reddy, Robert H Williams., "Energy for a Sustainable World", I Edition June 23, John Wiley & Sons, 1988.
3. Kailash Thakur., "Environmental Protection Law and Policy in India", Deep publication private limited, 2007.

Reference Books:

1. Susan Baker., "Sustainable Development", Routledge, 2006.
2. Mohan Munasinghe and Peter Meier, "Energy Policy Modeling and Analysis", Cambridge university, 1993.
3. Hand book, "Renewable energy policy and politics", Earthscan UK, 2006.

03/09/2024

M.Sc. (RET) Semester-I

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
Course Code	Course Title		Course Type
RET106	BASIC & DIGITAL ELECTRONICS LABORATORY		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
2	0	0	4
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - I)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Identify and categorize basic electronic components such as resistors, capacitors, diodes, and transistors.**	R, U
2	**Assemble, analyze, and troubleshoot basic electronic circuits including voltage dividers, amplifiers, and rectifiers.**	U,An
3	**Apply theoretical concepts to practical analog circuits, demonstrating a clear understanding of component behavior and circuit operation.**	Ap,An,E
4	**Understand the component behavior and digital circuit operation.**	U, An
5	**To design complex analog & digital circuits**	U,Ap,An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

03/09/2024

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Analyze the behavior of diodes and its various applications
2	Analyze the behavior of transistors under different biasing conditions and load resistances
3	Learn the principles of passive filter circuits and their frequency response characteristics
4	Study of combinational circuits and Analyze the behavior of flip-flops in sequential logic circuits and digital systems

COs-POs/PSOs Mapping for the course:

POs / COs	POs												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	1	-	2	-	2	3	2	3	3	2	1	1	1
CO-2	3	3	3	3	1	-	2	-	2	3	2	3	2	2	1	1	1
CO-3	3	3	3	3	1	-	2	1	2	3	2	3	3	1	2	1	1
CO-4	3	3	3	3	1	-	2	2	2	3	2	3	2	1	2	1	1
CO-5	3	3	3	3	1	-	2	2	2	3	2	3	2	1	2	2	1

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Exp. No.	Name of Experiment
1	Study of Forward & Reverse Characteristics of Silicon & Germanium diode.
2	Study of Half-wave Rectifier, Full-wave & Center-tapped Rectifier & calculation of Ripple Factor and Efficiency of various Rectifiers.
3	Study of Zener Diode as a voltage regulator, when input voltage, V_{in} is fixed while load resistance, R_L is variable & V_{in} is variable while load resistance, R_L is fixed.
4	To determine the characteristics of transistor for both PNP & NPN in Common

09/09/2024

	Emitter Configuration.
5	To study characteristics of Low pass, High pass, Band Pass filter.
6	To study & verify the truth table of basic, universal & arithmetic logic gates.
7	To study the Boolean algebraic theorems and verification of variable theorem.
8	To study the Boolean algebraic theorems and verification of Demorgan's theorem.
9	To verify the operation of 16 line to 1 line digital multiplexer.
10	To verify the operation of 1 line to 16 line demultiplexer.
11	To study the operation of 4 bit binary full adder and subtractor for addition of two 4 bit binary numbers.
12	To construct various flip flop & study its characteristics.

- **Students has to perform at least 10 Experiments.**
- **Any other experiment of the same standard can be added.**

03/09/2024

M.Sc. (RET) Semester-I

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
Course Code	Course Title		Course Type
RET107	PHOTOVOLTAIC LABORATORY		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
2	0	0	4
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - I)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Demonstrate a comprehensive understanding of photovoltaic principles, technologies, and experimental techniques.	R, U
2	Proficient in designing, assembling, and analyzing photovoltaic systems, and will possess the skills to troubleshoot and diagnose common issues.	U,An
3	Measuring key performance parameters, interpreting data, and applying safety protocols relevant to photovoltaic experimentation and research.	Ap,An,E
4	Study and Analyse the behavior of solar cell	U, An
5	To understand working of Solar Panel.	R,U

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

03/09/2024

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Understand the principles of measuring current-voltage (I-V) and power-voltage (P-V) characteristics, spectral response and calculate the quantum efficiency of solar cells,
2	Understand the impact of tilt angle and seasonal variations on the performance of solar panels.
3	Learn how to simulate and analyze the electrical characteristics of solar cell combinations in series and parallel configurations.

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	2	2	2	1	2	3	2	3	3	-	2	1	1
CO-2	3	3	3	3	2	2	1	1	2	3	2	3	2	-	2	2	1
CO-3	3	3	3	3	2	2	1	1	2	3	2	3	3	-	2	2	1
CO-4	3	3	3	3	2	2	1	1	2	3	2	3	2	-	2	2	1
CO-5	3	3	3	3	2	2	1	1	2	3	2	3	2	-	2	2	1

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Exp. No.	Name of Experiment
1	To measure I-V and P-V characteristics of single solar cell & cells in series and parallel combinations of PV module in field.
2	To measure I-V and P-V characteristics of a single solar cell & cells in series and parallel combination at constant intensity using mini solar simulator.
3	To measure I-V and P-V characteristics of a single solar cell & cells in series and parallel combination at variable intensities using mini solar simulator.
4	To measure I-V and P-V characteristics of a single solar cell at constant intensity using solar simulator.

03/09/2024

5	To measure I-V and P-V characteristics of a single solar cell at variable intensities using solar simulator.
6	To measure I-V and P-V characteristics of a single solar cell at variable temperature & fixed intensity using solar simulator.
7	To measure the spectral response of a solar cell and to learn about quantum efficiency.
8	Study of the parameters of solar panels at different tilt and Seasonal angles.
9	Study of solar cell combination is series using simulator.
10	Study of solar cell combination in parallel using simulator

- **Students has to perform all the Experiments.**
- **Any other experiment of the same standard can be added.**

03/09/2024

DETAILED SYLLABUS

Semester -II

03/09/2024

M.Sc. (RET) Semester-II

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	II
Course Code	Course Title		Course Type
RET201	SOLAR THERMAL ENERGY CONVERSION		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - II)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Understand solar radiation and its interaction with Earth, including geometry, angles, day length, shadow determination, atmospheric effects, measurement, estimation, and practical applications.**	R, U
2	**Grasp the basics of solar collectors, including heat conversion estimation, types of collectors like evacuated tubular and flat plate collectors, efficiency analysis, coating characteristics, and their applications.**	R, U
3	**Learn about different types of Line-focusing and point-focusing concentrators.**	R,U
4	**Explore solar heating and cooling systems, including liquid-based heating, mathematical modeling, absorption refrigeration cycles, desiccant cooling, system design, and sizing methods for solar heating systems.**	U, An
5	**Discover solar energy's industrial applications, including flat plate collectors for process heat, thermal storage design, energy transport, and various solar thermal systems such as solar stills, cookers, ponds, and other related technologies.**	U, Ap

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

03/09/2024

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Learn the principles of solar energy conversion into heat energy
2	Explore the classification, design, and performance parameters of concentrating collector systems
3	Understand mathematical modeling techniques for solar heating systems and vapor absorption refrigeration cycles
4	Learn about the design considerations for thermal storage and energy transport in solar thermal systems

COs-POs/PSOs Mapping for the course:

POs / COs	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	2	2	2	2	1	2	2	1	2	3	3	2	2	1
CO-2	3	3	3	2	2	2	2	1	2	2	1	2	3	3	2	2	1
CO-3	3	3	2	2	2	2	2	1	2	2	1	2	3	3	2	2	1
CO-4	3	3	2	2	2	2	2	1	2	2	1	2	3	3	2	2	1
CO-5	3	3	2	2	2	2	2	2	2	2	1	2	3	3	2	2	1

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Solar radiation: Extra-terrestrial and terrestrial radiation; Solar radiation geometry Earth-Sun angles - Solar angle, Solar day length - Sun path diagram – Shadow determination; Calculation of total solar radiation on horizontal and tilted surface; Effect of earth atmosphere on solar radiation; Measurement & estimation of solar radiation on horizontal and tilted surfaces; Analysis of Indian solar radiation data and its applications.	15
02	Fundamentals of solar collectors: Introduction and estimation of conversion of solar energy into heat energy, evacuated tubular collectors; Calculation of heat capacity of flat plate collector; Air flat	15

03/09/2024

	plate Collectors: types, thermal analysis and drying; Solar flat plate collector: useful energy gain, energy losses, efficiency; Ideal coating characteristics to enhance the collector efficiency: Types and applications, anti-reflective coating, preparation and characterization.	
03	Line-focusing and point-focusing concentrators: parabolic trough, parabolic dish, heliostat field with central receiver, Fresnel lenses, compound parabolic concentrator; Sun tracking mechanisms; Concentrating collector designs: Classification, design and performance parameters; ASHRAE standards and performance estimation of solar collectors via ASHRAE; Tracking systems; Central receiver systems; parabolic trough systems; Solar furnaces.	**15**
04	Solar Heating & Cooling System: Liquid based solar heating system; Natural, forced and gravity flow, mathematical modelling, vapour absorption refrigeration cycle; Water, ammonia & lithium bromide and water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling; Design and sizing of solar heating systems: f-chart method, utilizability methods of solar thermal system evaluation.	**15**
05	Solar Energy for Industrial Process: heat generation, temperature requirement, consumption pattern; Applications of solar flat plate: water heater & air heater for industrial process heat; Designing of thermal storage; Transport of energy; Solar Thermal Energy Systems: Solar still; Solar cooker; Solar pond and other Solar Systems.	**15**

Text Book:

1. Sukhatme S P, Solar Energy: principles of Thermal Collection and Storage, TataMcGrawHill.
2. Duffie J A, Beckman W A, Solar Engineering of Thermal Processes, Johnn Wiley.
3. Goswari D.Y, FränkKreith and Kreider 1 F, Principles of Solar Engineering, Taylor and Francis, USA.

