INTRODUCTION TO SOLAR AND WIND TECHNOLOGY
(CHEN 4222)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The SI unit of Stefan-Boltzmann constant in the Stefan-Boltzmann radiation heat transfer law
(a) $Wm^{-1}K^{-4}$ (b) $Wm^{-2}K^{4}$ (c) $Wm^{-1}K^{4}$ (d) $Wm^{-2}K^{-4}$

(ii) What combination of surface characteristics is required for solar collectors?
(a) High absorptivity and low emissivity
(b) Low absorptivity and high emissivity
(c) Low absorptivity and low emissivity
(d) High absorptivity and high emissivity

(iii) Flat absorber plate of solar thermal collector is made up with
(a) toughened glass (b) fibre glass
(c) thermosetting plastic (d) aluminium

(iv) Which of the following is generally used as circulating fluid for solar collector in freezing climates?
(a) A mixture of ethylene glycol and water (b) Water
(c) Liquid nitrogen (d) Liquid carbon dioxide

(v) A typical output of a solar cell is
(a) 0.13V (b) 0.26V (c) 0.40V (d) 0.50V

(vi) If B is the number of blades, C the chord line, r the radial distance, local solidity ratio is given by
(a) $\frac{B \times C}{2\pi r}$ (b) $\frac{B}{C \times 2\pi r}$ (c) $B \times C$ (d) $\frac{2\pi r}{B \times C}$

(vii) The tip speed ratio is the ratio of
(a) Power developed to rotor torque
(b) Power coefficient to torque coefficient
(c) Torque coefficient to power coefficient
(d) Square of power coefficient to square of torque coefficient

(viii) The performance characteristic of a wind rotor is given by
(a) Power coefficient versus torque coefficient curve
(b) Power coefficient versus tip speed ratio curve
(c) Power generated versus tip speed ratio curve
(d) Power versus torque curve

(ix) The expression for maximum power generated in a horizontal axis wind turbine computed from axial momentum theory is
(a) $\frac{1}{2}\rho_a A_T v^3 \frac{16}{27}$ (b) $\frac{1}{2}\rho_a A_T v^3$ (c) $\frac{1}{2}\rho_a A_T v^3 \frac{4}{9}$ (d) $\frac{1}{2}\rho_a A_T v^2 \frac{16}{27}$

(x) Hour angle of a location at solar time 11:30 am is
(a) 7.5° (b) -7.5° (c) 15° (d) -15°

Fill in the blanks with the correct word

(xi) Declination angle of earth on 23rd September is _____.

(xii) Series and parallel combination of the solar cell is known as _____.

(xiii) The ratio of wind velocities at two different elevations Z_R and Z when Z_0 is the roughness height is given as_____.

(xiv) Piston pumps show poor performance at _____.

(xv) Wind firms in coastal areas are known as_____.

Group - B

2. (a) State and explain the following laws relating thermal radiation and temperature of a radiating body: Plank's distribution law; Stefan Boltzman law and Wien's displacement law. *[(CO1)(Understand/LOCQ)]*

(b) Define Solar Constant. Assuming the Sun is a black body of temperature 5760 K determine the solar constant at Mars with the help of the following given data. Diameter of sun = 1.39×10^9 m, Average distance between Sun and Mars = 2.15×10^{11} m. *[(CO1)(Apply/IOCQ)]*

6 + 6 = 12

3. (a) What is declination angle? Why solar time and standard time of a place are different? *[(CO1)(Understand/LOCQ)]*

(b) Derive an expression to determine the zenith angle of sun at any given location on earth at any instant of day time from the expression of angle of incidence on a horizontal surface. Using the expression determine the zenith angle of sun on Kolkata (latitude 22.57°) on the 1st April at 10 A.M solar time. *[(CO1)(Evaluate/HOCQ)]*

(2 + 2) + (5 + 3) = 12

Group - C

4. (a) Starting from the expression of instantaneous extraterrestrial solar radiation on a horizontal surface derive an expression to determine monthly average daily

extraterrestrial radiation on a horizontal surface. Determine monthly average daily extraterrestrial radiation on a horizontal surface received on Kolkata (latitude 22.57°) for the month of April. Given that, 15th April is the recommended monthly mean day with a mean declination angle of 9.4°.

