MEC316/6316 2013

Short questions:

1) Give one advantage and one disadvantage of silicon based solar cells when compared to compound semiconductor based solar cells.

2) When would you use solar cells in series and when would you use solar cells in parallel.

3) Name three items that you will need for a domestic photovoltaic system besides the solar panels and describe what function they serve.

4) If you have a multi-junction solar cell comprising Ge (E_g=0.7eV), GaAs (E_g=1.42eV) and GaInP (E_g=1.8eV), which would be the semiconductor material at the bottom? What would be the longest wavelength that this solar cell can absorb?

5) Explain briefly what the minority carrier diffusion length in a semiconductor is and how it affects the performance of a solar cell.

Answers:

1) Silicon advantage - cheap, compound semiconductor - expensive. Silicon disadvantage - efficiency is poor, compound semiconductor - efficiency can be high. Other answers may be acceptable.

2) Series - for higher voltage, Parallel - for higher current.

3) 3 from: Inverter - converting DC to AC, Maximum power point tracker - ensuring maximum power transfer from solar panels, meter - to monitor current flow, battery - to store power, blocking diode - prevent current flow back into solar panel.

4) Ge will be at the bottom cell. Longest wavelength absorbed is 1770nm.

5) The minority carrier diffusion length is the typical distance minority carriers travel in the p and n regions of a semiconductor before they recombine. A long diffusion length is desirable as it means that carriers created far from the electric-field of the p-n junction will still contribute to the current.

Long Question:

A commercial solar panel comprises 48 individual silicon cells connected in series. The panel has a rated open circuit voltage of 30.25V under AM1.5 illumination. It is known that each individual silicon solar cell has a dark current value of 2.66×10^{-10} amps at room temperature. Under AM1.5 illumination conditions (corresponding to $0.84 kW/m^2$) the solar panel has a 14% efficiency.

i) What is the short circuit current of this solar panel? **[4]**

ii) What is the maximum power that this module can provide under AM1.5 illumination? **[8]**

iii) What is the fill factor of each cell under optimum load conditions and AM1.5 illumination? Comment of the value. **[3]**

iv) What is the area of each individual silicon cell? **[4]**

v) The panel undergoes some damage such that two individual cells are effectively a short circuit while another two are effectively an open circuit. What happens to the maximum power that that this module can now produce? **[2]**

vi) The solar panel receives the same level of illumination in winter and in the summer. Explain qualitatively when you expect the module performance to be better and the reasons for it. **[4]**

Answer:

i) Voc of 48 cells in series gives 30.25V. Therefore V_{oc} of each cell is 30.25/48 = 0.63V.

The equation for a solar cell is:

$I = I_o[\exp(eV/kT)-1] - I_L$ and when under open circuit, I=0, so this gives us:

$I_o[\exp(eV_{oc}/kT)-1] = I_L$

We are given that $I_o = 2.66 \times 10^{-10}$ Amps, V_{oc} =0.63V from above, and we are at 300K, so

$I_L = 2.66 \times 10^{-10} \times [\exp(1.6 \times 10^{-19} \times 0.63/(1.38 \times 10^{-23} \times 300))-1] = 2.66 \times 10^{-10} \times 3.75 \times 10^{10} = 9.97$ Amps

In series, the current for the panel is the same as that for an individual cell, i.e. 9.97 Amps.

ii) To determine maximum power of the module, we need maximum power developed by each cell, so need I_{max} and V_{max}. To get this, we solve the equation iteratively

V(V)	0	0.2	0.4	0.5	0.53	0.55	0.57	0.6
I(A)	-9.97	-9.97	-9.97	-9.9	-9.76	-9.51	-8.99	-6.84
Power(W)	0	2	4	4.95	5.17	5.23	5.12	4.1

Maximum power per cell is 5.23W. For the panel it is 48 x 5.23 = 251W

iii) Fill Factor = $(V_{max} \times I_{max})/ (V_{oc} \times I_{sc}) = (0.55 \times 9.51)/ (0.63 \times 9.97) =0.83$

This is a good high value for the fill factor.

iv) Panel is 14% efficient. So Power Out/Power In = 0.14

251/Power in = 0.14, giving power in = 1792W.

AM1.5 illumination is $840W/m^2$, so total cell area under illumination is 1792/840 = $2.13m^2$.
As there are 48 cells in the panel, each cell is 2.13/48 = $0.0444m^2$.

v) For a series connection, the shot circuited cells don't matter but the two open circuited cells means that no power will be developed by the panel.

vi) During winter the cells will be at a lower temperature than during the summer. This means that the dark current values will be lower and this will result in a higher open circuit voltage, hence higher power.