Reference Books:

4. Garg H P, Prakash S, Solar Energy: Fundamental and Application, Tata McGrowHill, New Delhi.
5. Kreith F, Kreider J F, Principles of Solar Engineering, McGrawHill.
6. Kreider J F, Kreith F, Solar Energy Handbook, McGrawHill
7. Bent Sorensen, Renewable Energy, Academic press, New York.
8. Tiwari, G N, Solar Energy, Fundamentals Design, Modeling and Applications, *Narosa, New Delhi.*

03/09/2024

M.Sc. (RET) Semester-II

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	II
Course Code	Course Title		Course Type
RET202	INSTRUMENTATION AND CONTROL IN ENERGY SYSTEMS		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - II)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Understand the basic measurement principles, transducers and their types with applications.**	R, U, E
2	**Understand fundamentals of control theory, system modeling and PID Controllers.**	U,An
3	**Analyze the steady state and transient response of systems and to perform stability analysis in both time and frequency domain.**	R,U, An
4	**Understand the data acquisition principles with its application.**	U, An,Ap
5	**Understand Industrial Automation fundamentals for PLC, DCS and SCADA with industrial specific examples and ladder logic programming**	U, Ap

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

03/09/2024

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Study AC voltmeters using rectifiers, true RMS voltmeters, and digital VOM meters for accurate AC measurements and applications of transducers
2	Understand the concept of control systems and their components.
3	Understand how to interface input signals and output systems with continuous actuators using data acquisition systems
4	Explore the essential requirements of automation and control in industrial processes

COs-POs/PSOs Mapping for the course:

POs / Cos	POs												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	2	1	2	2	1	2	2	2	2	2	3	1	2	2
CO-2	3	3	3	2	1	2	2	1	2	2	2	2	2	3	1	2	2
CO-3	3	3	2	2	1	2	2	2	2	2	2	3	2	3	2	2	2
CO-4	3	3	2	2	1	2	2	2	2	2	2	3	2	3	2	2	2
CO-5	3	3	2	2	1	2	2	2	2	2	2	3	2	3	2	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Electrical Measurement: DC Measurement, DC Voltmeter Ammeter, Ohmmeter. Digital Voltmeter, Ammeter, & Ohmmeter. AC Voltmeter using rectifier, True RMS Voltmeter, Digital VOM Meter. Sensor & Transducer Principles: Principles and classification of Transducers, guidelines for selection and application of Transducers. Basic Requirement of Transducers.	15
02	Different type of Transducers: displacement, strain gauge, LVDT, Potentiometer, capacitive and inductive transducers, Piezo Electric,	15

03/09/2024

	Temperature, optical & Hall Effect Transducers.	
03	Control System & PID Controller: System Concept, differential equations and Transfer Function. Modeling of Electric, rotational and translational mechanical systems. Block diagram representation and reduction.	15
04	8Closed loop transfer function, signal flow graph, Meson's gain formula & PID Controller. Data Acquisition: Computer Interfacing for data acquisition and Control.	15
05	Interfacing input signals, output systems with continuous actuators. Industrial Automation: Introduction, Need of Automation& Control. Advantages and applications, essential requirement of automation & Control, structure of automation process, hardware and ladder logic for PLC, DCS & SCADA.	15

Text Books:

1. A K Sahwney, Electrical & Electronic measurement, Dhanpatrai publishers.
2. S Mukhopadhyay, S. Sen, A.K Deb, A Course in Electrical & Electronic Measurement, JAICO publishing house, New Delhi.
3. Frank. D. Petruzella, Programmable Logic Controller, McGraw Hill Education New Delhi

Reference Books:

1. R K Rajput, Electriacl Measurment and Instrumentation, S Chand Publishers Pvt. Ltd.
2. Norman S. Mise, Control System Engineering, Wiley Publishing Co.4.
3. R.T. Stefani, B.Shahian, C.J.Savant and G.H. Hostetter, "Design of Feedback Control Systems" Oxford University Press. 5.
4. Samarjit Ghosh, "Control Systems theory and Applications", Pearson Education
5. Nagrath & Gopal, "Control System Engineering", New age International.
6. K. Ogata, "Modern Control Engineering", Prentice Hall of India.
7. B.C. Kuo &FaridGolnaraghi, "Automatic Control System" Wiley India Ltd.
8. D.RoyChoudhary, "Modern Control Engineering", Prentice Hall of India.

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03/09/2024

M.Sc. (RET) Semester-II

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	II
Course Code	Course Title		Course Type
RET203	FLUID MECHANICS AND THERMODYNAMICS		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - II)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understanding forces, moments, stress-strain diagrams, fracture behavior, and various stress types. Also, covering fatigue, creep, hardness of materials, and basics of civil work and foundation engineering.	R, U, E
2	Exploring fluid types, fluid statics, Bernoulli's equation, mass conservation, viscosity, Reynolds number, Navier-Stokes equations, and laminar/turbulent flow distinctions.	U,An,E
3	Understanding thermodynamic system, Quasi-static Process and Zeroth Law of thermodynamics.	R,U, An
4	First & Second Laws of Thermodynamics: Internal energy as a point function, First Law limitations, heat engines, heat pumps, performance parameters, Kelvin-Planck and Clausius statements, and their equivalence.	U, An,Ap
5	Thermodynamic Relationships: Exploring T-dS equations, heat capacities, volume expansion, compressibility coefficients, adiabatic compressibility, and specific heat ratio.	U, E

03/09/2024

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	**Study the basics of civil work and foundation design principles**
2	**Understand fluid statics, including pressure distribution and buoyancy**
3	**Learn about thermodynamic processes and cycles**
4	**Understand the T-dS equations and their significance in thermodynamics**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	1	3	2	1	2	2	1	2	2	3	3	2	2
CO-2	3	3	3	3	1	3	2	1	2	2	1	2	2	3	3	2	2
CO-3	3	3	2	3	1	3	2	1	2	2	1	3	2	3	3	2	2
CO-4	3	3	2	3	1	3	2	1	2	2	1	3	2	3	3	2	2
CO-5	3	3	2	3	1	3	2	1	2	2	1	3	2	3	3	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Forces in Structures: Forces, Moments of forces, Types of forces and moments, Stress-Strain Diagrams, Fracture at Low Stresses, Tensile stress, Compressive stress, Fatigue, Creep, Hardness of materials, bending of beams, basic of civil work & foundation.	15
02	Fluid Mechanics: Types of Fluid, fluid statics, Bernoulli's equation, Conservation of mass, Definition of viscosity, Reynolds number, Navier-Stokes equations, Laminar and turbulent flow.	15

03/09/2024

03	Thermodynamic System: Introduction, Properties, process, cycle, thermodynamic equilibrium, Quasi-static Process, Zeroth Law of thermodynamics, Work and Heat transfer, flow work.	**15**
04	First Law of Thermodynamics: Internal energy, proof of internal energy as a point function.Second Law of Thermodynamics: Limitations of the First Law – Thermal Reservoir, Heat Engine, Heat pump, Parameters of performance, Second Law of Thermodynamics, Kelvin-Planck and Clausius Statements and their Equivalence.	**15**
05	Thermodynamic Relationships: T-dS equations, difference in heat capacities, coefficient of Volume expansion and isothermal compressibility, adiabatic compressibility, ratio of specific heat.	**15**

Text Books:

1. N.D. Bhatt, Elementary Engineering Drawing, Chartor Publishing house, Anand, India.
2. D. N. Johle, Engineering Drawing, Tata Mcgraw-hill Publishing Co. Ltd.
3. P. K Nag "Thermodynamics", Tata McGraw-Hill Publishing Co. Ltd

Reference Books:

1. Building Construction --- Bindra Arora; DhanpatRai publication.
2. Dr. R.K. Bansal, Fluid Mechanics, Laxmi Publication (P) Ltd. New Delhi
3. Engineering Mechanics (Statics and Dynamics); A. K. Tayal ,Umesh Pub., Delhi
4. Engineering Thermodynamics: C.P.Arora, TMH

03/09/2024

M.Sc. (RET) Semester-II

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	I
Course Code	Course Title		Course Type
RET204	ENERGY AUDITING AND MANAGEMENT		Elective
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - II)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**To identify and describe the present state of energy security and its importance.**	R, U,
2	**To identify and describe the basic principles and methodologies adopted in the energy audit of a utility.**	U,An
3	**To describe the energy performance evaluation of some standard installations.**	R,U, An
4	**To Review energy conservation opportunities in the steam distribution system**	U, An
5	**Hands on practice for Green building and application of non-conventional and renewable energy sources**	U, An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives

03/09/2024

1	**Understand the current global and Indian energy landscape, including types, forms, and sources of energy**
2	**Understand the objectives and background of energy management**
3	**Understand the concept of energy costs and the importance of benchmarking energy performance**
4	**Explore case studies related to green building design and implementation**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	2	1	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2
CO-2	2	1	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2
CO-3	2	1	2	2	2	2	2	2	3	2	2	3	2	2	2	2	2
CO-4	3	1	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2
CO-5	3	1	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Global & Indian energy scenario, types, forms, and energy consumption. Energy conservation, Acts and related policies, and energy ratings.	15
02	Objectives and background of energy management, energy audit: types & methodology, energy audit report format, instruments.	15
03	Understanding energy costs, benchmarking and energy performance, fuel, and energy substitution, material & energy balance, financial techniques for assessing energy conservation measures, fixed and variable cost, interest charges, simple payback period, net present value, and discounted cash flow method.	15
04	Review of different thermal loads, energy conservation opportunities in the steam distribution system, assessment of steam distribution losses,	15

03/09/2024

	steam leakages, steam trapping, condensate, and flash steam recovery system. General fuel economy measures in boilers and furnaces, waste heat recovery, use of insulation- types and application.	
05	Case studies: Green building, application of non-conventional and renewable energy sources. Case studies of an energy audit in different industries.	**15**

Text Books:

1. Smith CB, Energy management principles, Pergamon Press, New York, 2015.

2. T. D. Eastop and D. R. Croft,Energy efficiency for engineers and technologists, Longman Harlow,1996.

Reference Books :

1. LC Witte, PS Schmidt and DR Brown, Industrial energy management and utilization, Hemisphere Publishing Corporation, Washington Energy Management, 1998.

