**Name:**

**Enrolment No:**

# UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

## End Semester Examination, December 2019

**Programme Name: B.Tech – Mechanical, ME- spz-MD and THE** **Semester : VII**
**Course Name : Solar Thermal Technologies** **Time : 03 hrs**
**Course Code : MHEG 456** **Max. Marks : 100**
**Nos. of page(s) : 04**
**Instructions: Assume the suitable data if required**

### SECTION A

| S. No. | | **Marks** | **CO** |
|---|---|---|---|
| Q 1 | Explain a solar air heating system using different collector configurations along with their advantages and disadvantages. | **5** | **CO3** |
| Q 2 | Explain beam solar radiation and diffuse solar radiation. | **5** | **CO1** |
| Q 3 | Explain the following terms.<br>(a) The latitude and longitude<br>(b) The hour angles<br>(c) sun declination angle | **5** | **CO1** |
| Q 4 | Calculate the hour angle at sunrise and sunset on June 21 and December 21 for a sunrise is located at an angle of $10^o$ and facing due south. The surface is located in Mumbai ($19^o$07'N, $72^o$51'E). | **5** | **CO2** |

### SECTION B

| | | | |
|---|---|---|---|
| Q 5 | A concentrating collector is located in Pune ($18.53^o$ N) and operates in tracking mode II on May 1st. Calculate the values of the slope of the aperture plane from 9:00 to 13:00 h (solar time) at hourly intervals and the corresponding angle of incidence. | **10** | **CO2** |
| Q 6 | Explain the different energy storage methods used in the solar thermal systems. | **10** | **CO4** |
| Q 7 | Explain flat plate and concentrating solar energy collectors. What is tracking of the concentrator? | **10** | **CO3** |
| Q 8 | Calculate the length and direction of the shadow cast on the ground by a 1 m long vertical stick for the following situation<br>Location : Bombay ($19^o$07'N, $72^o$51')<br>Date : February 13th<br>Time : 10:00 AM (solar time)<br>**(OR)**<br>A horizontal stick, 1 m long, is fixed at right angles to a vertical south facing wall. Calculate the length and direction of the shadow cast by the stick on the wall for the following situation.<br>Location : Jodhpur (26o18,N', 73o01'E)<br>Date : November 5<br>Time : 9:00 h (Solar time) | **10** | **CO2** |

| SECTION-C | | | |
|---|---|---|---|
| Q 9 | Explain the working of solar vapor absorption with neat sketch. Write the advantages of solar power refrigeration system over vapor compression refrigeration system | **20** | **CO5** |
| Q 10 | Calculate the overall heat loss coefficient for cylindrical parabolic collector with the following data<br>Absorber tube outer diameter : 6.5 cm<br>Absorber tube inner diameter : 6.0 cm<br>Glass cover outer diameter : 15.8 cm<br>Glass cover inner diameter : 15.0 cm<br>Length of concentrator : 3.5 m<br>Emissivity/Absorptivity of glass cover : 0.88<br>Emissivity of absorber tube surface : 0.22<br>Ambient temperature : 20°C<br>Wind velocity : 1.5 m/s<br>Average absorber tube temperature : 200°C<br><br>**(OR)**<br><br>A CPC is mounted on a horizontal E - W axis and oriented with its aperture plane sloping at an angle of $40^0$. The concentration ratio of the collector is 6.5, the width of its absorber tube plate is 6 cm and its length is 2 m. The collector is used for heating a fluid (Cp = 2.35 kJ/kg-K) which enters at a temperature of $130^0$C. Calculate the exit temperature of the fluid and the instantaneous collection efficiency for the following situation.<br><br>Location of the collector : New Delhi ($28.58^0$N)<br>Date : November 5<br>Sun hour : $15^0$<br>Ig : 0.735 kW/$m^2$<br>Id : 0.162 kW/$m^2$<br>Number of tubes : 2<br>Tube outer diameter : 18 mm<br>Tube inner diameter : 14 mm<br>Transmissivity of glass cover : 0.89<br>Reflectivity of concentrator : 0.87<br>Absorptivity of absorber surface : 0.94<br>Overall heat loss coefficient : 10.5 W/$m^2$-K<br>Heat transfer coefficient on inside of absorber tube : 230 W/$m^2$-K<br>Mass flow rate of fluid : 1.25 kg/min<br>Ambient temperature : $21^0$C | **20** | **CO4** |

**Correlations for cylindrical parabolic concentrating collector.**

1) Heat transfer coefficient between absorber tube and glass tube

$$\frac{k_{\text{eff}}}{k} = 0.317\,(\text{Ra}^*)^{1/4}$$

$$(\text{Ra}^*)^{1/4} = \frac{\ln(D_{ci}/D_o)}{b^{3/4}\left(\frac{1}{D_o^{3/5}} + \frac{1}{D_{ci}^{3/5}}\right)^{5/4}}\,\text{Ra}^{1/4}$$

$$\frac{2\pi k_{\text{eff}}}{\ln(D_{ci}/D_o)}(T_{pm} - T_c) = h_{p-c}\pi D_o(T_{pm} - T_c)$$

$$h_{p-c} = \frac{2k_{\text{eff}}}{D_o \ln(D_{ci}/D_o)}$$

2) Heat transfer coefficient on the outer surface of the glass cover.

