Name:	
Enrolment No:	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2018

Programme Name: **B. Tech EE** **Semester : VII**
Course Name : Solar Cell Technology **Time : 03 hrs**
Course Code : ELEG-432 **Max. Marks : 100**
Nos. of page(s) : 4

SECTION A

S. No.		Marks	Cos
Q 1	Calculate the day length on May 1 and December 1 for a south facing surface tilted at an angle of 40^0 and located at New Delhi (28^0 $35^/$ N , 77^0 $12^/$ E).	**4**	**CO1**
Q.2	Narrate the merit and demerit of $Cu(InGa)Se_2$ (CIGS) and CdTe thin film solar cells	**4**	**CO2**
Q.3	Find the wavelength of radiation whose photons have energy equal to the band gap of cuprous sulphide (Cu S) cell (1.80 eV), compounds of cadmium sulphide (CdS) cell (2.42 eV), and gallium arsenide (GaAs) cell (1.40 eV).	**4**	**CO2**
Q.4	Define the following for solar cell (a) Short circuit current (b) Open circuit voltage (c) conversion efficiency (d) Fill factor	**4**	**CO3**
Q.5	Describe the structure of a-Si thin film solar cell. What is the role of intrinsic layer between p and n.	**4**	**CO2**

SECTION B

Q.6	Calculate the hourly extraterrestrial radiation between 12:00 and 13:00 (AST) on horizontal surface and the daily extraterrestrial irradiation on a plane surface Tokoyo (35^0 $40^{'}$ N) oriented due to south and inclined at angle of 30^0 from the horizontal on Feb 1.	**10**	**CO1**
Q.7	The Sieman's process is used to purify MG-Si. Describe the process and give values for Si purity before and after the process.	**10**	**CO2**
Q.8	$I=I_L-I_O\left(e^{\frac{V}{\eta V_T}}-1\right)$ (a) What does the above equation describe? Explain the meaning of each variable in the equation, giving their units in each case and Identify the dark and light currents. (b) Draw the equivalent circuit of a solar cell and relate the elements of the equivalent circuit to the solar cell equation. (c) A solar cell will deviate from its ideal behavior in the presence of parasitic series and shunt resistances.	**3+3+4**	**CO2**

	(i) What are the physical origins of these resistances in the solar cell? (ii) Describe, clearly, how the parasitic resistances will affect the IV curves of the solar cell. You should illustrate answers with appropriate sketches of IV characteristics. (iii) Describe, how the parasitic resistances will affect the efficiency and fill factor of the solar cell. Write the expressions for them.		
Q.9	If the dark saturation current of a solar cell is 1.7×10^{-8} A/m^2, the cell temperature is 27^0 C and J_{SC} is 250 A/m^2, calculate V_{OC}, V_{mp}, I_{mp}, P_{max}, and η_{max}. What cell area is required to get an output of 20W when the available solar radiation is 820 W/m^2.	**10**	**CO3**
	SECTION-C		
Q.10	**(a)** Define the following terms related to the lead acid batteries (i) Stratification (ii) Gassing (iii) Battery Capacity (iv) Self-discharge (v) Specific Gravity **OR** 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**
	(b) What is the effect of intensity of light, temperature and parasitic resistance on a solar cell I-V Characteristics? You should illustrate answers with appropriate sketches of IV characteristics. **OR** **Explain:** **(i)** how localized 'hot spots' can occur in a partially shaded cell connected into a large photovoltaic array. **(ii)** the steps that can be taken to prevent damage arising from such 'hot spots'.	**10**	
Q.11	(a) Estimate the daily load and the peak power required by a PV system that has the following equipment connected: 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, operated from 7 am–10 am. (b) A 6 m^2 PV system gives 24 V and 18 A when exposed to solar radiation of 750 W/m^2. Estimate the cells' efficiency. (c) Draw a schematic of a stand-alone photo-voltaic system. Labelling each component, discuss the function of each component and its importance to the system.	**8+2+10**	**CO4**

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
January	i	17	17
February	$31+i$	16	47
March	$59+i$	16	75
April	$90+i$	15	105
May	$120+i$	15	135
June	$151+i$	11	162
July	$181+i$	17	198
August	$212+i$	16	228
September	$243+i$	15	258
October	$273+i$	15	288
November	$304+i$	14	318
December	$334+i$	10	344

Useful Models and Equations

1. 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 $\omega_s > 81.4^\circ$

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

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

2. Monthly average Extraterrestrial Solar Radiation

$$H_0 = \frac{24 \times 3600\ G_{sc}}{\pi} \left(1 + 0.033 \cos \frac{360n}{365}\right) \times \left[\cos\varnothing \cos\delta \sin\omega_s + \frac{\pi\ \omega_s}{180}\ \sin\varnothing \sin\delta\right]$$

$$I_0 = \frac{12 \times 3600\ G_{sc}}{\pi} \left(1 + 0.033\ \cos \frac{360n}{365}\right) \times \left[\cos\varnothing\ \cos\delta\ \left(\sin\omega_2 - \sin\omega_1\right) + \frac{\pi(\omega_2 - \omega_1)}{180}\ \sin\varnothing\ \sin\delta\right]$$

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

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

5. Solar Constant G_{sc} = 1367 W/m^2

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

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

7. Sun set/sun rise hour angle

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

8. Angle of incidence on inclined surface

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