2. A. K. Tyagi, Handbook on energy audits and management, Tata Energy Research Institute (TERI).

3. Geofry Stokes, Handbook of electrical installation practice, Blackwell Science.

4. Anil Valia, Designing with light: Lighting handbook, Lighting system.

5. Dale R. Patrick, S. Fardo, Ray E. Richardson, energy conservation guidebook, Fairmont Press.

6. Albert Thumann, W. J. Younger, T. Niehus, Handbook of energy audits, CRC Press.

03/09/2024

M.Sc. (RET) Semester-II

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	II
Course Code	Course Title		Course Type
RET205	Advanced Heat Transfer Technology		Elective
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - II)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Understand advanced heat transfer mechanisms beyond conduction.**	R, U
2	**Be familiars with analytical and numerical techniques for solving complex heat transfer problems.**	U, Ap, E
3	**Understand advanced heat transfer using convection.**	U, Ap
4	**Explore applications of advanced heat transfer techniques in engineering design and innovation.**	U, An
5	**Understand modern experimental methods and measurement techniques used in heat transfer research.**	U, An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Theoretical understanding and practical applications in advanced heat transfer technology
2	To understand the knowledge of heat exchanger technology.

03/09/2024

3	To study radiative heat transfer technique.
4	Understand the use of nanotechnology for heat transfer.

COs-POs/PSOs Mapping for the course:

POs / COs	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	2	2	3	1	2	2	2	2	1	3	3	2	2
CO-2	3	3	3	3	2	2	3	1	2	2	2	2	1	3	3	2	2
CO-3	2	3	2	3	2	2	3	1	2	2	2	3	1	3	3	2	2
CO-4	2	2	2	3	2	2	3	1	2	2	2	3	1	3	3	2	2
CO-5	2	2	2	3	2	2	3	1	2	2	2	3	1	3	3	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Transient Heat Conduction: Analytical solutions for transient heat conduction in various geometries, Phase Change Heat Transfer: Fundamentals of boiling and condensation, Pool boiling and nucleate boiling heat transfer ,Film condensation and drop wise condensation, Heat pipes and phase change materials	15
02	Advanced Convection: Boundary layer theory and laminar flow heat transfer ,Turbulent flow and turbulent heat transfer correlations, Heat exchanger design and analysis.	15
03	Radiative Heat Transfer: Radiative properties of surfaces and materials , View factors and radiation exchange between surfaces, Radiative heat transfer in participating media.	15
04	Advanced Heat Transfer Enhancement Techniques: Extended surfaces and fin theory, Microscale heat transfer and microchannel cooling, Nanofluids and nanotechnology in heat transfer	15
05	Experimental Techniques in Heat Transfer: Measurement of temperature, heat flux, and thermal conductivity, Heat transfer	15

Kolkata
03/09/2024

	coefficient measurement techniques, Introduction to modern experimental setups and instruments	

Text Books:

1. "Heat and Mass Transfer: Fundamentals and Applications" by Yunus A. Çengel and Afshin J. Ghajar
2. "Convective Heat and Mass Transfer" by Kays, Crawford, and Weigand
3. "Radiative Heat Transfer" by Michael F. Modest
4. "Heat Exchanger Design" by Arthur P. Fraas
5. "Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics, and Heat Transfer" by Michael J. Moran et al.

03/04/2024

M.Sc. (RET) Semester-II

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	II
Course Code	Course Title		Course Type
RET206	SOLAR THERMAL LABORATORY		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
3			6
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - II)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Evaluate heat transfer coefficient (UL), fluid flow rate (FR), and thermal efficiency (η) in thermosyphonic mode with fixed input parameters.	U, E
2	Assess thermosyphonic flow's performance using fixed input parameters in the Solar Thermal Training System.	U, E
3	Evaluate the performance of PCM thermal storage system during charging.	U, E
4	Assess the performance of PCM thermal storage system during discharging.	U,E, An
5	Assess the performance of PCM thermal storage system during discharging& discharging containing phase change material.	U, ,E,An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No	Learning Objectives
1	Understand the concept of overall heat loss coefficient (UL), heat removal factor (FR), and thermal efficiency (η) in thermosyphonic solar water heating systems.
2	Understand the principles of thermal energy storage using phase change materials

03/09/2024

	(PCM) and their applications.
3	**Understand the concept of overall efficiency in PCM-based thermal storage systems, considering both charging and discharging processes**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	-	-	-	2	2	3	2	3	3	1	1	2	2
CO-2	3	3	3	3	-	-	-	2	2	3	2	3	2	1	1	2	2
CO-3	3	3	3	3	-	-	-	2	2	3	2	3	3	1	1	2	2
CO-4	3	3	3	3	-	-	-	2	2	3	2	3	2	1	1	2	2
CO-5	3	3	3	3	-	-	-	2	2	3	2	3	2	1	1	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

S.NO.	Name of Experiment
1.	Evaluate U_L, F_R, η in thermosyphonic mode of flow with fixed input parameters.
2.	Evaluate U_L, F_R, η in thermosyphonic mode of flow with different wind speeds.
3.	Evaluate U_L, F_R, η in thermosyphonic mode of flow with different intensity.
4.	Evaluate U_L, F_R, η in thermosyphonic mode of flow with different tilt angles.
5.	To test the performance of the given thermal storage system containing phase change material (PCM) under charging mode.
6.	To test the performance of the given thermal storage system containing phase change material (PCM) under discharging mode.
7.	To calculate the overall efficiency of PCM.

- **Students has to perform all the Experiments.**
- **Any other experiment of the same standard can be added.**

03/09/2024

M.Sc. (RET) Semester-II

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1	II
Course Code	Course Title		Course Type
RET207	SOLAR CONCENTRATOR LABORATORY		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
2			4
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - II)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Assess the performance of the parabolic trough collector with fixed parameters and (i) Water and (ii) Oil as working fluid.	U, E
2	Evaluate the Performance (U_L, F_R, η) of the Parabolic Trough collector with varying solar insolation with (i) Water and (ii) Oil as working fluid.	U, E
3	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector by varying the flow rate of fluid with (i) Water and (ii) Oil as working fluid.	U, E
4	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector for different wind speed with (i) Water and (ii) Oil as working fluid.	U,E, An
5	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector at different ambient temperature with (i) Water and (ii) Oil as working fluid.	U, ,E,An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

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03/09/2024

LO No.	Learning Objectives
1	Understand the concept of overall heat loss coefficient (UL), heat removal factor (FR), and thermal efficiency (η) in parabolic trough collectors.
2	Analyze the optimal flow rate for maximizing collector performance
3	Learn how to assess UL, FR, and η at different ambient temperatures

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	2	2	2	1	2	3	2	2	3	2	1	2	2
CO-2	3	3	3	3	2	2	2	1	2	3	2	2	2	2	1	2	2
CO-3	3	3	3	3	2	2	2	1	2	3	2	2	3	2	1	2	2
CO-4	3	3	3	3	2	2	2	1	2	3	2	2	3	2	2	2	2
CO-5	3	3	3	3	2	2	2	1	2	3	2	2	3	2	2	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

S.NO.	Name of Experiments
1.	Determine the performance (U_L, F_R, η) of the parabolic trough collector with fixed parameters and (i) Water and (ii) Oil as working fluid.
2.	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector with varying solar insolation with (i) Water and (ii) Oil as working fluid.
3.	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector by varying the flow rate of fluid with (i) Water and (ii) Oil as working fluid.
4.	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector with changing insulation thickness with (i) Water and (ii) Oil as working fluid.
5.	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector with different inlet water temperature with (i) Water and (ii) Oil as working fluid.
6.	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector for different wind speed with (i) Water and (ii) Oil as working fluid.
7.	Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector at different ambient temperature with (i) Water and (ii) Oil as working fluid.

- **Students has to perform all the Experiments.**
- **Any other experiment of the same standard can be added.**

03/09/2024

DETAILED SYLLABUS

Semester -III

03/09/2024

M.Sc. (RET) Semester-III

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	III
Course Code	Course Title		Course Type
RET301	WIND ENERGY		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
6	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester -III)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Understand wind energy, atmospheric dynamics, and factors influencing wind at different heights and times.**	R, U,
2	**Analyze wind turbine design, including aero generator classification, rotor dynamics, and safety mechanisms.**	U, An
3	**Understand the methodology and principles of wind energy generation, including theoretical simulation and testing methods.**	R,U
4	**Explore wind energy electricity generation principles for stand-alone, grid-connected, and hybrid WECS applications.**	U, An
5	**Analyze wind energy in India via case studies, exploring supply-demand matching and control options.**	U, An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives

03/09/2024

1	**Explore wind speed monitoring techniques and the use of wind maps for resource assessment.**
2	**Learn about different types of wind electric generators and their components.**
3	**Explore case studies highlighting successful wind energy projects in India**
4	**Understand the factors influencing the cost of wind energy generation**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	2	2	1	1	2	2	1	2	3	3	2	1	2
CO-2	3	3	3	3	2	2	1	1	2	2	1	2	3	3	2	2	2
CO-3	3	3	3	3	2	2	2	2	2	2	1	2	3	3	2	2	2
CO-4	3	3	3	3	2	2	2	2	2	2	2	3	3	3	1	2	2
CO-5	3	3	3	3	2	2	2	2	2	2	2	3	2	3	1	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Introduction to wind energy, Atmospheric circulations, Factors influencing wind: variation with height and time. Classification, Wind shear, Turbulence, Wind speed monitoring and maps. Wind energy conversion principles; Types and classification of wind energy conversion systems (WECS), Power, Torque and speed characteristics, Betz limit.	15
02	Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and combine theory. Rotor characteristics: Solidity, Tip speed ratio, Tip loss correction, Maximum power coefficient; Dynamic matching, Extension of linear momentum theory, Power extraction by a turbine.	15
03	Wind electric generators: Aero generator classification, tower, rotor, gearbox, power regulation, safety mechanisms. Wind turbine design considerations; methodology. Theoretical simulation of wind turbine	15

03/09/2024

	characteristics; test methods.	
04	Wind pumps: Performance analysis, Design concept and standard testing conditions. Principle of wind energy electricity generation; Stand alone, grid connected and hybrid applications of WECS	**15**
05	Wind energy in India; Case studies. Matching supply and demand, Control option, Environmental benefits and problems of wind energy. Economics of wind energy: Factors influencing the cost of energy generation, Life cycle cost analysis.	**15**

Text Books:

1. G. D. RaI, Non-Conventional Energy Sources, Khanna Publications.
2. R K Rajput, A Textbook of Power Plant Engineering, Fourth Edition, Laxmi Publications (P) Ltd.
3. Johnson G L, Wind Energy Systems, Prentice Hall Inc, New Jersey, USA.
4. David A Ed, Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, American Society of Mechanical Engineers.

