POSTAL Book Package 2023

Mechanical Engineering

Objective Practice Sets

Renewable Sources of Energy

Contents

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CHAPTER

Solar Radiation

Q.1 Estimate the surface temperature of the sun if extraterrestrial radiation flux received are 1367 W/m^2. The mean distance between the Sun and Earth is 1.496×10^8 km and radius of sun is 6.95×10^5 km. You can assume Sun as blackbody.

(a) 5780 K (b) 5880 K
(c) 4088 K (d) 6180 K

Q.2 A scientist is carrying out experiments on solar plate collectors in an observatory located at 78°N, 38°E. Due to malfunction of instruments, experimental results are not available. Find out theoretical value of extraterrestrial radiation on 21st June for the given location.

(a) 1367 W/m^2 (b) 1441 W/m^2
(c) 1353 W/m^2 (d) 1323 W/m^2

Q.3 A space shuttle is partially powered by solar energy. It has crossed Earth's atmosphere at 1100 h (LAT, Florida). If Zenith angle (θ_z) is 60° at the location and time of launching. Estimate the air-mass (AM) ratio at 1400 h (LAT).

(a) 1.0 (b) 2.0
(c) 1.15 (d) zero

Q.4 What is the orientation angle of Earth and solar flux received outside the atmosphere of Earth on 14th November, 2016?

(a) 16.47°, 1398 W/m^2
(b) –19.15°, 1116 W/m^2
(c) 16.47°, 1116 W/m^2
(d) –19.15°, 1398 W/m^2

Q.5 Wien's displacement law is given by $\lambda_{max} T$ = constant. What is λ_{max}?

(a) Wavelength corresponding to mean surface temperature of the source.
(b) Maximum possible wavelength in spectral distribution for a given temperature.
(c) Wavelength corresponding to maximum spectral power of the source.
(d) Mean value of the wavelengths in spectral distribution for give temperature.

Q.6 The hour angle made by Earth at a location in New Delhi (25°35′N, 77°12′E) at 1200 h (LAT) will be _______.

(a) –7.5° (b) 7.5°
(c) 15° (d) zero

Q.7 The atmosphere of earth is

(a) opaque for short-wavelength but transparent for long-wavelength radiation.
(b) transparent for short-wavelength radiation but opaque for long-wavelength radiation.
(c) transparent for both short and long-wavelength radiation.
(d) opaque for both short and long-wavelength radiation.

Q.8 In solar radiation, the term 'albedo' is used to quantify:

(a) amount of radiation reflected back to the space
(b) amount of diffuse radiation received on the surface of earth
(c) amount of air-mass ratio for maximum radiation
(d) amount of global radiation received on earth

Q.9 Find out hour angle at a location in Shillong (25°34′ N, 91°56′E) on 23rd May 2006 at 1000 h (IST). Standard time in India is based on 82.5°E.

(a) –30° (b) –22.5°
(c) –20.5° (d) –15°

Q.10 Find out local apparent time in Jodhpur (26°18′ *N*, 73° 01′ E)

(a) 1008 h (b) 0.852 h
(c) 0930 h (d) 0922 h

Q.11 A flat plate collector is located in New Delhi (28° 35′N, 77°12′E) and tilted at an angle 36° with horizontal. The collector is facing due south. Find out air-mass ratio on 30th June at 0945 (LAT).

(a) 1.24 (b) 1.70
(c) 1.16 (d) 1.96

Q.23 Find out the monthly average daily diffuse radiation if sunrise angle is 102°, clearance index on the basis of monthly average data is 0.6 for a location (17.39° N, 78.49°E). From the metereology department record books it is known that the monthly average daily extraterrestrial radiation received on the specified location use 4.2 MJ/m^2 and sunshine hours are 8.6 h. It is also known that the following correlation is applicable to estimate the diffused radiation.

$$\frac{\bar{H}_d}{\bar{H}_g} = 0.88 - 0.33\,\bar{K}_T - 0.53\left[\frac{\bar{S}}{\bar{S}_{max}}\right]$$

