Central Institute of Technology Kokrajhar
End Semester Examination 2023
Solar Energy Conversion System (PGET 1105)

Full Marks: 100

Time: Three hours

The figures in the margin indicate full marks for the questions.

Answer all the questions

1. Choose the correct answer [1x 6 =6]

a) The most important criteria for selecting sensible heat storage is
   i) Volume of the material
   ii) Volumetric heat capacity of the material
   iii) Heat of fusion of the material
   iv) Melting and solidification temperature of the material

b) The amount of energy stored in the case of a latent heat storage system depends on
   i) Mass and specific heat of the material
   ii) Mass, temperature difference and specific heat of the material
   iii) Mass, temperature difference and latent heat of fusion
   iv) Mass and latent heat of fusion

c) In the case of thermochemical storage, thermal energy storage is done by
   i) Endothermic reaction of different reactants
   ii) Exothermic reaction of different reactants
   iii) Either endothermic or exothermic reaction based on the materials
   iv) Exothermic breakage reaction of products

d) Match the following

CSP Technology	Operating temperature range (°C)
1. Parabolic trough collector (PTC)	a. 50–300
2. Solar Power Tower (SPT)	b. 20–400
3. Linear Fresnel Reflector (LFR)	c. 120–1500
4. Parabolic Dish (PD)	d. 300–565

   i) 1-b, 2-d, 3-a, 4-c
   ii) 1-c, 2-b, 3-a, 4-d
   iii) 1-c, 2-b, 3-d, 4-a
   iv) None of the above

e) Which one of the following is not a solar radiation measuring instruments ?
   i) Pyrometer
   ii) Anemometer
   iii) Pyrheliometer

f) Silicon p-type is doped with some
   i) Trivalent atoms
   ii) Pentavalent atoms
   iii) None of these

2. Answer in short ***any ten*** of the following questions [2 x 10 =20]
   a) What are the beam and diffuse radiations?
   b) Define the latitude and declination of a location.
   c) With diagrams explain the distinction between yearly and diurnal energy storage.
   d) What is the difference between a solar air heater and a liquid flat plate collector?
   e) Explain about the construction of solar air heater.
   f) Why is a tracking device necessary for a solar concentrator?
   g) What is the maximum temperature that a solar concentrator can achieve? Why is the temperature reaching such a high level?
   h) What is the purpose of heliostat?
   i) Write the expression for 'energy of a photon'.
   j) What do you by doping in a semi-conductor?
   k) Explain with the line diagram the stand-alone solar system with battery storage and a DC load.

3. Answer briefly ***any ten*** of the following questions. [3 x 10 = 30]
   a) Define the term 'solar radiation' ? State Stefan-Boltzmann's law of radiation.
   b) What do you mean by 'emissivity'? Derive the relation between absorptivity, reflectivity and transmissivity.
   c) Explain the mechanism of absorption and scattering (i.e., depletion) of solar radiation briefly as it passes through the atmosphere to reach the earth's surface with a schematic diagram.
   d) Explain the construction of a two-pass solar air heater with matrix along with a proper diagram.
   e) Describe how the parabolic dish system functions when it is coupled to a Stirling engine.
   f) Justify the need for energy storage in solar applications.
   g) How can solar air heater can be used for space heating in buildings?
   h) Define the following
      i) Acceptance angle for solar concentrating collector
      ii) Geometrical concentration ratio for concentrating collector
      iii) Storage capacity of an energy storage system
   i) Derive the expression for stability criteria of concentration of a solar pond.
   j) What are the solar cell, solar module, and solar array?
   k) Write short notes on solar pond.

4. Answer ***any three*** of the following questions. [4 x 3=12]
   a) Compare solar flat plate collector and solar concentrating collector.
   b) Draw the diagram for single single-axis and two-axis tracking concentrating collector.
   c) Explain briefly the different zones of a solar pond with diagram.
   d) Explain briefly a stand-alone solar system with battery storage and supplying an AC load

5. Solve the following. [3 x 4=12]
   a) An opaque horizontal plate is well insulated on the edges and the lower surface. The irradiation on the plate is 2500 W/m^2, of which 800 W/m^2 is reflected. The plate has a uniform temperature of 700 K and has an emissive power of 9000 W/m^2. Determine the total emissivity and absorptivity of the plate.
   b) Calculate the concentration ratio for a two-dimensional geometry if the acceptance angle is 40^o and compare the result with that of a three-dimensional geometry.
   c) Calculate the rate of useful heat gain from the concentrating collector.
      Overall loss coefficient = 6.12 W/m^{2}K
      Ambient temperature = 31.9°C

Absorbed solar flux = 486.03 W/m^2

The average temperature of the absorber plate = 441.3 K

Concentration ratio = 8.5

Absorber area of the collector = 15.32 m^2

d) Sodium chloride is used as the salt in a solar pond. Estimate the minimum concentration (kg of salt per kg of water) required at the bottom if the concentration at the top is 0.02 and a temperature difference of 65°C is to be maintained. Assume that the concentration and temperature profiles are straight lines and take the average values of to be - 0.5kg/m^3 °C and 650 kg/m^3 respectively.

6. Solve the following. [4 x 3=12]

a) With the following assumptions and given data, calculate the maximum possible conversion efficiency obtainable with the solar chimney. Also, estimate the efficiency of the plant as a whole and the daily electrical output in a typical summer month (6.5 kWh/m^2).

Given data: height of the chimney, H=300 m, Solar collection area: 50000 m^2, C_p = 1005 J/kg-K, Ta = 305 K, the turbine-generator set converts only 50% out of the maximum available energy into electrical energy, the collection efficiency of the solar collector: 25%

b) Calculate the concentration ratio of a parabolic trough collector having an aperture of 32.25 m and a length of 3.65 m. The absorber tube has an inner and outer diameter of 3.8 and 4.2 cm, respectively. If ground-reflected radiation is neglected, calculate the instantaneous collector efficiency of the above collector if I_b= 705 W/m^2, r_d=0.9, r_b=1.01, and useful heat gain rate is 6894.8 W.

c) Calculate the number of daylight hours (sunshine hours) in Guwahati on January 2nd and July 2nd. The latitude of Guwahati is 26.15° N.

7. Calculate the angle (θ) made by the beam radiation with the normal to a flat-plate collector on May 1 at 0900 h (LAT). The collector is located at New Delhi (28°35′ N, 77°12′E). It is tilted at an angle of 36° with the horizontal and is pointing due south. Hints. Use the following Eq. [8]

$$\cos\theta = \sin\delta\sin(\phi-\beta) + \cos\delta\cos\omega\cos(\phi-\beta)$$

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