Tutorial problems for "Solar Energy" lecture (23745), WS 2021/2022

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Tutorial Questions #3:
Charge recombination; Doping; Open circuit; Fill factor;

1. Pn-junction

The p-type region of a silicon p-n junction is doped with 10^{16} boron atoms per cubic centimetre, and the n-type region is doped with 10^{18} phosphorus atoms per cubic centimetre. Assume a step p-n junction and that all doping atoms are ionized. The intrinsic carrier concentration in silicon at $300\,\mathrm{K}$ is $1{,}5\cdot10^{10}\,\mathrm{cm}^{-3}$.

a) What are the electron and hole concentrations in the p- and n-type regions at thermal equilibrium?

b) Calculate the built-in voltage V_{bi} at $300\,\mathrm{K}$.

c) Calculate the width of the depletion region at $300\,\mathrm{K}$

2. Open circuit voltage 1

A crystalline silicon solar cell generates a photocurrent density of $J_{\mathrm{ph}} = 35\,\frac{\mathrm{mA}}{\mathrm{cm}^2}$ at $T = 300\,\mathrm{K}$. The saturation current density is $J_{\mathrm{ph}} = 1{,}95\cdot10^{-10}\,\frac{\mathrm{mA}}{\mathrm{cm}^2}$. Assuming that the solar cell behaves as an ideal p-n junction, calculate the open circuit voltage V_{oc}.

3. Open circuit voltage 2

Which of the following statements is true?

a) The open circuit voltage decreases when the lifetime of the minority charge carriers increases.

b) The open circuit voltage increases when the irradiance increases.

c) The open circuit voltage increases when the intrinsic density of charge carriers increases.

d) The open circuit voltage does not depend on the doping.

4. Fill factor

John has used a solar simulator setup to measure the relationship between the voltage and the current of a small photovoltaic module ($40\,\text{cm}$ long and $40\,\text{cm}$ wide). The measurement setup maintains the standard measurement conditions: the temperature is controlled to $25\,^{\circ}\text{C}$, the incident spectrum is the AM1.5 spectrum with an incident power density of $1000\,\frac{\text{W}}{\text{m}^2}$. The result is illustrated in Figure 1. John determined that the maximum power he could get out of this module is $19{,}5\,\text{W}$.

a) Determine the short-circuit current density.

b) Calculate the fill factor of the module.

c) What is the efficiency of the module?

d) John decides to connect two of these modules with a cable in series. This results in an additional $2\,\text{m}\Omega$ series resistance loss. What is the new fill factor? (Hint: use the voltage drop at the maximum power point)

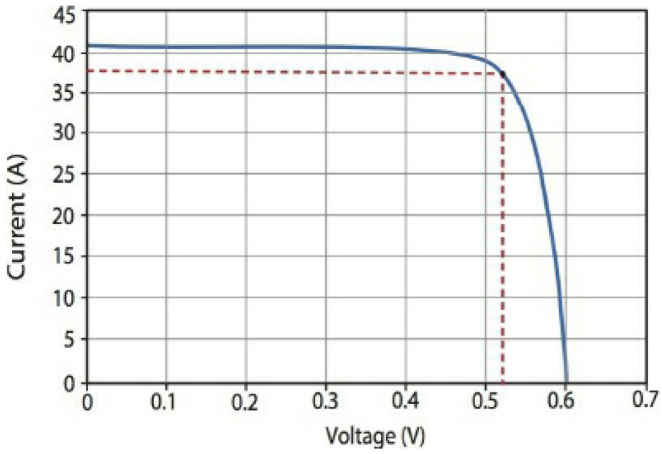

Figure 1