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) If the temperature of a hot body is increased by 50%, the amount of radiation by it would increase by nearly
(a) 50% (b) 100% (c) 200% (d) 400%

(ii) If azimuthal angle of a surface is 45°, then orientation the surface would be
(a) South-east (b) South-west (c) North-east (d) North-west

(iii) 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

(iv) Which of the following is generally used as circulating fluid for solar thermal collector in tropical and sub-tropical climates?
(a) A mixture of ethylene glycol and water
(b) Water
(c) A mixture of propylene glycol and water
(d) Glycerol

(v) Which collector gives the maximum efficiency?
(a) Flat plate (b) Line focussing
(c) Paraboloid dish (d) Evacuated tube.

(vi) Magnitude of geostrophic wind is given by _____, where 'f' is the coriolis parameter, 'ρ' is the density of air, '$\frac{\partial p}{\partial n}$' is the pressure gradient normal to the streamline.
(a) $\frac{\rho}{f}\frac{\partial p}{\partial n}$ (b) $\frac{1}{\rho f}\frac{\partial p}{\partial n}$ (c) $-\frac{\rho}{f}\frac{\partial p}{\partial n}$ (d) $-\frac{1}{\rho f}\frac{\partial p}{\partial n}$

(vii) Average wind power density on hourly basis is considered good if it is _____.
(a) equal to 100 Wm^{-2} (b) more or equal to 400 Wm^{-2}
(c) in between 100 and 300 Wm^{-2} (d) more than 700 Wm^{-2}

(viii) For low angle of attack (α) at a thin airfoil the lift coefficient is given by _____.
(a) 4πα (b) 2πα
(c) 4π (d) 2π

(ix) The cost of wind power is given by _____ (symbols have their usual meaning).

(a) $\frac{C_I}{8760n}\left(\frac{1}{P_R C_F}\right)\left\{1+m\frac{(1+I)^n-1}{I(1+I)^n}\right\}$ (b) $\frac{C_I}{8760n}\left(\frac{m}{P_R C_F}\right)\left\{1+\frac{(1+I)^n-1}{I(1+I)^n}\right\}$

(c) $\frac{C_I}{8760n}\left(\frac{1}{P_R C_F}\right)\left\{1+m\frac{(1+I)^n-1}{(1+I)^n}\right\}$ (d) $\frac{C_I}{8760n}\left(\frac{m}{P_R C_F}\right)\left\{1+\frac{(1+I)^n-1}{(1+I)^n}\right\}$

(x) Safety brakes used in wind turbine are _____.
(a) mechanical brakes (b) aerodynamic brakes
(c) hydraulic brakes (d) all of the above

Fill in the blanks with the correct word

(xi) A black surface has emissivity equal to _____.

(xii) _____ is used to measure solar radiation flux.

(xiii) _____ is the algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions.

(xiv) The value of relative wind velocity at a wind velocity of 10 m/s _____, given axial induction factor 0.33; angle of attack 10^o; blade pitch angle 5^o.

(xv) Commercial wind turbines have blade made up of _____.

Group - B

2. (a) Derive an expression to calculate the radiation heat transfer between two flat surface with different emissivity at different equilibrium temperature.
[(CO1)(Analyse/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) Why standard time is different from solar time of a place on earth. Determine the solar time of Kolkata (latitude 22.57°N, longitude 88.4° E) while the Indian standard time is 12 noon on the day of your exam. Given that the Indian Standard time is based on longitude 82.5°E. Take the time correction factor *E = 9.87 sin2B - 7.53 cosB -1.5 sinB;* where B = 0.989×(n-81) and *n* is the day of the year.
[(CO1)(Evaluate/HOCQ)]

(b) Determine the sunset hour angle of Kolkata (latitude 22.57°N, longitude 88.4° E) on 23rd March, 2025. *[(CO1)(Apply/IOCQ)]*

(3 + 5) + 4 = 12

Group - C

4. (a) 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)(Analyse/IOCQ)]*

(b) Classify the solar cell based on the materials they made of. Solar insolation of a rectangular module (1.5 m × 2.0 m) of photovoltaic cell is 550 W/m^2. If the efficiency of the solar cell is 15% what is the power output of the module. *[(CO2)(Apply/IOCQ)]*

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

5. (a) How characteristic resistance of a solar cell is measured? Why series resistance and shunt resistance are to be included in the solar cell representation. How they affect the power generated by the solar cell? *[(CO3)(Analyse/HOCQ)]*

(b) What is tilt factor of Beam radiation? Determine the tilt factor for beam radiation of a south facing solar module at Kolkata (latitude 22.57°N, longitude 88.4° E) with an angle inclination 15° on 21st June, at 12 noon solar time. *[(CO1)(Evaluate/LOCQ)]*

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

Group - D

6. (a) What is meant by NACA3355 nomenclature for an airfoil? Calculate the maximum section thickness and leading edge distance from maximum camber for the 2D NACA3355 airfoil. *[(CO3)(Remember/LOCQ, Analyse/HOCQ)]*

(b) Show three types of airfoils – symmetrical, cambered and reflex cambered after drawing a neat sketch for each one. *[(CO3)(Remember/LOCQ)]*

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

7. (a) What will be the power outcome from a wind turbine when the wind velocity is 10 m/s with 7 m long blade fixed on rotor of diameter 4 m? The speed of the rotor is 180 rpm. Given: Power coefficient = 0.3 and the efficiency is equal to - $0.078369\lambda^2 + 0.92146\lambda - 2.3532$, where λ is the tip speed ratio. *[(CO3)(Analyse/HOCQ)]*

(b) Show that according to momentum theory the maximum thrust coefficient is equal to 1.0 when the angular induction factor is equal to '0'. *[(CO3)(Apply/IOCQ)]*

(c) Define drag force and lift force. *[(CO3)(Remember/LOCQ)]*

6 + 4 + 2 = 12

Group - E

8. (a) What are the basic four steps on which induction generator works? Elaborate. *[(CO4)(Remember/LOCQ)]*

(b) For an induction generator a 6 pole machine is connected with an AC three phase 50 Hz grid. What will be the rotor speed to be generated in order to generate electricity? Consider there is 1% slip and no frictional losses. *[(CO4)(Apply/IOCQ)]*

8 + 4 = 12

9. (a) A 3 MW wind farm is planned in a square area of 2 km x 2 km. Around the land there are roadways and is instructed to leave 0.5 km from the roadways. Calculate the total number of installation rows. Given: Rated power 550 kW, Hub height = 40 m, Rotor radius = 40 m. *[(CO4)(Analyse/HOCQ)]*

(b) A centrifugal pump has specific speed of 0.095, specific diameter 5.5 and the peak efficiency 65 per cent. The pump is coupled with a 5 m wind rotor with maximum power coefficient of 0.4 at a tip speed ratio 2. If the pumping head is 5 m, find out the gearing required between the wind rotor and pump. Also calculate the size of the pump for optimum matching. Given: Density of water: 1000 kgm^{-3}; Density of air: 1.24 kgm^{-3}; Design wind velocity of wind: 7 m/s. *[(CO4)(Analyse/HOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	32.29	31.25	36.46