[(CO2)(Evaluate/HOCQ)]

(b) What are the major components of a flat plate solar collector? Discuss with a schematic diagram showing all the major components of a double glazed flat plate collectors. *[(CO2)(Remember/LOCQ)]*

(4 + 2) + (2 + 4) = 12

5. (a) Define the following in relation to solar PV system: Fill factor, Maximum power point, Efficiency. *[(CO2)(Understand/LOCQ)]*

(b) A single solar cell on illumination by insolation of about 800 W/m^2 produces a voltage of 0.5 V and a current upto 2.0 A. The efficiency of the solar cell is 12%. Calculate the area of the solar cell. *[(CO2)(Apply/IOCQ)]*

6 + 6 = 12

Group - D

6. (a) Design the rotor for an aero generator to develop 100 W at a wind speed of 7 m/s. Given: The design power coefficient is 0.4 and the combined drive train and generator efficiency is 0.9, air density is 1.224 kg/m3. Consider a three bladed rotor with a design tip speed ratio of 5and the angle of attack is 4° and the corresponding design lift coefficient is 0.8. The total blade length is divided into 9 sections from 0.2 times rotor radius to the rotor radius at intervals of 6.5 cm. Compute the chord and blade setting angles at each sectional radius.

[(CO3)(Evaluate/HOCQ)]

(b) Discuss the method of estimating wind velocity using Griggs Putnam index with illustration of the rating scale. *[(CO3)(Analyze/IOCQ)]*

(c) The wind velocity measured at 10 m height at a meteorological observatory is 10 m/s. Find out the velocity at 40 m height at a wind turbine site having similar wind profile. The roughness heights at the observatory and wind turbine location are 0.03 and 0.1 m respectively. *[(CO3)(Apply/HOCQ)]*

6 + 3 + 3 = 12

7. (a) A wind turbine model of 1 m diameter was tested in a wind tunnel. Test results are provided in the Table. Plot the power coefficient versus tip speed ratio profiles for the rotor. *[(CO4)(Evaluate/HOCQ)]*

4 m/s		6 m/s		8 m/s	
Rotor speed (r/min)	Power (W)	Rotor speed (r/min)	Power (W)	Rotor speed (r/min)	Power (W)
306	12.3	482	42.55	673	104.54
352	13.37	550	45.66	764	109.46
397	13.68	619	47.73	856	113.15
443	14.33	688	48.46	948	110.69
489	13.53	757	44.62	1039	100.85
535	11.99	768	43.58	1055	98.39

(b) Consider a wind turbine with 5 m diameter rotor. Speed of the rotor at 10 m/s wind velocity is 130 rad/min and its power coefficient at this point is 0.3. Calculate the tip speed ratio and torque coefficient of the turbine. What will be the torque available at the rotor shaft? Assume density of air is 1.24 kg/m^3 *[(CO4)(Apply/HOCQ)]*

(c) Experiments are conducted in a wind tunnel with wind speed of 50 km/h on a flat plate of size 2 m long and 1 m wide. Density of air is 1.24 kg/m3. The plate is kept at an angle such that the drag and lift coefficients are 0.75 and 0.15 respectively. Determine the lift force, drag force, resultant force and power exerted by the air stream on the plate. *[(CO4)(Analyze/IOCQ)]*

(3 + 2) + 4 + 3 = 12

Group - E

8. (a) Discuss the different types of generators in a wind energy conversion system *[(CO4)(Remember/LOCQ)]*

(b) A centrifugal pump has specific speed of 0.095, specific diameter 5.5 and peak efficiency 65%. The pump is coupled with a 5 m wind rotor with maximum power coefficient 0.4 at a tip speed ratio 2. If the pumping head is 5 m, find the gearing required between the wind rotor and pump. Calculate the size of the pump for optimum matching. *[(CO3)(Analyse/IOCQ)]*

(c) Discuss the limitations of a wind piston pump. *[(CO4)(Understand/LOCQ)]*

6 + 3 + 3 = 12

9. (a) Specifications of a wind electric pump are given below. Generate the performance of the pump at different wind velocities (mm graph required)

Table Specifications of wind electric pump

Rated power	1400 W
Cut-in wind speed	3 m/s
Rated wind speed	10 m/s
Cut-out wind speed	15 m/s
Efficiency (pump+ power conversion)	0.52
Pumping head	5 m
Velocity power proportionality	2

[(CO4) (Evaluate/HOCQ)]

(b) List the different components of a wind turbine. *[(CO4)(Understand/LOCQ)]*

(c) Distinguish between fixed and variable speed wind turbines. *[(CO2)(Apply/IOCQ)]*

(4 + 2) + 2 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	34.38	26.04	39.58

Course Outcome (CO):

After completing this course students will be able to:

1. Understand different technologies used for solar collectors.
2. Students will be able to evaluate the performance and efficiency of different devices that extract power from solar energy.
3. Students will be able to understand the main components of wind energy system and its functions.
4. Understand the different types of wind turbines.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*