(a) 1.46 MJ/m^2 (b) 0.87 MJ/m^2
(c) 0.35 MJ/m^2 (d) 0.05 MJ/m^2

Q.24 The latitude angle is zero at
(a) Southern Hemisphere
(b) Northern Hemisphere
(c) Equator
(d) All of the above

Q.25 The extraterrestrial solar intensity flux is dependent on:
(a) Height from the surface of earth
(b) Atmospheric conditions
(c) Locations of the observer
(d) Day of the year

Q.26 Which of the following angle varies seasonally due to the tilt of the earth on its axis and rotations of the earth around the sun?
(a) Tilt angle (b) Altitude angle
(c) Hour angle (d) Declination angle

Q.27 Which of the following statements is correct in regard of solar Zenith angle?
(a) It is zero at the time of sunrise
(b) It is zero at the solar noon
(c) It is zero at the time of sun fall
(d) It is maximum at solar noon

Q.28 Which of the following instruments is used to measure direct/beam radiation?
(a) Pyrheliometer (b) Pyranometer
(c) Anemometer (d) Albedometer

Q.29 The purpose of shading ring which is being used in pyranometer is/are
(a) to avoid overheating of the sensor.
(b) to measure diffuse radiation.
(c) to measure day length i.e. sunfall-sunrise hours.
(d) to measure direct radiation.

Q.30 Solar flux are reported in 'Langley' sometimes, which is the unit of radiation adopted after the name of Samuel Langley. 1 Langley is equal to ______.
(a) 1 cal (b) 1 kcal
(c) 1 cal/cm^2 (d) 1kcal/cm^2

Answers Solar Radiation

1. (a)	2. (d)	3. (d)	4. (d)	5. (c)	6. (d)	7. (b)	8. (a)	9. (c)
10. (d)	11. (c)	12. (b)	13. (c)	14. (d)	15. (b)	16. (b)	17. (a)	18. (b)
19. (b)	20. (d)	21. (b)	22. (d)	23. (b)	24. (c)	25. (d)	26. (d)	27. (b)
28. (a)	29. (b)	30. (c)						

Explanations Solar Radiation

1. (a)

The total emitted radiation by the surface of the Sun will be given by:

$$\sigma T_s^4 (4\pi R_s^2)$$

These radiation are received by a sphere having radius equal to mean distance between the Sun and the Earth.

i.e. $I_{sc} \times (4\pi R_m^2)$

Hence $\sigma T_s^4 (4\pi R_s^2) = I_{sc} \times (4\pi R_m^2)$

$$\Rightarrow \quad \sigma T_s^4 = 1367 \times \left(\frac{1.496 \times 10^{11}}{6.95 \times 10^8}\right)^2$$

$$\Rightarrow \quad T_s = (11.17 \times 10^{14})^{1/4}$$

$$T_s = 5781.22\text{ K}$$

2. (d)

Extraterrestrial solar flux (I'_{sc}) is given by:

$$I'_{sc} = I_{sc}\left[1 + 0.033\cos\frac{360n}{365}\right]$$

Solar constant,

$$I_{sc} = 1367 \text{ W/m}^2$$

For 21st June, $n = 31 + 28 + 31 + 30 + 31 + 21$
$= 172$

$$\therefore \quad I'_{sc} = 1367\left[1 + 0.33\cos\frac{360 \times 172}{172}\right]$$
$$= 1322.62 \text{ W/m}^2$$

***Note:** Location data and 21st June is given to create confusion. On 21st Jun, Earth's declination angle will be 23.45° i.e. default value. One should not select default value of I_{sc} i.e. 1367 W/m² for the given data.*

3. (d)

Air mass ratio

$$= \frac{\text{path length of beams radiation traversed in atmosphere}}{\text{pathlength when sun is overhead}}$$

$$\text{Mathematically (AM)} = \frac{1}{\cos\theta_z}$$

Since, space shuttle has crossed the atmosphere of earth and hence there is no question of attenuation of solar radiation. Air-mass ratio is a measure of attenuation of solar radiation because of the atmosphere.