Reference Books:

1. Paul Gipe, Karen Perez, Wind Energy Basics: A Guide to Small and Micro Wind Systems, Chelsea Green Publishing Company.
2. Kruger P, Alternative Energy Resources: The Quest for Sustainable Energy, Wiley Publications. 5. Rosa Aldo V, Fundamentals of Renewable Energy Processes, Second Edition, Academic Press.
3. Boyle G, Renewable Energy: Power for a Sustainable Future, Second Edition, Oxford University Press.
4. Hau Erich, Wind Turbines: Fundamentals, Technologies, Application and Economics, Springer Verlag

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M.Sc. (RET) Semester-III

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	III
Course Code	Course Title		Course Type
RET302	E-VEHICLES & ENERGY STORAGE		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
6	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - III)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understand different drive train topologies for Battery Electric Vehicles (BEV) & Hybrid Electric Vehicles (HEV), Drive Cycle implications & Fuel Efficiency estimations.	R, U
2	understand the different Electric Motor Drives used in BEV / HEVs and their configurations, optimization, control and applications (Induction motor drives, Permanent magnet motor drives, Switch reluctance motor drives); and Sizing of the propulsion motor.	U, R
3	Understand Energy Storage Technologies used in BEV / HEVs and their characteristics (Batteries, Super capacitors, Flywheels, Fuel cells),ED, based energy storage, for energy storage; and the Selection / Hybridization of energy storage technologies.	R,U
4	Understand the Energy storage, battery-based energy storage and simplified models of battery &Hybridization of various energy storage devices	U, R
5	Understand the Electrical Overlay harness & Communications, the Steering and Braking system, and Energy Management Strategies (EMS).	R,U, An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

03/09/2024

LO No.	Learning Objectives
1	Understand the causes and effects of air pollution and global warming
2	Gain knowledge of the evolution and development of hybrid electric vehicles (HEVs), electric vehicles (EVs), and fuel cell vehicles (FCVs)
3	Understand the basic architecture of hybrid drive trains
4	Gain knowledge of battery-based energy storage systems, fuel cells, super capacitors, and flywheels

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	1	1	1	1	-	2	2	2	3	3	2	2	3
CO-2	3	3	3	3	1	2	1	1	-	2	2	2	3	3	2	2	3
CO-3	3	3	3	3	2	2	2	2	-	2	2	3	3	3	2	2	3
CO-4	3	3	3	3	2	2	3	2	-	2	2	3	3	3	1	2	3
CO-5	3	3	3	3	2	2	3	2	-	2	2	3	2	3	1	2	3

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Air pollution and global warming. Impact of different transportation technologies on environment and energy supply. History of hybrid electric, electric and fuel cell vehicles. Vehicle motion and the dynamic equations for the vehicle. Vehicle power plant and transmission characteristics and vehicle performance including braking performance. Fuel economy characteristics of internal combustion engine.	15
02	Basic architecture of hybrid drive train and analysis series drive train. Analysis of parallel, series parallel and complex drive trains and power flow in each case. Drive cycle implications and fuel efficiency estimations. Sizing of components for different hybrid drive train topologies. Basic concept of electric traction and	15

03/09/2024

	architecture. Topologies for electric drive-train and their analysis. Drive cycle implications and fuel efficiency estimations and well to wheel fuel efficiency analysis.	
03	Sizing of components for different electric drive train topologies. Electric drives used in HEV/EVs, their classifications and general characteristics. DC Motor drives and their principle of operation and performance including multi-quadrant control. Induction motors, their configurations and optimization for HEV/EVs. Induction motor drives, their control and applications in EV/HEVs. Permanent magnet motors, their configurations and optimization & applications in EV/HEVs. Switch reluctance motors, their configurations and optimization. Switch reluctance motor drives, their control and applications in EV/HEVs. Losses in traction motors, inverters and efficiency maps.	**15**
04	Energy storage, battery-based energy storage and simplified models of battery. Fuel cells, their characteristics and simplified models. Super capacitor-based energy storage, its analysis and simplified models. Flywheels and their modeling for energy storage in HEV/BEV. Hybridization of various energy storage devices, its advantages and challenges.	**15**
05	Matching the electric drive and ICE, Transmission selection and gear step selection. Sizing the propulsion motor, its torque, constant power speed ratio and machine dimensions. Sizing the power electronics based on Switch Technology, Switching Frequency and Ripple capacitor design. Selecting the energy storage technology. Electrical overlay harness and communications. Supporting system including steering and braking system. Energy management strategies and its general architecture. Rule and optimization based energy management strategies (EMS). EMS based on deterministic rules & Fuzzy rule base EMS based on Global Optimization. & Real time Optimization Case study of design of a HEV. Case Study of design of a BEV.	**15**

Text Books:

1. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

Reference Books:

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

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M.Sc. (RET) Semester-III

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	III
Course Code	Course Title		Course Type
RET303	MATERIALS SCIENCE FOR SOLAR APPLICATIONS		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
6	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - III)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Develop a foundational understanding of materials science and engineering, including the basic principles and concepts in this field.	R, U
2	Gain knowledge about the properties of different materials, as well as special coatings used in various applications. They will also learn about the practical applications of these materials in the context of solar energy systems.	U, R,Ap
3	Learn testing techniques to evaluate the behavior of materials for suitability in solar energy systems.	R,U
4	Assess and implement strategies to protect materials from corrosion and ensure the durability and longevity of solar system components.	U, R,E
5	Understand the construction and behavior of solar photovoltaic cell, modules, batteries, inverters, charge controller, supporting structures. SPV collector and will be ble to perform Cost analysis and payback calculations of solar panels and collectors.	U,An,E

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

03/09/2024

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Understand the mechanical and electrical properties of ceramics
2	Explore the optical and thermal properties of materials such as concrete and composite materials.
3	Learn the concepts of stress and strain, Hooke's law, tension, compression, and shear.
4	Explore the characteristics of solar photovoltaic cells, modules, batteries, inverters, charge controllers, and supporting structures

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	2	2	2	2	-	1	1	2	2	-	2	3	3	2	1	2
CO-2	3	2	2	2	2	-	1	1	2	2	-	2	3	3	2	2	2
CO-3	3	2	2	2	2	-	2	1	2	2	-	3	3	3	2	2	2
CO-4	3	3	3	3	2	-	3	2	2	2	-	3	3	3	1	2	2
CO-5	3	3	3	3	2	-	3	2	2	2	-	3	2	3	1	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Fundamental Principles of Materials Science Electronic and atomic structures, atomic bonding in solids, crystal structure, microstructure, solidification, alloys. Mechanical and electrical behavior of ceramics. Description of optical and thermal materials of concrete and composite materials. Intrinsic and extrinsic semi-conductors, super conductivity and applications.	15
02	Properties of Materials - Mechanical, photonic, thermal electrical and magnetic properties of metals, alloys, semiconductors, polymers, glass, nanomaterials and magnetic materials. Environmental effects - corrosion, erosion, wind loads, thermal stress and weathering properties of solar	15

03/09/2024

	materials.	
03	Testing of Materials - Concepts of stress and strain, Hooke's law, tension, compression and shear. Stress strain diagram and thermal stresses. Elasticity in metals and polymers, plastic deformation, yield stress, shear strength, strengthening mechanisms, effect of temperature, fracture behavior of various materials, failure analysis, solid solutions and phase diagrams.	**15**
04	Materials for Solar Thermal Systems - Design and development of heat transfer systems - Domestic community and commercial solar thermal applications. Design considerations of solar collectors, special coatings, reflectors, lenses, receivers, tracking and non- tracking concentrator, thermal energy storage, heat exchangers, solar chimney, solar steam generators, solar ponds and solar still, solar dryer and furnace.	**15**
05	Materials for Solar Photovoltaics - Characteristics of solar photovoltaic cell, modules, batteries, inverters, charge controller, supporting structures. Construction of SPV collector, array and fields. Cost analysis and payback calculations of solar panels and collectors.	**15**

Text Books:

1. Ramamrutam .S, "Strength of Materials", 16th edition, DanpatRai Publications, 2010.
2. Callister .W.D, "Materials Science and Engineering", 6th edition, Wiley India, 2009.
3. Sheckel ford J., F. Muralidham M.K., "Introduction to Materials Science for Engineers", 6th edition, Pearson, 2007.

Reference Books:

1. Raghavan .V, "Materials Science and Engineering", Prentice-Hall India, 2007.
2. Askeland .D.R, "Science and Engineering of Materials", 4th edition, Thomson, 2003.
3. Balasubramaniam .R, "Callister's Materials Science and Engineering", Wiley India, 2007

Cathak 03/09/2024

M.Sc. (RET) Semester-III

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	III
Course Code	Course Title		Course Type
RET304	ENERGY ECONOMICS, PLANNING AND POLICIES		Elective
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
6	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - III)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Develop a profound knowledge of energy economics, enabling them to grasp the intricate dynamics of energy markets, pricing, and policies.**	R, U
2	**Develop the skills to conduct economic analyses of energy systems, enabling them to assess the cost-effectiveness and feasibility of different energy projects and initiatives.**	U, R,Ap
3	**Understand the priorities in renewable energy technology development, empowering them to identify and advocate for the most promising and sustainable solutions.**	R,U
4	**Learn to apply the concepts and methods of energy economics specifically to solar energy systems, enabling them to evaluate the economic viability and potential impact of solar energy projects.**	U, R,E
5	Learn about Energy Policy &Security , Energy pricing and impact of Global variations, Energy Productivity-National and sector wise productivity.	U, An,E

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

03/09/2024

LO No.	Learning Objectives
1	**Understand the basics of financial and economic performance in the context of solar energy projects.**
2	**Understand the significance of renewable energy sources for sustainable economic development**
3	**Explore the socio-economic aspects, basic needs, and ethics related to energy management**
4	**Gain insight into global energy issues and their impact on national and state-level energy policies.**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	2	2	2	2	2	1	1	2	2	1	2	3	3	2	1	2
CO-2	3	2	2	2	2	2	1	1	2	2	2	2	3	3	2	2	2
CO-3	3	2	2	2	2	2	2	1	2	2	2	3	3	3	2	2	2
CO-4	3	3	3	3	2	2	3	2	3	2	3	2	3	3	1	2	1
CO-5	2	2	3	3	3	2	3	2	3	2	3	2	2	3	1	2	1

