Section-A

Note: All questions are compulsory.

Q.1 Find the solar altitude and solar azimuth angles at 2hrs after local noon on June 15 for a city Dehradun (30^0 $19^{'}$ N). Also find the sunrise and sunset hours and the day length. [5]

Q.2 With the help of neat diagram, detailed the construction and measuring principle of sun shine recorder. [5]

Q.3 What is the principle of dye-sensitized solar cell (DSSC)? What is the role of a dye and wide band semiconductor in DSSC? [5]

Q4. Explain the single diode equivalent circuit for solar cell. [5]

Section-B

Q.5 Determine the extraterrestrial normal radiation and the extraterrestrial radiation on a horizontal surface on March 10 at 2:00 pm solar time for 35^0N latitude. Determine also the total solar radiation on the extraterrestrial horizontal surface for the day. [10]

Q.6 The dark saturation current of a solar cell is $1.75x10^{-8}$ A when the cell is at 35^0C and the short circuit current when in sunlight is 4A. Estimate the open circuit voltage, the maximum power output of the cell, and the number and arrangement of cells required to make power output to make a panel to supply 90W at 12V. [10]

Q.7 Draw the block diagram of shunt and series type of charge controllers. How does a DC to DC converter help in maximum power transfer? [10]

A buck converter is connected to a load of 50 Ω impedance and operated at 40% duty cycle. What would be the reflected impedance at the input side of the converter? What would happen if the buck type converter is replaced by a boost type converter with same duty cycle? [6+4]

Q.8 What is a grid-connected PV system? What are single stage and multi-stage grid-connected PV systems? [10]

OR

Define total harmonic distortion in relation with inverter. What should be the value of THD of an ideal sine wave inverter?
[10]

Section-C

Q.9 (a) Define the following with respect to solar cell
(i) Carrier life time (ii) Carrier diffusion length (iii) Spectral responsivity (iv) Loss mechanism associated (v) Direct and indirect band gap materials. [10]
(b) Write the chemical equations of lead acid batteries showing half reactions at anodes and at the cathodes. With the help of neat diagram, discuss the common charging stages as used by different controllers. [4+6]

Q.10 (a) Explain the IV and PV characteristics of solar cell? Explain how the insolation and temperature affects the IV characteristics of a solar cell? [6+4]
(b) Using the simple design method, design a PV system using 60W, 12V panels and 145 Ah, 6V batteries. The PV system is required to offer 3 days of storage, the battery efficiency is 75% and the depth of discharge is 70%, The location where the system to be installed has 6 hrs of day light during winter times and application is 24V with a load of 1500 Wh.
[10]

OR

(b) Illustrate the designing steps of one of the following standalone PV systems. You may assume appropriate data to justify your steps. [10]
(i) Water solar pump
(ii) Cathodic protection system

Appendix-I

Useful Relations

1. Equations relating the angle of incidence of beam radiation on a surface, θ, to the other angles is

$$\begin{aligned}\cos\theta = {} & \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma \\ & + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega \\ & + \cos\delta\sin\beta\sin\gamma\sin\omega\end{aligned}$$

For β=0 $\cos\theta_z = \cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta$

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

3. Sun rise hour angle for tilted surfaces $\cos^{-1}\left[-\tan(\varnothing-\beta)\tan\delta\right]$ in Northern Sphere

4. $G_{sc} = 1367\ W/m^2$

5. Sun set/sun rise hour angle
   $\omega_s = \cos^{-1}(-\tan\varnothing tan\delta)$

6. DayLength $N = \frac{2}{15}\cos^{-1}(-\tan\varnothing tan\delta)$

7. Solar azimuth angle
$$\gamma_S = \text{sign}(\omega)\left|\cos^{-1}\left(\frac{\cos\theta_z\sin\phi-\sin\delta}{\sin\theta_z\cos\phi}\right)\right|$$

8. Extraterrestrial solar radiation normal to surface

$$G_{on} = G_{sc}\left(1+0.033\cos\frac{360n}{365}\right)$$

9. Extraterrestrial daily solar radiation

$$H_o = \frac{24\times 3600 G_{sc}}{\pi}\left(1+0.033\cos\frac{360n}{365}\right)\times\left(\cos\phi\cos\delta\sin\omega_s+\frac{\pi\omega_s}{180}\sin\phi\sin\delta\right)$$

Table: Recommended Average Days for Months and Values of n by Months

Month	n for ith Day of Month	For Average Day of Month		
		Date	n	δ
January	i	17	17	−20.9
February	$31+i$	16	47	−13.0
March	$59+i$	16	75	−2.4
April	$90+i$	15	105	9.4
May	$120+i$	15	135	18.8
June	$151+i$	11	162	23.1
July	$181+i$	17	198	21.2
August	$212+i$	16	228	13.5
September	$243+i$	15	258	2.2
October	$273+i$	15	288	−9.6
November	$304+i$	14	318	−18.9
December	$334+i$	10	344	−23.0