Hence, Air-mass ratio = 0

***Note:** Careful reading of question will reveal θ_z is giving for the launching time and AM is being asked after crossing the atmosphere of Earth i.e. at 1400 h.*

Hence, $\text{A.M} = \frac{1}{\cos\theta_z} = \frac{1}{\cos 60°} = 2$ is for the time of launching and not at 1400 h.

4. (d)

The variation of Earth's orientation angle is given by cooper's relation:

$$\delta = 23.45 \sin\left[\frac{360}{365}(284 + n)\right]$$

On 14th November

$$n = 31 + 29 + 31 + 30 + 31 + 30 + 31 + 31 + 30 + 31 + 14 = 319$$

$$\delta = 23.45 \sin\left[\frac{360}{365}(284 + 319)\right]$$
$$= -19.15°$$

Flux received outside of the atmosphere of Earth i.e. extraterrestrial flux (I'_{sc}) is given by:

$$I'_{sc} = I_{sc}\left[1 + 0.033\cos\frac{360n}{365}\right]$$
$$= 1367\left[1 + 0.033\cos\frac{360 \times 319}{365}\right]$$
$$= 1396.645 \text{ W/m}^2$$
$$= 1398.69 \text{ W/m}^2$$

5. (c)

Wien's displacement law is obtained by differentiating total spectral emissive power of blackbody i.e.

$$\frac{dE_{\lambda, sc}}{d\lambda} = 0 \text{ to maximize}$$

For blackbody radiation

$$E_{\lambda, sc} = \pi I_{\lambda, sc}$$

Where spectral intensity distribution is obtained from Planck's distribution.

6. (d)

$$\text{Hour angle } (\omega) = 15\,(\text{LAT} - 1200)$$
$$= 15\,(1200 - 1200) = 0$$

7. (b)

Solar radiation are short wavelength (0.25 μ_m to 3.0 μ_m). Earth's atmosphere allow to pass short wavelength radiation, that is why we receive radiation of sun at the surface of the earth.

Earth's surface get heated by solar radiation and emits radiation. These radiation are long-wavelength radiation. Earth's atmosphere is opaque to these radiation and as a result temperature of most of the location on earth is supporting life.

9. (c)

$$\text{Hour angle } (\omega) = 15\,(t_{zone} - 1200) + \omega_{eq.} + (\psi - \psi_{zone})$$

$$t_{zone} = 1000 \text{ h}; \quad \psi = 91.93°$$

$$\psi_{zone} = 82.5°$$

The correction equation $\omega_{eq.}$ can be find out by:

$$\omega_{eq} = 229.18\,[0.000075 + 0.001868 \cos B - 0.032077 \sin B - 0.014615 \cos 2B - 0.04089 \sin 2B]$$

$$B = \frac{(n-1)360}{365}$$

For 23rd May $n = 31 + 28 + 31 + 30 + 23 = 143$

$\therefore \quad B = 14.05$

Substituting value of B into equation (1)

$$\omega_{eq} = [0.000075 + 0.001868 \cos 140.05 - 0.032077 \sin 140.05 - 0.014615 \cos 280.1 - 0.04089 \sin 280.1] = 3.61 \text{ min.}$$

$$\therefore \omega = 15\,(1000 - 1200) + \frac{3.61}{60} + (91.93 - 82.5)$$

$$= -20.51°$$

Note: *ω_{eq} is negligible and hence it can be omitted from almost all the calculation.*

10. (d)

$$\text{LAT} = \text{Standard Time} \pm 4\,(\psi_{standard} - \psi_{zone}) + \omega_{eq.} \quad \text{....(1)}$$

India is in eastern hemisphere and hence negative sign is applicable in equation (1)