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Financial and Economic Performance - Introduction to financial and economic performance - Merits and limitations for solar energy projects - time value of money, benefits/cost ratios, discount rate, standard and discount payback period, depreciation and net present benefit - Uncertainty over financial incentives-Methods for financing solar energy projects-regulations, legislation, cultural aspects and maintenance issue.	15
02	Economic Analysis - Elements of economic principle, economic calculation. Energy economics-basic concepts, unit cost of power	15

03/09/2024

	generation from different sources, payback period, NPV, IRR and benefit cost analysis. Conventional and solar energy resources and costs. Direct and indirect costs, pricing system and project management.	
03	Energy Technology Development Priorities - Significance of renewable energy sources for sustainable economic development. Economics of solar energy system. Increase in value creation. Funding and sponsoring facilities, international organizations, national possibilities. Incentives, subsidies and feed-in traffic.	**15**
04	Energy Management - Socio-economics, basic needs and ethics. Ecological issues, sustainable energy for future and carbon credit. Energy auditing and management. Conservation of thermal and electrical energy in buildings and various industries.	**15**
05	Energy Policy and Security -Global Energy issues, National and state level energy issues - National and state energy policy, Industrial energy policy, energy security, energy vision. Energy pricing and impact of Global variations. Energy Productivity-National and sector wise productivity.	**15**

Text Books:

1. Subhes C.Bhattacharyya., "Energy Economics", Springer, 2011.
2. Aswath narayana U., "Green energy: Technology, Economics and policy", CRC press, 2010.
3. Russel, C., "Managing energy from the top Down", Fairmount press, 2010.

Reference Books

1. :Danny Harvey L.D., "Energy and the New Reality 2: Carbon-free Energy Supply", Earthscan, 1st edition, 2010.
2. Jacob, "Energy Policy", Nova publisher, 2009.
3. Kreith F., Goswami D.Y., "Energy Management and conservation handbook", Taylor and Francis, 2007.
4. CIPEC., "Energy Saving Toolbox", Natural Resources Canada, 2007.
5. Mallon K., "Renewable Energy Policy and Politics", Earthscan, 2006.

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M.Sc. (RET) Semester-III

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	III
Course Code	Course Title		Course Type
RET305	BIOMASS POWER GENERATION SYSTEMS		Elective
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - III)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Understand the basics of Biomass- Generation and Utilization, Properties of biomass, its application in agriculture, Biochemical and Thermo chemical conversion, combustion, Gasification and can apply these concepts for a suitable site.**	R, U
2	**Perform Biomass resource analysis**	U, Ap
3	**Identify the pre-production process requirements for each type of biomass & can Conduct the tests to identify the moisture content, carbon content and calorific value of the biomass available**	U,An
4	**Analyse the pre-site selection baseline data for project execution suitability , identify location for Power Curve test , collect and analyse the biomass availability data**	U, R,E
5	**Perform Project Evaluation according to relevant applicable policies, regulations and procedures.**	U, An,E

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

03/09/2024

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Understand the properties of biomass and its classification
2	Understand methods to identify the type, quantity, moisture content, carbon content, and calorific value of biomass
3	Analyze pre-site selection baseline data to assess project execution suitability
4	Identify limitations and incentives according to relevant policies, regulations, and procedures

COs-POs/PSOs Mapping for the course:

POs / Cos	POs												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	2	2	2	1	1	1	1	2	2	1	2	3	3	2	2	2
CO-2	3	2	2	2	2	1	1	1	2	2	1	2	3	3	2	2	2
CO-3	3	2	2	2	2	1	2	1	2	2	2	3	3	3	2	2	2
CO-4	3	3	3	3	2	2	3	2	3	2	3	2	3	3	1	2	1
CO-5	2	2	3	3	3	2	3	2	3	2	3	2	2	3	1	2	1

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Biomass- Generation and Utilization, Properties of biomass, Agriculture crop and forestry residues and as fuels, Biochemical and Thermo chemical conversion, combustion, Gasification, Biomass gasifiers and types etc., Biomass as a decentralized power generation source for villages.	15
02	Biomass resource analysis - analyze detailed site information including source of biomass and storage space requirements, if any, Identify the type and quantity of biomass available,	15

03/09/2024

	Conduct the tests to identify the moisture content, carbon content and calorific value of the biomass available.	
03	Identify pre-production process requirements for each type of biomass, Study present market linkages and data on current practices of use or disposal of biomass, Collect information about the local weather conditions such as temperature range, wind speed, humidity, rainfall and seasonal availability of the resource, assess the ground water availability and, load bearing capacities, pH levels, seismic risk and do a detailed risk analysis for fire accidents.	**15**
04	Project Planning & Management : Analyse the pre-site selection baseline data for project execution suitability , identify location for Power Curve test , collect and analysethe biomass availability data	**15**
05	Case Study : Project Evaluation based on at least 10 years data to establish trends, Identify limitations and incentives according to relevant applicable policies, regulations and procedures.	**15**

Text Books:

1. Non-Conventional Energy Resources, B.H. Khan, Tata McGraw-Hill Education (2006).
2. Renewable Energy Technologies: A Practical Guide for Beginners, Chetan Singh Solanki, PHI School Books (2008).

Reference Books:

1. Fundamentals of Renewable Energy Systems Paperback – D. Mukherjee, New Age International Publisher; First edition (2011)
2. Renewable Energy Sources and Emerging Technologies, Kothari D.P. and Singal K.C., New Arrivals - PHI; 2 edition (2011)
3. G. D. Rai, Non- conventional Sources of Energy, Khanna Publishers, Delhi.

03.09.2024

M.Sc. (RET) Semester-III

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	III
Course Code	Course Title		Course Type
RET306	WIND ENERGY LABORATORY		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
2			4
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - III)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Perform the evaluation of Tip Speed ratio (TSR), DC power at different wind speeds& loads	U,E
2	Evaluate the cut-in speed, coefficient of performance of wind turbine experimentally.	E,An
3	Analyse various parameters of wind turbines.	E,An
4	Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with DC load only.	U,E,An
5	Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with AC load only.	U,E,An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E-Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Understand the concept of Tip Speed Ratio (TSR) and its significance in wind turbine performance
2	Learn about the cut-in speed of a wind turbine and its importance in turbine operation
3	Gain practical experience in evaluating the DC power output of a wind turbine for

Cathak 03/09/2024

	various wind speeds
4	**Learn how to analyze power distribution in a wind turbine energy system with both AC and DC loads**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	2	2	2	1	2	3	2	3	3	1	2	2	2
CO-2	3	3	3	3	2	2	2	1	2	3	2	3	2	1	2	2	2
CO-3	3	3	3	3	2	2	2	1	2	3	2	3	3	1	2	2	2
CO-4	3	3	3	3	2	2	2	2	2	3	2	3	2	2	2	2	2
CO-5	3	3	3	3	2	2	2	2	2	3	2	3	2	2	2	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

S.No.	Name of Experiment
1.	To evaluate the Tip Speed ratio (TSR) at different wind speeds
2.	To evaluate the cut-in speed of wind turbine experimentally.
3.	To evaluate the coefficient of performance of wind turbine.
4.	Evaluate the DC power for a given load at different wind speeds.
5.	Draw the turbine Power versus wind speed curve.
6.	Draw the curve between TSR and coefficient of power.
7.	Demonstrate the power analysis at turbine output (for high wind speeds).
8.	Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with AC load only.
9.	Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with DC load only.
10.	Draw the power curve of turbine with respect to the rotational speed of rotor at fixed wind speed.

- **Students has to perform all the Experiments.**
- **Any other experiment of the same standard can be added.**

03/09/2024

M.Sc. (RET) Semester-III

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	III
Course Code	Course Title		Course Type
RET307	RENEWABLE ENERGY LABORATORY		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
2			4
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - III)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	**Evaluate PV losses of 10 W, 20 W and 100 W solar cells at different loads with fixed intensity of light & to Study PWM charge controllers**	U,E
2	**To study the PV losses of 10 W, 20 W and 100 W solar cells at different loads with different intensity of light.**	U,E,An
3	**Analyze the setup for DC-DC & DC-AC Converter with Standalone PV system.**	An
4	**Study the operation of solar based battery charger using solar based single phase power generation module.**	U,An
5	**Study the open loop and close loop control operator of single-phase inverter using solar based single phase power generation module.**	U,An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	**Understand the concept of PV losses in solar cells.**

03/09/2024

2	**Learn about the operation and components of DC-DC converters and DC-AC inverters.**
3	**Gain insight into the design and operation of solar-based battery chargers.**
4	**Learn about Maximum Power Point Tracking (MPPT) techniques in solar charge controllers**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	2	1	1	1	2	3	2	2	3	2	2	1	1
CO-2	3	3	3	3	2	1	2	1	2	3	2	2	2	2	2	2	2
CO-3	3	3	3	3	2	1	2	2	2	3	2	3	3	2	2	2	2
CO-4	3	3	3	3	2	2	2	2	2	3	2	3	2	2	2	2	2
CO-5	3	3	3	3	2	2	2	2	2	3	2	3	2	2	2	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

S.No.	Name of Experiment
1	To study the PV losses of 10 W, 20 W and 100 W solar cells at different loads with fixed intensity of light.
2	To study the PV losses of 10 W, 20 W and 100 W solar cells at different loads with different intensity of light.
3	To analyze the setup for DC-DC & DC-AC Converter with Standalone PV system.
4	To study the operation of solar based battery charger using solar based single phase power generation module.
5	To study the open loop and close loop control operator of single-phase inverter using solar based single phase power generation module.
6	Study of PWM charge controllers using single & series/parallel combination of solar panel.
7	Study of MPPT charge controllers using single & series/parallel combination of solar panel.

