Enrolment No: **Name:**	

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2021

Course: Solar PV Technologies **Semester: I**
Program: M. Tech. (Renewable Energy Engineering) **Time 03 hrs**
Course Code: EPEC 7035 **Max. Marks: 100**
Total Number of Pages: 4

SECTION A

Each Question carries 4 Marks.

S. No.	Questions	CO
Q.1	Describe the structure of a-Si thin film solar cell. What is the role of intrinsic layer between p and n.	CO2
Q.2	How localized 'hot spots' can occur in a partially shaded module connected into string of modules?	CO3
Q.3	How bypass diode protects the PV module from hot spot.	CO3
Q.4	Differentiate between conversion efficiency and quantum efficiency of solar photovoltaic cell.	CO2
Q.5	What is the effect of intensity of light, temperature and parasitic resistance on a solar cell I-V Characteristics?	CO1

SECTION B

Each Question carries 10 Marks.

Q.6	Calculate monthly average daily radiation for the month of April on the roof of a house in Chennai (13^0 N) inclined at 60^0 from the horizontal position and facing due south in the absence of the earth's atmosphere.	CO1
Q.7	When the cell temperature is 300K, a certain silicon cell of area 100 cm^2 has an open circuit voltage of 600 mV and a short circuit current of 3.3A under $1kW/m^2$ illumination. Assuming that the cell behaves ideally, what is its energy conversion efficiency at the maximum power point.	CO2
Q.8	Define the following terms related to the lead acid batteries (a) State of Charge (b) Depth of discharge (c) Self-discharge (d) Stratification (d) Cycle life.	CO3
Q.9	Starting with the solar cell equation, given below, derives the expression for open circuit voltage (V_{OC}). What factors determine the order of magnitude of V_{OC}.? $I=I_L-I_o\left[e^{qv/kT}-1\right]$	CO2

Section C

Each Question carries 20 Marks.

Q.10	(a) Estimate the daily load and the peak power required by a PV system that has the following equipment connected: [10] Four lamps, 15 W each, operated from 6 pm–11 pm. Television, 80 W, operated from 6 pm–11 pm. Computer, 150 W, operated from 4 pm–7 pm. Radio, 25 W, operated from 11 am–6 pm. Water pump, 50 W (with surge current of 6A), operated from 7 am–10 am.	CO4

	(b) Using the simple design method, design a PV system using 60 W, 12 V panels and 145 Ah, 6 V 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 is located has 6 h of daylight during wintertime and the application is 24 V with a load of 1500 Wh. [10] OR You want to design a large rooftop solar PV system array in Dehradun (30.32N, 78.03E) facing due south. Because of the space limitations, the system is designed to have various rows of modules behind each other. The lower end of the module is resting on the ground and each module length is 2m from top to bottom. You want to space them so far apart that front row will not shadow the back row at solar noon on the shortest day of the year. (a) Which day is the shortest day of the year at the Dehradun site? [2] (b) What is the Sun's elevation angle at the Dehradun site at the solar noon on the shortest day of the year? [6] (c) What distance should the modules rows be spaced apart to satisfying the shading requirements (include a sketch in your answer)? [6] (d) At what time is the Sunrise and Sunset on the shortest day and how long would this shortest day be. [6]	
Q.11	(a) Draw a schematic of a stand-alone system with labeling of each component and briefly discuss the function of each component. [10] (b) Discuss the charge control strategies of the controller for stand-alone PV system. How they can be implemented with series and shunt switch controllers. [10]	**CO3**

Appendix-I

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

Useful Relations

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

$$\cos\theta = \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega + \cos\delta\sin\beta\sin\gamma\sin\omega$$

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 horizon $\cos^{-1}[-\tan(\emptyset)\tan\delta]$ in Northern Sphere

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

5. Sun set/sun rise hour angle

$$\omega_s = \cos^{-1}(-\tan\emptyset\tan\delta)$$

6. DayLength

$$N = \frac{2}{15}\cos^{-1}(-\tan\emptyset\tan\delta)$$

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

8. Estimation models for diffuse component of hourly and monthly radiations.

For $\omega_s \leq 81.4^\circ$

$$\frac{H_d}{H} = \begin{cases} 1.0 - 0.2727K_T + 2.4495K_T^2 - 11.9514K_T^3 + 9.3879K_T^4 & \text{for } K_T < 0.715 \\ 0.143 & \text{for } K_T \geq 0.715 \end{cases}$$

and for $\omega_s > 81.4^\circ$

$$\frac{H_d}{H} = \begin{cases} 1.0 + 0.2832K_T - 2.5557K_T^2 + 0.8448K_T^3 & \text{for } K_T < 0.722 \\ 0.175 & \text{for } K_T \geq 0.722 \end{cases}$$

$$\frac{I_d}{I} = \begin{cases} 1.0 - 0.09k_T & \text{for } k_T \leq 0.22 \\ 0.9511 - 0.1604k_T + 4.388k_T^2 - 16.638k_T^3 + 12.336k_T^4 & \text{for } 0.22 < k_T \leq 0.80 \\ 0.165 & \text{for } k_T > 0.8 \end{cases}$$

9. Monthly average Extraterrestrial Solar Radiation

$$H_0=\frac{24\times3600\ G_{sc}}{\pi}\left(1+0.033\cos\frac{360n}{365}\right)\times\left[\cos\emptyset\cos\delta\sin\omega_s+\frac{\pi\ \omega_s}{180}\sin\emptyset\sin\delta\right]$$

$$I_0=\frac{12\times3600\ G_{sc}}{\pi}\left(1+0.033\cos\frac{360n}{365}\right)\times\left[\cos\emptyset\cos\delta\ (\sin\omega_2-\sin\omega_1)+\frac{\pi(\omega_2-\omega_1)}{180}\sin\emptyset\sin\delta\right]$$

10. Isotropic Model to estimate the total Insolation on tilted surface

$$I_T=I_bR_b+I_d\left(\frac{1+\cos\beta}{2}\right)+I\rho_g\left(\frac{1-\cos\beta}{2}\right)$$