Solved and Additional Problems

VIDEO COURSE ON

SOLAR ENERGY TECHNOLOGY

By

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Note: All times in the following problems are SOLAR TIME except when specified otherwise

Exercise 1 Solved Problems

1.1 From the diameter and effective surface temperature of the sun, estimate the rate of which it emits energy. What fraction of this emitted energy is intercepted by the earth? Estimate the solar constant, given the mean earth-sun distance. **(Lecture 23)**

1.2 Calculate the angle of incidence of direct radiation at 1100 solar time on January 20 at latitude of 28^0 N on surfaces with the following orientation: **(Lecture 23)**

a. Horizontal
b. Tilted to south at slope of 35^0
c. At slope of 35^0, but facing 25^0 east of south
d. Vertical, facing south

e. Vertical, facing west

1.3 Calculate the angle of incidence of direct radiation at 1100 solar time on June 20 at latitude of 35^0 N for surfaces with the following orientation: **(Lecture 23)**

a. Vertical, facing south
b. Vertical, facing north

1.4 Determine the sunset hour angle and day length for Srinagar and for Port Blair, for the following dates: Dec. 23, March 22, June 23. **(Lecture 24)**

1.5 When it is noon as per the clock time (or Indian Standard time), what is the solar time on Jan 20^{th} in Mumbai, (Latitude: 19° 1'N, Longitude: 72° 67' E) Kolkata (Latitude: 22° 39'N, Longitude: 88° 27' E), and Kohima (Latitude: 25° 40' N, Longitude: 94° 07' E) on Jan. 20. **(Lecture 24)**

1.6 What are the sunset hour angles and the day length for the following: i) $\varphi = 15^0$, $\delta = 15^0$: ii) $\varphi = 45^0$, $\delta = 23^0$: iii) $\varphi = 45^0$, $\delta = -23^0$: iv) $\varphi = 77^0$, $\delta = 15^0$: v) $\varphi = 82^0$, $\delta = -15^0$**(Lecture 24)**

1.7 Estimate R_b for a collector with a slope of $\beta = \varphi + 15^0$, $\beta = \varphi$ and $\beta = \varphi - 15^0$ from horizontal with $\gamma = 0^0$, at New Delhi(φ = 28° 34' N and L: 77° 07' E) at 9.30 AM on March 21th, June 23 and Dec. 23. **(Lecture 27)**

1.8 What is the extraterrestrial radiation on a horizontal surface, I_o at Chennai, (φ = 13° 00' N) during the hour 10.30 AM to 11.30 AM on Jan 15. What is the daily H_o (for Jan 15) and the monthly (for January) average daily extraterrestrial radiation on a horizontal surface, $\overline{H}_o$?**(Lecture 27)**

1.9 If the daily horizontal radiation for Jan 15, in the above problem has been measured to be 19.8 MJ/(m^2-day), what is the daily clearness index? **(Lecture 27)**

1.10 If the global radiation on a horizontal surface has been found to be 1.8 MJ/(m^2-hr) for the hour 10-11 at a location of latitude 40^o, on monthly mean day of January, find the clearness index. **(Lecture 27)**

1.11 Estimate the ratio of beam radiation on a surface tilted 45^0 toward the south to that on a horizontal surface, if located at a latitude of 40^0 on March 1, **a** at noon, **b** at 3:30 pm. **(Lecture 27)**

1.12 Estimate maximum likely error in the ratio of beam radiation on a surface, facing south, tilted at 50^0 , to that on a horizontal surface, if located at a latitude of 40^0 on Nov. 15, for the hour, 11AM -12 Noon. **(Lecture 27)**

Exercise 1 Additional Problems

1.13 Estimate the ratio of beam radiation on a surface tilted 45^0 toward the south to that on a horizontal surface, if located at a latitude of 40^0 on March 1, **a** at noon, **b** at 3:30 pm. **(Additional 1)**

1.14 Estimate maximum likely error in the ratio of beam radiation on a surface, facing south, tilted at 50^0 , to that on a horizontal surface, if located at a latitude of 40^0 on Nov. 15, for the hour, 11AM -12 Noon. **(Additional 2)**

1.15 Estimate the monthly average radiation for January and July from the average hours of sunshine data given for Poona., (φ=18° 32’ N). The constants in the Angstrom relation, a=0.3 and b=0.51. The average sunshine hours in percentage of possible being 37 and the range 25-49. **(Additional 3)**