- **Students has to perform all the Experiments.**
- **Any other experiment of the same standard can be added.**

03/09/2024

DETAILED SYLLABUS

Semester -IV

03/09/2024

M.Sc. (RET) Semester-IV

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	IV
Course Code	Course Title		Course Type
RET401	ENERGY MODELING AND PRODUCT MANAGEMENT		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
6	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - IV)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Gain a solid understanding of the methods used for modeling and analysing solar thermal and PV systems.	U,E,An
2	Apply these methods to evaluate the performance and efficiency of such systems.	U, Ap
3	Acquire knowledge of mathematical modeling development methods, quantitative techniques, and various numerical methods for solving equations.	An,U
4	Become proficient in using software tools to solve problems related to mathematical modeling and analysis.	U,An,Ap
5	Perform Power system modeling using HOMER software and understand Solar concentrators.	U, An,Ap

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E-Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives

03/09/2024

1	**Understand the concept of proportionality in mathematical modeling**
2	**Learn techniques for fitting mathematical models to empirical data**
3	**Understand the principles of experimental modeling and its application in real-world scenarios**
4	**Gain an understanding of power system modeling using software like HOMER**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	3	3	2	1	2	1	2	2	1	2	3	3	2	1	2
CO-2	3	3	3	3	2	1	2	1	2	2	1	2	3	3	2	1	2
CO-3	3	3	3	3	1	1	2	1	2	2	1	3	3	3	2	1	2
CO-4	3	3	3	3	2	2	3	2	2	2	2	3	3	3	1	2	2
CO-5	3	3	3	3	2	2	3	2	2	2	2	3	2	3	1	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Modeling: Testing for proportionality, Modeling change with difference equations, examples- A saving certificate, mortgaging a home, approximating change with difference equations, examples growth of yeast culture, growth of yeast culture revisited, Solutions to Dynamical systems, examples- A saving certificate revisited, sewage treatment.	15
02	Systems of difference equations, examples- A car rental company, discrete epidemic models, Modeling process- mathematical models, example- vehicular stopping distance, modeling using proportionality, example- kepler's third law.	15

03/09/2024

03	Modeling process- modeling using geometric similarity, example- rain drops from a motionless cloud, automobile gasoline mileage, body weight and height, strength and agility, Model fitting- Fitting models to data graphically, Analytic methods of model fitting, Applying the Least- Squares Criterion, choosing a best model.	**15**
04	Experimental Modeling- Introduction, harvesting in the Chesapeake Bay and other one term models, example harvesting Blue fish and harvesting Blue crabs, Higher order Polynomial models, example- Elapsed time of a tape recorder, Smoothing- Low Polynomial models, example- Elapsed time of a tape recorder revisited.	**15**
05	Power system modeling- HOMER software, Power system modeling. Solar energy: Solar radiation - Review. Models for radiation analysis and beam radiation calculations. Solar concentrators: Parabolic trough, paraboloid dish: continuous type and Fresnel type.	**15**

Text Books:

1. Bender E.A., "Introduction to Mathematical Modeling", Dover Publ., 2000.
2. Meyer W.J., "Concepts of Mathematical Modeling", Dover Publ., 2004.
3. Dym C.L., "Principles of Mathematical Modeling", Elsevier, 2002

03/09/2024

M.Sc. (RET) Semester-IV

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	IV
Course Code	Course Title		Course Type
RET402	SOLAR BUSINESS SOLUTIONS		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - IV)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Assess the market opportunities and evaluate the market trends to decide the strategy for sale of solar lighting solutions	U,E,An
2	Provide consultancy to Customer as per customized requirements .	U,An,Ap
3	Provide broad estimate and give solutions as per client's requirements .	An,U
4	Prepare a proposal with detailed cost benefit analysis for solar lighting solutions to close the deal.	U,An,Ap
5	Perform the Case Study Ground Mounted, Utility Scale & Rooftop Solar PV Plants.	U, An,Ap

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Understand the process of market assessment and trend analysis for smart grids,

03/09/2024

	microgrids, biomass power generation, small-scale wind power plants, solar water pumping systems, and rooftop solar PV businesses
2	**Learn how to identify customer requirements and assess their queries regarding solar lighting solutions**
3	**Develop proficiency in preparing working calculation sheets to estimate the scope and cost of solar lighting solutions**
4	**Learn strategies for maintaining strong customer relationships and fostering repeat business**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	2	2	2	3	2	1	2	3	2	2	3	2	3	3	2	1	2
CO-2	2	2	2	3	2	2	2	3	2	2	3	2	3	3	2	1	2
CO-3	2	3	3	3	1	2	2	3	2	2	3	3	3	3	2	1	2
CO-4	2	3	3	3	2	2	3	3	2	2	3	3	3	3	1	2	2
CO-5	2	3	3	3	2	2	3	3	2	2	3	3	2	3	1	2	2

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	For smart grids and micro grids, biomass power generation systems business, small scale wind power plant business, solar water pumping systems business, rooftop solar PV business- Assess the market and evaluate the market trends to decide the strategy for sale of solar lighting solutions, identify market opportunities and potential customers, Devise strategy to reach potential customer through business promotion techniques, media outreach plan.	15
02	Content for brochures and product catalogues, etc. , identify the customer requirements , clarify the customer queries with respect to solar lighting solutions , assess the area of installation, power output expectation, budget, etc. during discussion with the	15

03/09/2024

	customer.	
03	Create relevant solutions to meet customer requirements, develop the working calculation sheet outlining the broad estimate for the solar lighting solutions.	**15**
04	Prepare the cost benefit analysis for solar lighting solutions, prepare a proposal for solar lighting solutions, prepare a pitch for the customer and close the sale.	**15**
05	Create and manage a pipeline of potential customers. Case Study Ground Mounted, Utility Scale & Rooftop Solar PV Plants.	**15**

Text Books:

1. Development of Solar and Wind Power in Karnataka and Tamil Nadu, Edition by Asian Development Bank
2. The Solar Economy: Renewable Energy for a Sustainable Global Future, Hermann Scheer,
3. Solar Revolution – The Economic Transformation of the Global Energy Industry Travis Bradford, The MIT Press.

Reference Books:

1. The Solar Electricity Handbook: A Simple, Practical Guide to Solar Energy: How to Design and Install Photovoltaic Solar Electric Systems 2017, Michael Boxwell

03/09/2024

M.Sc. (RET) Semester-IV

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	IV
Course Code	Course Title		Course Type
RET403	HYDROGEN ENERGY AND FUEL CELL TECHNOLOGY		Elective
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - IV)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understand the hydrogen fuel production, storage, and applications	U,An
2	Develop an understanding of various fuel cell technologies.	U,An, Ap
3	Become familiar with the principles of operation and key characteristics of each type of fuel cell.	An,U
4	design and develop suitable hydrogen systems to be used in conjunction with fuel cell systems	U,An,Ap
5	Perform application of Fuel Cell Technology as Fuel cell usage for domestic power systems; Large scale power generation; Application of fuel cells in automobiles and space and will be able to perform the Economic and environmental analysis of usage of hydrogen fuel cells	U, An,Ap

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E-Evaluate; C- Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Understand the fundamental properties of hydrogen as an element and its potential as a fuel source.

03/09/2024

2	**Learn about various methods of hydrogen production, including thermal, electrochemical, and biological processes**
3	**Learn about the history, principles, and working mechanisms of fuel cells**
4	**Conduct economic and environmental analyses of hydrogen and fuel cell usage in various sectors.**

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	2	2	3	2	1	2	3	2	3	3	3	3	3	2	1	3
CO-2	3	2	2	3	2	1	2	3	2	3	3	3	3	3	2	1	3
CO-3	3	3	3	3	2	2	2	3	2	3	3	3	3	3	2	2	3
CO-4	3	3	3	3	2	2	3	3	2	3	3	3	3	3	1	2	3
CO-5	3	3	3	3	2	2	3	3	2	3	3	3	2	3	1	2	3

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Introduction of hydrogen as an element; Properties of hydrogen as fuel; Physical and chemical properties of hydrogen gas; Overview of hydrogen energy utilization; Hydrogen sensing methods using Thermal conductivity measurements, Gas chromatography, Mass Spectrometry.	15
02	Methods of Hydrogen Production; Thermal-steam reformation, Gasification, Pyrolysis, Thermo-chemical water splitting, Nuclear thermal catalytic and Partial oxidation methods; Electrochemical-electrolysis, Photo-electro chemical; Biological-anaerobic digestion, Fermentation, Catalysts and electrolysers.	15
03	Hydrogen separation and purification-pressure swing adsorption, solvent based adsorption, membrane separation, cryogenic separation; Hydrogen storage-compressed storage, liquid state storage, solid state storage, different materials for storage-metal	15

03/09/2024

	hydrides, high surface area materials, complex and chemical hydrides; Hydrogen storage system-design and material aspects.	
04	History of Fuel cells; Principle and working of fuel cells; Thermodynamics and kinetics of fuel cell process; Concept of electrochemical potential and Nernst equation; Performance and evaluation of fuel cell; Comparison of battery and fuel cells; Types of fuel cell-AFC, PFAC SOFC, DMFC, PEMFC and Microbial fuel cell, relative merits and demerits.	**15**
05	Application of Fuel Cell Technology; Fuel cell usage for domestic power systems; Large scale power generation; Application of fuel cells in automobiles and space; Economic and environmental analysis of usage of hydrogen and fuel cells; Future trends in fuel cell technology; Hydrogen safety-codes and standards	**15**

Text Books:

1. Sorenson B, Hydrogen and Fuel cells, Elsevier, Academic Press, USA
2. YurumYuda, Hydrogen Energy Systems, NATO ASI Series, London

Reference Books:

1. Baker BS, Hydrogen Fucl cell Technology, Academic Press, New York
2. OHayre R, Cha S, Colella W., Prinz F.B, Fuel Cell Fundamentals, John Willey and Sons, New York
3. Hydrogen and Fuel Cells: A comprehensive Guide Rebecca L, Busby, PennWell Books.