$$\text{Nu} = C_1 \text{Re}^n$$

where $C_1$ and $n$ are constants having the following values:

For $40 < \text{Re} < 4000$, $C_1 = 0.615$, $n = 0.466$

For $4000 < \text{Re} < 40\,000$, $C_1 = 0.174$, $n = 0.618$

For $40\,000 < \text{Re} < 400\,000$, $C_1 = 0.0239$, $n = 0.805$

**Equations for Compound parabolic collector**

1) Heat flux

$$S = \left[I_b r_b + \frac{I_d}{C}\right]\tau\rho_e\alpha$$

2) Useful heat gain

$$q_u = F_R W L\left[S - \frac{U_l}{C}(T_{fi} - T_a)\right]$$

$$F_R = \frac{\dot{m}C_p}{bU_l L}\left[1 - \exp\left\{-\frac{F' b U_l L}{\dot{m}C_p}\right\}\right]$$

$$\frac{1}{F'} = U_l\left[\frac{1}{U_l} + \frac{b}{N\pi D_i h_f}\right]$$

3) Tilt angle

$$r_b = \frac{\cos(L-\beta)\cos\delta\cos\omega + \sin(L-\beta)\sin\delta}{\cos L\cos\delta\cos\omega + \sin L\sin\delta}$$

Properties of air

| $T$ (K) | $\rho$ ($kg/m^3$) | $c_p$ (kJ/kg-°C) | $\mu$ (kg/m-s) $\times 10^{-5}$ | $\nu$ ($m^2/s$) $\times 10^{-6}$ | $k$ (W/m-°C) | $\alpha$ ($m^2/s$) $\times 10^{-4}$ | Pr |
|---|---|---|---|---|---|---|---|
| 100 | 3.6010 | 1.0266 | 0.692 | 1.923 | 0.00925 | 0.0250 | 0.770 |
| 150 | 2.3675 | 1.0099 | 1.028 | 4.343 | 0.01374 | 0.0575 | 0.753 |
| 200 | 1.7684 | 1.0061 | 1.329 | 7.490 | 0.01809 | 0.1017 | 0.739 |
| 250 | 1.4128 | 1.0053 | 1.488 | 9.490 | 0.02227 | 0.1316 | 0.722 |
| 300 | 1.1774 | 1.0057 | 1.983 | 16.84 | 0.02624 | 0.2216 | 0.708 |
| 350 | 0.9980 | 1.0090 | 2.075 | 20.76 | 0.03003 | 0.2983 | 0.697 |
| 400 | 0.8826 | 1.0140 | 2.286 | 25.90 | 0.03365 | 0.3760 | 0.689 |
| 450 | 0.7833 | 1.0207 | 2.484 | 31.71 | 0.03707 | 0.4222 | 0.683 |
| 500 | 0.7048 | 1.0295 | 2.671 | 37.90 | 0.04038 | 0.5564 | 0.680 |
| 550 | 0.6423 | 1.0392 | 2.848 | 44.34 | 0.04360 | 0.6532 | 0.680 |
| 600 | 0.5879 | 1.0551 | 3.018 | 51.34 | 0.04659 | 0.7512 | 0.680 |
| 650 | 0.5430 | 1.0635 | 3.177 | 58.51 | 0.04953 | 0.8578 | 0.682 |
| 700 | 0.5030 | 1.0752 | 3.332 | 66.25 | 0.05230 | 0.9672 | 0.684 |
| 750 | 0.4709 | 1.0856 | 3.481 | 73.91 | 0.05509 | 1.0774 | 0.686 |
| 800 | 0.4405 | 1.0978 | 3.625 | 82.29 | 0.05779 | 1.1951 | 0.689 |
| 850 | 0.4149 | 1.1095 | 3.765 | 90.75 | 0.06028 | 1.3097 | 0.692 |
| 900 | 0.3925 | 1.1212 | 3.899 | 99.30 | 0.06279 | 1.4271 | 0.696 |
| 950 | 0.3716 | 1.1321 | 4.023 | 108.2 | 0.06225 | 1.5510 | 0.699 |
| 1000 | 0.3524 | 1.1417 | 4.152 | 117.8 | 0.06752 | 1.6779 | 0.702 |

*Notes:* $T$ = *temperature*, $\rho$ = *density*, $c_p$ = *specific heat capacity*, $\mu$ = *viscosity*, $\nu = \mu/\rho$ = *kinetic viscosity*, $k$ = *thermal conductivity*, $\alpha = c_p\rho/k$ = *heat (thermal) diffusivity*, Pr = *Prandtl number*