1.16 Solar radiation on a horizontal surface integrated over the day of December 22nd at Srinagar (φ=34° 05’) is 5.12 MJ/m^2. What is the clearness index, K_T, for that day? What is the estimated fraction of the day’s energy which is diffuse? **(Additional 4)**

1.17 At $\varphi=28^0$ on December 22, K_T was 0.63.

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a. Estimate the total horizontal radiation for 10 to 11.
b. Estimate the beam and diffuse for 10 to 11.
c. What is R_b for that hour?

d. If all the radiation is treated as beam, what is total radiation on the tilted surface for that hour?
e. If the diffuse radiation is isotropic , and ground reflectance is 0.2, what is I_T for that hour? **(Additional 5)**

1.18 The day's radiation on a horizontal surface in Srinagar (φ = 34° 05') on a December 22 is 7.77 MJ/m^2. Estimate the diffuse radiation, ground-reflected radiation and the total radiation on a south-facing vertical surface during the hour 11 to 12. There is a fresh snow cover on the ground. **(Additional 6)**

1.19 What will be the hourly beam and diffuse components of solar radiation on a collector on January 13 in Delhi (φ = 28° 34' N) at a slope of 45^0, facing south. if the total radiation on a horizontal surface for that day is 7.9 MJ/m^2, and ground reflectance is 0.2? **(Additional 7)**

Exercise 2 Solved Problems

2.1 At a location of latitude 40^0N, a process heating system employing flat plate collectors, facing south with a slope of 40^0 ,of area 50 m^2 has been installed. The collector parameters are $F_R U_L$ = 2.63 W/m^2 ^{0}C and $F_R(\tau\alpha)_n$=o.0.72. The system is required to supply energy at a minimum temperature of 60^0C at a rate of 12 kW for 12 hrs a day. Assume that the ground reflectance to be 0.2. Calculate the following for the month of January if $\bar{H} = 8.6 MJ/(m^2 - day)$, $\bar{T}_a = -5^0 C$ .What is the critical radiation level? What is the non-dimensional critical radiation level? **(Lecture 33)**

2.2 In the Problem No. 1, above, what is the monthly average daily utilizability? **(Lecture 33)**

2.3 What is the solar load fraction met by the system for the specifications given in Problem 1. **(Lecture 33)**

2.4 Include the tank losses for the system described in Problem 1 and calculate the solar load fraction. The tank $(UA)_{tank}$=5.9 W/^{0}C and the surrounding temperature is 20^{0}C. **(Lecture 33)**

2.5 For the system described in Problem 1, estimate the solar load fraction if the load heat exchanger has $\varepsilon_L C_{min}$=1350 W/^{0}C

2.6 A space heating system is to be designed for Srinagar φ=34° 05', for the month of December. Calculate the Degree days and the space heating load, if $(UA)_h$ =400 W/^{0}C, http://www.indiaenvironmentportal.org.in/files/srd-sec.pdf **(Lecture 33)**

2.7 A space heating system is to be designed for Srinagar φ=34° 05’, for the month of December. Assume β=50^0 and γ=0With the space heating load calculated in Problem 6, obtain the solar load fraction if the liquid based solar collectors have, $F_R U_L$ = 2.63 W/m^2 ^{0}C and $F_R(\tau\alpha)_n$=0.72, employ a storage tank of 125 l/m^2 and has a standard heat exchanger. You may assume $\frac{(\overline{\tau\alpha})}{(\tau\alpha)} = 0.94$. The collector area is 50 m^2. For the month of December, $\bar{H} = 6.99 MJ/(m^2 - day), \bar{H}_d = 4.99 MJ/(m^2 - day)$ and $\bar{T}_a = 2.8^0 C$ for Srinagar. **(Lecture 34)**

2.8 What will be the solar load fraction if air based collectors with standard flow rate have been employed, with standard storage and assume $F_R U_L$ = 2. 63 W/m^2 ^{0}C and $F_R(\tau\alpha)_n$=0.72 remain the same as the values for the liquid based collector. You may also assume $\frac{(\overline{\tau\alpha})}{(\tau\alpha)} = 0.94$ **(Lecture 34)**

2.9 What will be the solar load fraction if the air based collector system of the Problem 8, employs double the standard flow rate? **(Lecture 34)**

2.10 Calculate the solar load fraction met by the liquid based space heating system described in Problem 8, using the $\bar{\phi}, f - Chart$ method. **(Lecture 35)**