INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

MECHANICALENGINEERING

COURSE DESCRIPTOR

Course Title	SOLAR ENERGY SYSTEMS				
Course Code	AME525				
Programme	B.Tech				
Semester	VI	ME			
Course Type	Professional Elective				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	-
Chief Coordinator	Mr. M. Sunil Kumar, Assistant Professor				
Course Faculty	Mr. M. Sunil Kumar, Assistant Professor				

I. COURSE OVERVIEW:

This course will helps the students to develop an understanding of the physical and technological principles of photovoltaic energy systems. It will address the solar energy resource, and assessment and measurement techniques for the available insolation. The components in a PV system, with a particular focus on the module will be central topic.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AME013	V	Thermal Engineering	3
UG	AAE018	III	Basic Electrical and Electronic Engineering	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Solar Energy Systems	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✔	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✔	Videos
✔	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each unit. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	**Theory**		**Total Marks**
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):
Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video and MOOCs.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering Knowledge**:Capability to apply the knowledge of mathematics, science and engineering in the field of mechanical engineering.	3	Assignments
PO 2	**Problem Analysis:**An ability to analyze complex engineering problems to arrive at relevant conclusion using knowledge of mathematics, science and engineering.	2	Seminars
PO 4	**Design/ Development of solutions:**Competence to design a system, component or process to meet societal needs within realistic constraints.	1	Guest Lectures
PO 6	**Modern tool usage:**An ability to formulate solve complex engineering problem using modern engineering and information Technology tools.	2	Videos

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Professional Skills:** To produce engineering professional capable of synthesizing and analyzing mechanical systems including allied engineering streams.	1	Lecture, Assignments.
PSO 2	**Problem solving skills**: An ability to adopt and integrate current technologies in the design and manufacturing domain to enhance the employability.	-	-
PSO 3	**Successful career and Entrepreneurship**: To build the nation, by imparting technological inputs and managerial skills to become technocrats.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Understand the concept related various laws in solarengineering
II	Outline the basic idea of solar energy collecting as well as energy storagedevices.
III	Development of solar cells and photo voltaiccells.

IX. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AHS010.01	CLO 1	Understand types and applications of various form of energy sources and its environmental impacts.	PO 1	3
AHS010.02	CLO 2	Construct a practical knowledge on various devices of solar PV systems and trying with an assortment of parameters.	PO 1	3
AHS010.03	CLO 3	Generate perception on practice usages of solar PV gadgets/ industrial utilities	PO 1	3
AHS010.04	CLO 4	Explain the various characteristics of the solar cell under local climatic working conditions	PO 2	2
AHS010.05	CLO 5	Visualize the performance of the Solar PV cell under various specified operating temperature ranges and will be able to relate it with nominal values.	PO 2	2
AHS010.06	CLO 6	Explain to clarify impression of various solar thermal energy collectors.	PO 2	2

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AHS010.07	CLO 7	Summarize the basic economics of solar energy collection system.	PO 4	1
AHS010.08	CLO 8	Delineate the other applications and the devices used to collect solar energy.	PO 4	1
AHS010.09	CLO 9	Explain the performance of the solar PV cell under various specified operating temperature ranges and will be able to relate it with nominal values.	PO 2	2
AHS010.10	CLO 10	Understand the concept and the diverse materials used for solar devices	PO 2	2
AHS010.11	CLO 11	Explicate in depth knowledge of about solar cells, thermal energy storage and electrical energy storages	PO 1	3
AHS010.12	CLO 12	Learn the fundamental concepts about solar energy systems and devices	PO 1	3
AHS010.13	CLO 13	Study about approaches for the storage of solar energy along with solar energy collectors	PO 1	3
AHS010.14	CLO 14	Explain the fundamental concepts of solar energy power generating systems and devices	PO 1, PO 2	3
AHS010.15	CLO 15	Analyze various types of energy storage devices and perform the selection based on techno-economic view point.	PO 2	2
AHS010.16	CLO 16	Explore the use of modern engineering tools, software and equipment to prepare for competitive exams, higher studies etc.	PO 2	2

3 = High; 2 = Medium; 1 = Low

X. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1	3												1		
CLO 2	3												1		
CLO 3	3												1		
CLO 4		2													
CLO 5		2													
CLO 6		2													
CLO 7				1											
CLO 8				1											
CLO 9		2											1		
CLO 10		2											1		
CLO 11	3														
CLO 12	3														

