Department of Energy Science and Engineering, Indian Institute of Technology Delhi
ESL 880: Solar Thermal Power Generation (II Semester, 2021-22)

Time: One Hour **Minor Test** **Maximum Marks: 30**

Note: Please answer all the questions in legible handwriting. The maximum marks assigned to a question are indicated at the end of the question within square brackets. In case any required details appear to be missing in numerical questions, please make a suitable assumption and explicitly mention the same in the response to the question. ***Few formulae are given at the end of the question paper (on the backside of this sheet).***

1. Choose the correct answer for the below questions from (i) to (iv). Each question carries one mark. [4]

(i) Shading of a solar collector installed in Australia (Southern hemisphere) at 10:30 hrs would fall on the ---------- direction

(a) East (b) West (c) North-West
(d) South-West (e) North-East (f) South-East

(ii) The focal length of a parabolic concentrator …….. with an increase in rim angle

(a) Increases (b) Decreases (c) Remains same (d) None of the above

(iii) Among the CSP technologies, the following technology has best land-to-electricity ratio due to its compact design.

(a) Linear Fresnel Reflector (b) Parabolic Trough Collector
(c) Central Receiver (d) Parabolic Dish Collector
(e) Compound Concentrating Collector

(iv) Solar concentrator has better conversion efficiency at higher operating temperature as compared to non-concentrating solar collector by having …….

(a) Higher flux on the absorber surface (b) Smaller absorber area
(c) both beam and diffuse radiation (d) both (a) and (b)
(d) Both (b) and (c)

2. Match each of the parameters in the second column with the definition in the third column: [2]

S. No.	Parameters	Definition
a)	Optical concentration ratio	$\frac{\text{Energy intercepted by the absorber}}{\text{Energy reflected/refracted by the concentrator}}$

b)	Local flux concentration ratio	$\frac{\text{Energy absorbed by the absorber}}{\text{Energy incident on the aperture}}$
c)	Intercept factor	$\frac{\text{Flux at the point on the absorber}}{\text{Flux incident on the aperture}}$
d)	Optical efficiency	$\frac{\text{Average energy flux integrated over the receiver surface}}{\text{Flux on the aperture}}$
		$\frac{\text{Area of the aperture of the concentrator}}{\text{Area of the absorber}}$
		$\frac{\text{Energy delivered by the receiver}}{\text{Energy incident on the aperture}}$

3. Explain why **(any two)** [4]
   a) The linear Fresnel reflector and central tower receiver solar concentrators usually have higher cosine losses as compared to parabolic trough and dish concentrators?
   b) A parabolic dish solar concentrator is expected to collect more solar energy per unit aperture area as compared to a parabolic trough concentrator?
   c) For designing solar concentrators, the sun cannot be considered as a point source?

4. Explain any four differences between linear Fresnel reflector and parabolic trough collector? [2]

5. List any four benefits and limitations of the concentrating solar collectors [2]

6. A parabolic trough solar concentrator uses a back coated glass mirror of thickness 3 mm. The glass has a refractive index of 1.526 and extinction coefficient of 15 m^{-1}. If the solar beam radiation is incident at 45^o with respect to normal to the mirror, determine the percentage loss due to absorption in the glass. [3]

7. Determine the focal length of the parabolic trough collector which has aperture of 5 m and rim angle of 70^o with an intercept factor of unity. [2]

8. Calculate the size of the absorber of parabolic trough solar collector which has aperture diameter of 4.5 m and rim angle of 85^o at horizontal plane as well as normal to the reflected solar radiation at the focal point. [3]

9. Calculate the ratio of the height to the aperture (H/a) of the parabolic trough and compound parabolic concentrator with rim angle of 70°. The half acceptance angle of both the concentrators are 16′. Compare the results and write your observations. [3]

10. Linear Fresnel reflector based concentrating solar energy system has 10 reflector rows, 5 on either side of the receiver. Each reflector's width is 2 m, the pitch of the row is 3 m and the length is 250 m. The height of the receiver from the reflector is 12 m. Calculate the tilt angle of the third reflector at 11:30 hrs of solar time for New Delhi location on February 15, 2022. The latitude and longitude of New Delhi is 28.61° N and 77.2° E, respectively. [5]

Formulae:

- Zenith Angle of solar radiation: $\cos\theta_z = \cos\phi\cos\delta\cos\omega + \sin\delta\sin\phi$
- Decliantion Angle: $23.45 sin\left[\frac{360}{365}(284+n)\right]$
- Angle between the vertical line and the incident solar radiation on the E-W plane: $\tan^{-1}\left[\tan\theta_Z \sin\gamma_S\right]$
- Angle between the vertical line and the reflected solar radiation of on E-W plane: $\tan^{-1}\left[\left(\frac{n}{2}-i+\frac{1}{2}\right)p/H\right]$
- Solar Azimuth Angle: $Cos\gamma_s = \left(Cos\theta_z Sin\phi - Sin\delta\right)/Sin\theta_z Cos\phi$
- Fraction of solar radiation absorbed by the plane glass: $\alpha_g = 1-e^{-Kx}$
- Absorber diameter of the parabolic trough collector: $\frac{a\sin(16')}{\sin\phi_r}$
- Absorber width of the parabolic trough collector: $\frac{a\sin(16')}{\sin\phi_r\cos(\phi_r+16')}$
- The ratio of aperture to the height of the parabolic concentrator: $\frac{4\sin\phi_r}{(1-\cos\phi_r)}$
- The ratio of height to the aperture of the compound parabolic concentrator: $\frac{\cot\theta_{max}}{2}(1+\sin\theta_{max})$
- Relation between the aperture, rim angle and focal length: $a = 4f\tan\left(\frac{\phi_r}{2}\right)$