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M.Sc. (RET) Semester-IV

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	IV
Course Code	Course Title		Course Type
RET404	ALTERNATIVE ENERGY SYSTEMS		Elective
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5	5	1	
Maximum Marks	CIA		ESE
100	30		70

Course Outcomes (Semester - IV)

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understand the Small Scale Hydroelectric, Power station and fundamental concepts of Hydroelectric power equations,, micro mini and small hydro, nature of small hydro development	U,An
2	Understand the turbine and its types and analyse the characteristics of various types of turbines. Will be able to assess a small hydro project.	U,An,
3	Get a sound knowledge of Ocean energy; Ocean thermal energy conversion (OTEC) and generation: Basic Principle of OTEC System. Also able to perform the energy and power estimation and understand the working of Wave energy conversion Devices	An,U
4	Understand single tidal basin system, ways of storing electricity produced by tidal energy; site requirements; Advantages and Limitation of tidal power generation	U,An
5	Understand the concept of Geothermal energy, Vapour-dominated systems and Liquid dominated systems.	U, An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

Learning Objectives (LO) :

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LO No.	Learning Objectives
1	Understand the basic concepts of small-scale hydroelectric power generation.
2	Understand the characteristics and selection criteria of various types of turbines used in small hydro projects
3	Gain an introduction to ocean energy and tidal and its potential for power generation
4	Gain an introduction to geothermal energy and its sources

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	2	2	3	2	1	2	3	2	3	3	3	3	3	2	1	3
CO-2	3	2	2	3	2	1	2	3	2	3	3	3	3	3	2	1	3
CO-3	3	3	3	3	2	2	2	3	2	3	3	3	3	3	2	1	3
CO-4	3	3	3	3	2	2	3	3	2	3	3	3	3	3	1	2	3
CO-5	3	3	3	3	2	2	3	3	2	3	3	3	2	3	1	2	3

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	Introduction to Small Scale Hydroelectric, Power Equation, Overview of micro mini and small hydro, small hydral development, nature of small hydro development, classification of small hydro power stations. Water Turbines, Components of a Hydroelectric Scheme, Turbines & Generators for small scale hydroelectric.	15
02	Turbine classification: Reaction Turbines, Tube Turbine, Bulb Turbine, Straflo Turbine. Impulse Turbine: Pelton Turbine, Turgo Turbine, Crossflow Turbine, Characteristics & Selection, Specific Speed, Range of application of various types of turbines for small hydro project, Low head small hydro projects, Advantages and	15

03/09/2024

	Limitations of Small Scale Hydroelectric.	
03	Introduction to ocean energy; Ocean thermal energy conversion (OTEC): Basic Principle of OTEC System; Methods of Ocean Thermal Energy power generation: Open cycle OTEC Systems, Closed or Anderson OTC Cycle and Hybrid Cycle; Heat Exchangers; Bio-Fouling; Site selection and prospects of Ocean Thermal Energy in India. Ocean Wave: Introduction, energy and power estimation; Wave energy conversion Devices: Wave energy conversion by floats and oscillating water columns; Advantages and Disadvantages of ocean wave energy; Problems associated with wave energy collection.	15
04	Energy from tides: Introduction; Basic principle of tidal energy generation: Tidal Range, Spring Tides, Neap Tides; Tidal power plant: introduction and its components; utilization and operation of tidal energy: Single and Double basin arrangement; Estimation of energy and power: in a simple single basin tidal system and in a double cycle system, ways of storing electricity produced by tidal energy; site requirements; Advantages and Limitation of tidal power generation.	15
05	Geothermal Energy: Introduction, nature and division of geothermal fields; Geothermal sources; Hydrothermal (Convective) resources; Vapour-dominated systems and Liquid dominated systems, comparison of flashed steam and total flow concept; Hot Dry Rock (HDR): resources of Petro thermal systems; Geopressured resources; Magma resources; Interconnection of geothermal and fossil fuel systems (Hybrid Systems); Advantages and disadvantages of geothermal energy over other forms of energy; Operational environmental Problem.	15

Text Books::

1. G. D. Rai, Non-Conventional Energy Sources, Khanna Publications.
2. R K Rajput, A Textbook of Power Plant Engineering, Fourth Edition, Laxmi Publications (P) Ltd.
3. Kruger P, Alternative Energy Resources: The Quest for Sustainable Energy, Wiley Publication.

Reference Books:

1Rosa Aldo V, Fundamentals of Renewable Energy Processes, Second Edition, Academic Press.

2.Boyle G, Renewable Energy: Power for a Sustainable Future, Second Edition, Oxford University Press.

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M.Sc. (RET) Semester-IV

Program	Subject	Year	Semester
M.Sc.	Renewable Energy Technology	1I	IV
Course Code	Course Title		Course Type
RET405	RESEARCH PROJECT/ DISSERTATION		Core
Credits	Total No. of Lectures-Tutorials-Practical(in hours per week):		
	L	T	P
5			18
Maximum Marks	CIA		ESE
100	30		70

Learning Objectives (LO) :

LO No	Learning Objectives:
1	The course is designed to facilitate the student to acquire special/advanced knowledge, such as supplement study/support study/ solving /analyzing /exploring a real life situation / difficult problem into a project work. The candidate studies this course on his own with an advisory support by a teacher/faculty member.

Course Outcomes (CO):

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Survey and study of published literature on the assigned topic	U,An
2	Working out a preliminary Approach to the Problem relating to the assigned topic	C,U,E
3	Conducting preliminary Analysis/ Modelling/ Simulation/ Experiment/ Design/ Feasibility	Ap,U,E
4	Preparing a Written Report on the Study conducted for presentation	C,An

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03/09/2024

	to the Department Final Seminar, as oral Presentation before a departmental committee	
5	**Work on innovative projects and future work**	C, Ap,An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C- Create)

COs-POs/PSOs Mapping for the course:

POs / Cos	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	3	3	2	1	3	2	3	2	3	3	3	3	3	2	3	3	3
CO-2	3	2	2	2	3	1	2	3	2	2	3	3	3	2	3	3	3
CO-3	3	3	2	1	2	3	3	3	2	3	3	2	3	2	2	2	3
CO-4	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3

"3"- Strong; "2"- Moderate; "1"- Low; "-" No correlation

Project work & Seminar
• The students are expected to take up a Project under the guidance of a faculty from the institute. • The topic of the project should be justified for the degree of M.Sc. in Renewable Energy technology. • The project selected should ensure the satisfaction of the urgent need to establish a direct link between education, national development and productivities. • Execution and documentation of a project on a specific topic with one of the following aspects: 1. Part of ongoing research projects in the department 2. Developmental work related to industry requirements 3. State of the art new technological studies 4. Theoretical and experimental studies 5. Development of prototypes in the finished product form

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03/09/2024

6. Technical Writing and Project Documentation
7. Presentation and Appreciation.

- Contents:
  1. Identification of research problem
  2. Survey of literature
  3. Formulation of hypothesis, design and methodology
  4. Analysis of data and interpretation of results
  5. Discussion and conclusion
  6. Writing a project report
- The students may be asked to work individually or in a group having not more than THREE students.
- The students/group of students shall collect all necessary information from literature on selected topic/project.
- It should include the scope of project, identification of necessary data, source of data, development of design method and identification, methodology, software analysis.
- The students are expected to submit the report in standard format approved by university.
- Students should deliver a **Seminar** on selected project/topic.
- There will be an external viva-voce at the end of the semester and the students are demonstrate the project at the time of viva-voce.

Note: Project work will involve investigative work and the student will have to do this in the time after their regular theory and practical classes. The final evaluation of the project work will be through a committee involving internal and external examiners. Guidelines provided by University for executing and evaluation of project work will be final.

Activities with direct bearing on Employability/ Entrepreneurship/ Skill development:

It helps to development of skill of presentation and project planning

03/09/2024

Guidelines for preparing the Project Report

I. General Guidelines

- ThereportmustbewritteninEnglishandbewordprocessedonsinglesideofpaper.Then umbers of pages should not exceed 100.
- Every chapter must begin on new page.
- Page numbers are mandatory and should be in Arabic numerals put at the bottom(centre)with all preliminary pages numbered in lower case Roman script.
- Spell checks should be carried out.
- Equations, figures and tables should be numbered as per the chapter number (E.g.Fig.3.1for first figure in chapter 3) and they should be cited in the text in proper and suitable manner.
- Appropriate Caption to each figure and Heading to each table should be provided.
- Maintain uniformity in writing the report.
- Reportsaretobeboundinskybluecoloredhardcoverwithwrittenmaterialsinblackscrip tonthe cover page of the report.

II. Report Format

- Report Title Page(Outer Cover)as per the format given by the department (should be printed in Black color on a blue background)
- Report Title Page(Inner Cover)as per the format given by the department (should be printed in Black on white background)
- Declaration by the students
- Certificate from Supervisor/s
- Certificate from Examiners
- Acknowledgements
- Abstract
- Table of Contents
- List of Tables
- List of Figures
- Chapters
- Appendix
- References

III. Components of the Report

- **Preliminary Pages**
  The preliminary pages must include the title page, the certificates ,acknowledgements, abstract, Table of Contents, List of Tables and List of Figures.

- **Abstract**
  TheAbstractshouldbeacomprehensiverestatementofthedocument'spurpose,scope,met hods, results, conclusions, findings, and recommendations. The length should not exceed one page.

03/09/2024

- **Introduction**
  The introduction provides the students with background information for the project work. Its purpose is to establish a frame work, so that the students can understand how it is related to other area. The Introduction has multiple purposes, namely to create student interest in the topic or the motivation, objectives of the problem that leads to the study, and the contribution made by the students.

- **Literature Review and Theory**
  This should deal with review of the associated theory or the related background of their work .It shares with the students the results of other studies that are closely related to the study being reportedandprovidesaframeworkforestablishingtheimportanceofthestudy.Itcanserveasa benchmark for comparing the results of the study with other findings.

- **Methodology**
  This section specifies the design utilized in the proposed work. It should detail the context of their work,indicatinghowthedesignwasselected,discusstechniquesfordatacollection,andexplainthe underlying rationale for these decisions. It may be useful to discuss the strengths and weaknesses of the chosen design.

- **Results Analysis and Discussions**
  The analysis compares the findings of the study. It may point out similarities and differences, agreements and contradictions, and explanations for these relationships.

- **Conclusions and Future Scope**
  Although this section does not need to belong, the students have an opportunity to tie up loose ends, summarize findings, and draw inferences. Specific recommendations are a good way of concluding the report. The students should recommend possible changes in current practices, suggest new methods or analysis, or propose changes.

IV. Typing of the Project Report

- Type of paper :Executive bond (white)
- Papersize:A4size
- Font: Times new roman
- Font size(chapter title):22bold
- Font size(heading):16bold
- Font size(subheading):14bold
- Font size(body of the text):12 normal
- Font size(footnote):10 normal
- Margins :Normal
- Linespacing:1.5,with space after paragraph
- Text alignment: Justified
- Equation :Right aligned

03/09/2024

Generic Elective Courses

CBCS II Semester

RET501 : Energy, Environment and Climate Change

Learning Objective (LO):

LO No.	Learning Objective
1.	To understand the social, economic impacts, financial aspects of various energy sources.
2.	To make the students aware about conservation act, security of energy and environment.