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 13	3														
CLO 14	3	2											1		
CLO 15		2													
CLO 16		2													
CLO 17	3	2											1		

3 = High; 2 = Medium; 1 = Low

XI. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO 1, PO 2 PO 4, PO 6	SEE Exams	PO 1, PO 2 PO 4, PO 6	Assignments	PO 1	Seminars	PO 2
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-						

XII. ASSESSMENT METHODOLOGIES-INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XIII. SYLLABUS

UNIT-I	INTRODUCTION TO SOLAR ENERGY
Basics of solar energy, brief history of solar energy utilization, various approaches of utilizing solar energy, blackbody radiation, relation between radiation field energy density and radiation spectrum, Planck's formula in energy unit, maximum spectral density; Planck's formula in wavelength unit, Wiendisplacement law, Stefan-Boltzmann law; Photoelectric effect, Einstein's theory of photons, Einstein's derivation of the black body formula.	
UNIT-II	**ORIGIN OF SOLAR ENERGY,TRACKING SUNLIGHT AND ATMOSPHERIC INTERACTION**
Basic parameters of the sun, measurement of the solar constant, the structure of the Sun, the origin of solar energy, rotation and orbital motion of the earth around the sun; solar time, sidereal time, universal standardtime,localstandardtime,equationoftime,intensityofsunlightonanarbitrarysurfaceatanytime, interaction with the atmosphere, absorption of the molecules, air mass, rayleigh scattering, direct and scatteredsunlight.	
UNIT-III	**SOLAR CELLS, PHOTOVOLTAIC BASICS**
Formation of a p-n junction, space charge and internal field, quasi Fermi levels, the Shockley diode equation, structure of a solar cell , the solar cell equation, fill factor and maximum power, various electron hole pair recombination mechanisms, crystalline silicon solar cells; Thin film solar cells: CIGS, cite and a silicon Tandem solar cells, dye sensitized solar cells, organic solarcells. Structure and working of Solar Cells, types, electrical properties and behavior of Solar cells, cell properties and design, PV cell interconnection and module fabrication, PV modules and arrays, basics of load estimation.	

UNIT-IV	SOLAR ENERGY
Solar radiation at the earth's surface, solar radiation measurements, estimation of average solar radiation, solar thermal flat plate collectors , concentrating collectors, solar thermal application, heating, cooling, desalination, drying, cooking etc, solar thermal electric power plant , principle of photovoltaic conversion of solar energy, types of solar cells; photovoltaic applications: battery charger, domestic lighting, streetlighting, water pumping etc, solar PV power plant, net metering concept.	
UNIT-V	**CONCENTRATION OF SOLAR ENERGY, ENERGY STORAGE**
Three types of imaging optics: trough or linear collectors, central receiver with heliostats, and parabolic dish concentrator with on axis tracking, solar thermal electricity using stirling engine or ranking engine, solar photovoltaic's with concentration; necessity of storage for solar energy, chemical energy storage, thermal energy storage, thermal flywheels, compressed air, rechargeable batteries**.**	
Text Books:	
1. V Duffie, J.A., Beckman, W.A., "Solar Energy Thermal Process", John Wiley and Sons,2007. 2. Jui Sheng Hsieh, "Solar Energy Engineering", Prentice-Hall, 1st Edition,2007. 3. M. Stix, "The Sun, An Introduction", Springer, 2nd Edition,2002. 4. G. D. Rai, "Solar Energy Utilization", Khanna Publishers, 1st Edition,2010. 5. B. G. Streetman, S.Banerjee, " Solid state Electronic Devices", Prentice Hall, 6th Edition,2006. 6. S. P. Sukhatme, "Solar Energy", Tata McGraw-Hill, 1st Edition,1984.	
Reference Books:	
1. C S Solanki, "Solar Photovoltaics–Fundamentals, Technologies and Applications", PHI LearningPvt. Ltd., 2011. 2. Solar Energy International, "Photovoltaics: Design and Installation Manual", Solar Energy International, 1st Edition,2010.	

