Name: **Enrolment No:**	UPES

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	Distinguish between active and passive solar heating system.	**5**	**CO3**
Q 2	Explain the following terms (a) Solar Time (b) Insolation (c) Irradiance	**5**	**CO1**
Q 3	Define and explain the following terms (a) Solar constant (b) concentration ratio (c) solar altitude angle	**5**	**CO1**
Q 4	Derive an expression for solar day length.	**5**	**CO2**

SECTION B

Q 5	Explain the different tracking modes used in the concentrating solar collectors.	**10**	**CO3**
Q 6	Calculate the declination and the zenith angle of the sun for New York City (latitude 40.77°N) on October 1 at 2:00 p.m. solar time.	**10**	**CO2**
Q 7	Classify the concentrated solar collectors and mention its applications. Specify the advantages of concentrating solar collector over flat plate collectors.	**10**	**CO3**
Q 8	Explain the working of solar thermal power plant with neat sketch and describe its components. (OR) Explain various solar thermal energy storage systems.	**10**	**CO2** **CO3**

SECTION-C

Q 9	Explain the working of solar vapor absorption and vapor compression refrigeration system with neat sketch, and describe its components.	**20**	**CO5**
Q 10	A cylindrical parabolic collector located in Mumbai (ϕ =19.12^o N), operating in tracking mode II, is used for heating a thermic fluid. The concentrator has an aperture of 1.25 m and a length of 3.657 m. Values of other parameters are as follows:	**20**	**CO4**

Absorber tube inner diameter : 3.81 cm
Absorber tube outer diameter : 4.135 cm
Glass cover inner diameter : 5.60 cm
Glass cover outer diameter : 6.30 cm
Reflectivity of the mirror (concentrator) : 0.85
Transmissivity of glass cover : 0.85
Emissivity/Absorptivity of glass cover : 0.88
Emissivity/Absorptivity of absorber tube : 0.95
Intercept factor : 0.95
Date : April 15
Time : 12:30 PM
I_b : 705 W/m^2
I_g : 949 W/m^2
Ambient temperature : 31.9^{o}C
h_w : 34.119 W/m^2-K
Mass flow rate of thermic fluid : 0.0986 kg/s
Inlet temperature : 150^{o}C
T_{pm} : 167.97^{o}C

Calculate:

(i) Slope of the aperture plane and the angle of incidence on the aperture plane
(ii) The absorbed heat flux (S)
(iii) Overall heat loss coefficient
(iv) The instantaneous efficiency

(OR)

A flat-plate solar collector has two glass covers, a black absorber with ε_p = 0.95, mean plate temperature of 110◦C at an ambient temperature of 10◦C, and a wind loss coefficient of 10 W/m2 ◦C. Estimate its top loss coefficient. If the back of the collector is insulated with 50mm of mineral wool insulation of k = 0.035 W/m ◦C, what is its overall loss coefficient? (Neglect edge effects.) The slope is 45◦. Plate-to-cover and cover-to-cover spacing is 25 mm.

Correlations for cylindrical parabolic concentrating collector.

1) Heat transfer coefficient between absorber tube and glass tube

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

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

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

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

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

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

where C_1 and n are constants having the following values:

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

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

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

Correlations for Flat plate collector.

$$\mathrm{Nu}_L = 1\ ;\ \mathrm{Ra}_L \cos\beta < 1708$$

$$\mathrm{Nu}_L = 1 + 1.446\left(1 - \frac{1708}{\mathrm{Ra}_L \cos\beta}\right);\ 1708 < \mathrm{Ra}_L \cos\beta < 5900$$

$$\mathrm{Nu}_L = 0.229\ (\mathrm{Ra}_L \cos\beta)^{0.252};\quad 5900 < \mathrm{Ra}_L \cos\beta < 9.23 \times 10^4$$

$$\mathrm{Nu}_L = 0.157\ (\mathrm{Ra}_L \cos\beta)^{0.285};\quad 9.23 \times 10^4 < \mathrm{Ra}_L \cos\beta < 10^6$$

$$h_w = 5.7 + 3.8\ V_\infty$$

Properties of air

T (K)	ρ (kg/m³)	c_p (kJ/kg-°C)	μ (kg/m-s) $\times 10^{-5}$	ν (m²/s) $\times 10^{-6}$	k (W/m-°C)	α (m²/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, ρ = density, c_p = specific heat capacity, μ = viscosity, $\nu = \mu/\rho$ = kinetic viscosity, k = thermal conductivity, $\alpha = c_p\rho/k$ = heat (thermal) diffusivity, Pr = Prandtl number

Correlations for cylindrical parabolic concentrating collector.

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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

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

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

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

3) Tilt angle

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

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