Course Outcomes (CO):

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Student will able to understanding need of Energy conservation and Energy sources.	U
2	Student will become aware of climate changes and will be able to understand global climate models	U, An

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C-Create)

CO-PO/PSO Mapping for the course:

PO / CO	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	2	2	2	1	-	1	2	1	2	2	2	-	1	2	2	-	-
CO-2	1	2	2	2	-	1	2	1	2	2	2	-	1	2	2	-	-
CO-3	2	2	3	3	-	1	2	1	2	2	2	1	1	2	2	-	-

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03/09/2024

CO-4	1	2	2	2	-	2	3	1	2	2	2	1	1	1	2	-	-
CO-5	1	2	2	2	-	2	3	1	2	2	2	1	1	1	2	-	-

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Detailed Syllabus:

Unit	Topics	No. of Lectures
1	Introduction to Energy: Definition and units of energy and power, Conversion, Energy terms, calorific value, Forms of energy, Classification of energy sources Quality and concentration of energy sources, Energy and Thermodynamics, Energy parameters, Conservation of energy.	12
2	Energy flow diagram to the earth, Origin of fossil fuels, Time scale of fossil fuels, Role of energy in economic development and social transformation, Energy security.	12
3	Beginning of earth and living things; structure of atmosphere; World energy use and current energy scenario; energy and carbon emissions; environmental pollution; climatic conditions.	12
4	Pollution of the environment; natural (volcanoes, forest fires) and anthropogenic (Antarctic ozone hole, global warming). Effects of urbanization, landscape changes, the influence of irrigation, desertification, and deforestation; environmental life cycle assessment (LCA).	12
5	Photosynthetic mechanism and global climate change; various impacts of global warming; prediction of future climate changes; global climate models.	12

Suggested Study material:

Text Books

1. Bani P. Banerjee, Energy and the Environment in India, Oxford University Press, New Delhi.
2. G. D. Rai, Non- conventional Sources of Energy, Khanna Publishers, Delhi.
3. Peter E Hodgson, Energy, the environment and climate change, Imperial College Press, 2010.
4. Richard Wolfson, Energy, environment, and climate, W. W. Norton & Company; 2nd edition, 2011.

03/09/2024

CBCS III Semester

RET502: Non-Conventional Energy Sources

Learning Objective (LO):

LO No.	Learning Objective
1.	To make the student aware of the various important renewable energy resources and the technologies

Course Outcomes (CO):

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Understand the generation of electricity from various Non-Conventional sources of energy.	U,Ap
2	Understand the utilization of solar, wind, ocean energy.	U,Ap
3	Understand the Fundamentals of Geothermal energy	U

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C-Create)

CO-PO/PSO Mapping for the course:

PO / CO	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	2	2	2	-	2	1	2	-	2	2	2	2	2	1	2	-	1
CO-2	2	2	2	-	2	1	2	-	2	2	2	2	2	1	2	-	1
CO-3	2	2	3	-	2	1	2	-	2	2	2	2	2	2	2	-	1
CO-4	2	2	2	-	2	2	3	-	2	2	2	2	2	2	2	-	1
CO-5	2	2	2	-	2	2	3	-	2	2	2	2	2	2	2	-	1

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

03/09/2024

Detailed Syllabus:

Unit	Topics	No. of Lectures
1	Need for Non-conventional energy sources, Types of Non-Conventional energy sources Fuel cells: Definition-Design and Principle of operation	12
2	Advantages and Disadvantages of fuel cells-Applications of Fuel cells. Biomass Energy: Definition-Biomass conversion technologies.	12
3	Solar Energy: Solar radiation and its measurements-Solar energy collectors: Flat Plate and Concentrating Collectors- solar pond - Applications of Solar energy.	12
4	Wind Energy: Nature of wind-Basic components of Wind Energy Conversion System(WECS)-Wind energy collectors: Horizontal and vertical axis rotors- Advantages and Disadvantages of WECS - Applications of wind energy.	12
5	Ocean Energy: Ocean thermal electric conversion (OTEC) methods: Open cycle and Closed cycle- Principles of tidal power generation- Advantages and limitations of tidal power generation. Geothermal Energy: Types of Geothermal resources- Applications of Geothermal Energy.	12

Text Book :

1. G.D. Rai, Non-Conventional Energy Sources ,Khanna Publishers, New Delhi, 2011.
2. 2. B H KHAN, Non-Conventional Energy Resources, McGraw Hill, 2nd Edition, 2009.
3. 3. Ashok Desai V, Non-Conventional Energy, Wiley Eastern Ltd, 1990.
4. 4. Mittal K.M, Non-Conventional Energy Systems, Wheeler Publishing Co. Ltd, 1997.
5. Ramesh R, Kurnar K.U, Renewable Energy Technologies, Narosa Publishing House, New Delhi, 1997.

03/09/2024

Indian Knowledge System

RET701 : Indian Knowledge System : Its Relevance to Renewable Energy Technology

Course Outcomes

CO No.	Expected Course Outcome At the end of the course, the students will be able to:	CL
1	Gain knowledge about Vedic Philosophy, Vedic Vidyapeeth and Non-Vedic Philosophical Systems.	R, U
2	Learn the IKS foundation concept for Science & Technology and Energy Utilization.	R, U
3	Learn about ancient Indian Mathematics, Great Mathematicians and their contributions, Arithmetic Operations, Geometry	U
4	Learn about contribution of Astronomy in Indian Knowledge System	U
5	Learn Importance of Yoga & Psychology for human beings	U

CL: Cognitive Levels (R-Remember; U- Understand; Ap- Apply; An- Analyze; E- Evaluate; C-Create)

Learning Objectives (LO) :

LO No.	Learning Objectives
1	Learn about Indian Knowledge System
2	Learn the basics of Ancient Indian Science, Mathematics and Energy Utilization
3	Study about the Ancient Indian Astronomy
4	Learn and understand the importance of Yoga for health and wellness of ones mind and body

03/09/2024

CO-PO/PSO Mapping for the course:

PO / CO	Pos												PSOs				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
CO-1	-	-	-	-	-	3	3	1	2	2	2	-	-	-	-	-	-
CO-2	1	1	2	2	-	3	3	1	2	2	2	-	2	2	-	-	-
CO-3	3	3	3	3	-	3	3	1	2	2	2	2	2	2	-	-	-
CO-4	1	2	2	2	-	3	3	1	2	2	2	2	1	1	-	-	-
CO-5	-	2	2	2	-	3	3	3	3	3	3	-	-	1	-	-	-

"3":- Strong, "2":- Moderate, "1":-Low, "-":- No Correlation

Unit	Topics	No. of Lectures
01	**Introduction to IKS** Introduction to Vedic Philosophy, Vedic Vidyapeeth, 64 Kalas, Shilpa Shastra, Four Vedas, Vedanga, Indian Philosophical Systems, Vedic Philosophy (Samkhya and Yoga, Nyaya and Vaisesika, Purva-Mimaṃsa and Vedanta), Non-Vedic Philosophical Systems (Carvaka, Buddhist, Jain), Puranas (Maha-puranas, Upa-Puranas and Sthala-Puranas), Itihasa (Ramayana, Mahabharata), Niti Sastras, Subhasitas	12
02	**Foundation concept for Science & Technology and Energy Utilization** Linguistics & Phonetics in Sanskrit Grammar, Role of Sanskrit in Natural Language Processing, Number System and Units of Measurement, concept of zero and its importance, Large numbers & their representation, Place Value of Numerals, Decimal System, Measurements for time, distance and weight. Utilization of different renewable energy sources like fire, wind, water and non-renewable energy sources : Natural gas, coal, wood etc.	12
03	**Indian Mathematics in IKS** Indian Mathematics, Great Mathematicians and their contributions, Arithmetic Operations, Geometry (Sulba Sutras, Aryabhatiya-bhasya), value of π, Trigonometry, Algebra, Chandah Sastra of Pingala	12

03/09/2024

04	**Indian Astronomy in IKS** Indian Astronomy, celestial coordinate system, Elements of the Indian Calendar Aryabhatiya and the Siddhantic Tradition Panchanga – The Indian Calendar System Astronomical Instruments (Yantras) Jantar Mantar or Raja Jai Singh Sawal	12
05	**Humanities & Social Sciences in IKS** Health, Wellness & Psychology, Ayurveda Sleep and Food, Role of water in wellbeing Yoga way of life Indian approach to Psychology, the Triguṇa System Body-Mind-Intellect-Consciousness Complex. Governance, Public Administration & Management reference to ramayana, Artha Sastra, Kauṭilyan State	12

Text Book:

1. Textbook on IKS by Prof. B Mahadevan, IIM Bengaluru.
2. Kapur K and Singh A. K (Eds) 2005). Indian Knowledge Systems, Vol. 1. Indian Institute of Advanced Study, Shimla. Tatvabodh of sankaracharya, Central chinmay mission trust, Mumbai, 1995.
3. Nair, Shantha N. Echoes of Ancient Indian Wisdom. New Delhi: Hindology Books, 2008.
4. SK Das, The education system of Ancient hindus, Gyan publication house, India

Reference Book:

1. BL Gupta,Value and distribution system in india, Gyan publication house, India
2. Gambirananda, Swami, Tr. *Upanishads with the Commentary of Sankarachrya.* Kolkata: Advaita Ashrama publication Department, 2002.
3. Ranganathananda, Swami. *The Massage of the Upanishads.* Bombay: Bharathya Vidya Bhaven, 1985.
4. Om Prakash, Religion and Society in Ancient India, Bhariya Vidhya Prakashan, 1985
5. DK Chakkrabarty, Makkhan Lal, History of Ancient India (Set of 5 Volumes), Aryan book Internation publication, 2014
6. Dr. Girish Nath Jha, Dr. Umesh Kumar Singh and Diwakar Mishra, Science and Technology in Ancient Indian Texts, DK Print World limited,
7. Swami BB Vishnu, Vedic Science and History - Ancient Indian's Contribution to the Modern World, gosai publication, 2015
8. Chatterjee, S.C. The Nyaya Theory of Knowledge. Calcutta: University of Calcutta Press, 1950.
9. Dasgupta, Surendra. A History of Indian Philosophy. Delhi: Motilal Banarsidass, 1991.Vols. III & IV.

03/09/2024