Also $\omega_{eq.}$ is contributing insignificantly and hence can be neglected.

$$\therefore \quad \text{LAT} = 0930 - 4(82.5 - 73.02)$$

$$= 0930 - 37.92 = 0852 \text{ h}$$

11. (c)

$$\text{Air-mass ratio} = \frac{1}{\cos\theta_z}$$

For given data

$$\cos\theta_z = \sin\delta \cdot \sin\phi + \cos\delta \cdot \cos\phi \cdot \cos\omega$$

Now $\quad \delta = 23.45 \sin\left[\frac{360}{365}(284 + n)\right]$

$$n = 31 + 28 + 31 + 30 + 31 + 30 = 181$$

$$\therefore \quad \delta = 23 \cdot 45 \sin\left[\frac{360}{365} 465\right] = 23.18°$$

$$\phi = 28°35' = 28 \cdot \frac{35}{60} = 28.58°$$

$$\omega = 15(0945 - 1200) = -33.75$$

$$\therefore \quad \cos\theta_z = \sin 23.18 \cdot \sin 28.58 + \cos 23.18 \cdot \cos 28.58 \cdot \cos(-33.75)$$

$$= 0.8595$$

$$\text{AM} = \frac{1}{\cos\theta_z} = \frac{1}{0.8595} = 1.16$$

13. (c)

$$I_b = 800 \text{ W/m}^2\text{-hr}$$

$$I_d = 80 \text{ W/m}^2\text{-hr}$$

$$I_g = I_b + I_d = 880 \text{ W/m}^2\text{-hr}$$

15. (b)

Earth declination angle (δ)

$$= 23.45 \sin\left[\frac{360}{365}(284 + n)\right]$$

on 8th August

$$n = 31 + 28 + 31 + 30 + 31 + 30 + 31 + 8 = 220$$

$$\therefore \quad \delta = 23.45 \sin\left[\frac{360}{365}(284 + 220)\right]$$

$$= 15.96°$$

Hour angle (ω) $= 15(1100 - 1200) = -15°$

Latitude angle (ϕ) $= 32.72°$

Inclination/Tilt angle (β) $= 20°$

For collector facing south

$$\cos\theta_z = \sin\phi \cdot \sin\delta + \cos\phi \cdot \cos\delta \cdot \cos\omega$$

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

$$\Rightarrow \quad \cos\theta = \sin 10.72° \cdot \sin 15.96 + \cos 10.72° \cdot \cos 15.96 \cdot \cos(-15°)$$

$$= 0.9636$$

$$\Rightarrow \quad \theta = \cos^{-1}(0.9636) = 15.5°$$

$$\cos\theta_z = \sin 32.72 \sin 15.96 + \cos 32.72 \cos 15.96 \,.\, \cos(-15) = 0.93$$

$$\theta_z = 21.57°$$

Solar Altitude (α_a) $= 90° - \theta_z = 90 - 21.51 = 68.43°$

16. (b)

Solar azimuth angle (r_s) is given by relations

$$\cos r_s = \frac{\cos\theta_z \sin\phi - \sin\delta}{\sin\theta_z \cos\phi} \quad \text{...(1)}$$

We know $\quad \text{AM} = \frac{1}{\cos\theta_z} = 1.24 \Rightarrow \theta_z$

$$= \cos^{-1}\left(\frac{1}{1.84}\right)$$

Zenith angle (θ_z) $= 57.08°$

Latitude (ϕ) $= 23.26°$

Declination angle (δ)

$$\delta = 23.45 \sin\left[(284 + n) + \frac{360}{365}\right]$$

$$n = 20$$

$$\therefore \quad \delta = -20.34°$$

Substituting these values into eq. (1)

$$\cos r_s = \frac{\cos 57.08 \cdot \sin 23.26 - \sin(-20.34)}{\sin 57.08 \cos 23.26}$$

$$= 0.729$$

$$r_s = \cos^{-1}(0.729) = 43.2$$