XIV. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Understand the Basics of solar energy, brief history of solar energy utilization, various approaches of utilizing solar energy.	CLO 1	T1:1.5 R1:2.3
2	Illustrate Black body radiation, relation between radiation field energy density and radiation spectrum, Planck's formula in energy unit,	CLO 2	T1:1.6 R1:2.4
3	Demonstrate Maximum spectral density; Planck's formula in wavelength unit, Wien displacement law, Stefan-Boltzmann law.	CLO 2	T1:1.6 R1:2.6
4-5	Explain photoelectric effect, Einstein's theory of photons, Einstein's derivation of the black body formula.	CLO 4	T1:1.7 R1:4.4
6-7	Summarize origin of solar energy, tracking of sunlight and atmospheric interaction.	CLO 4	T1:1.7.5 R1:4.10
8-9	Explain basic parameters of the sun, measurement of the solar constant.	CLO 7	T1:1.8 R1:4.15
10	Illustrate structure of the sun, the origin of solar energy, rotation and orbital motion of the earth around the sun.	CLO 9	T1:1.9 R1:5.4
11	Define solar time, side real time, universal standardtime,localstandardtime,equationoftime,	CLO 9	T1:2.0 R1:5.8
12-13	Explain intensityofsunlightonanarbitrarysurfaceatany time, interaction with the atmosphere,	CLO 11	T1:2.1 R1:5.8
14	Demonstrate absorption of the molecules, air mass, Rayleigh	CLO 11	T1:2.1

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
	scattering, direct and scattered sunlight.		R1:6.13
15-16	Define solar cells, photovoltaic basics formation of a p-n junction, space charge and internal field, quasi Fermi levels, the Shockley diode equation, structure of a solar cell.	CLO 13	T1:2.4 R1:7
17	Explain fill factor and maximum power, various electron hole pair recombination mechanisms.	CLO 11	T1:4.10 R1:7.5
18	Demonstrate crystalline silicon solar cells; Thin film solar cells: CIGS, cite and a silicon Tandem solar cells.	CLO 9	T1:4.11 R1:8.1
19	Explain dye sensitized solar cells, organic solarcells.	CLO 10	T1:8.1
20	Illustrate structure and working of Solar Cells, types,	CLO 10	T1:8.1
21	Explain electrical properties and behavior of Solar cells, cell properties and design, PV cell interconnection and module fabrication.	CLO 10	T1:7.1 R1:7.9
22-23	Explain photo voltaic modules and arrays, basics of load estimation.	CLO 11	T1:8.1 R1:9.10
24-25	Summarize solar radiation at the earth's surface, solar radiation measurements, estimation of average solar radiation	CLO 12	T2:7.5 R1:10.2
26	Explain solar thermal flat plate collectors, concentrating collectors, solar thermal application.	CLO 11	T2:6.7 R1:11.3
27	Demonstrate the process of heating, cooling, desalination, drying, cooking etc.	CLO 12	T2:2.8 R1:11.6
28-30	Explain solar thermal electric power plant, principle of photovoltaic conversion of solar energy, types of solar cells.	CLO 11	T2:6.12 R1:11.7
31-32	Demonstrate types of solar cells; photovoltaic applications.	CLO 12	T2:6.12 R1:11.8
33-34	Explain battery charger, domestic lighting, streetlighting, water pumping etc, solar PV power plant, net metering concepts.	CLO 15	T2:6.12 R1:11.9
35-36	Illustrate concentration of solar energy, energy storage	CLO 14	T2:6.12 R1:11.10
37-38	Explain three types of imaging optics: trough or linear collectors.	CLO 15	T2:6.14 R1:12.3
39	Explain solar thermal electricity using stirling engine	CLO 14	T2:6.1 R1:12.7
40-41	Explain Rankine engine, solar photovoltaic's with concentration.	CLO 15	T2:6.17 R1:12.15
42	Explain Rankine engine, solar photovoltaic's with concentration.	CLO 14	T2:6.18 R1:12.19
43-44	Understand necessity of storage for solar energy	CLO 15	T2:7.19 R2:7.4
45	Understand necessity of storage for solar energy	CLO 14	T2:7.19 R2:7.5
46	Understand necessity of storage for solar energy	CLO 15	T2:7.19 R2:7.5
47	Explain chemical energy storage	CLO 14	T2:7.19 R2:7.5
48	Explain thermal energy storage.	CLO 15	T2:6.18 R1:12.19
49	Explain thermal flywheels, compressed air.	CLO 14	T2:7.19 R2:7.4
50	Summarize of rechargeable batteries**.**	CLO 15	T2:7.19 R2:7.5

XV. GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	Proposed actions	Relevance with PO's	Relevance with PSO's
1	Design and development of solar Photovoltaic panels	Seminars	PO 1, PO 4	PSO 1
2	Summarize the estimation of solar radiation	Seminars/ NPTEL	PO 4	PSO 1
3	Development of storage batteries.	NPTEL	PO 2, PO 6	PSO 1

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