Assignment 8: Optoelectronic devices

1. A $p-i-n$ diode is made of a p-type, intrinsic, and n-type semiconductor (of the same material) joined together. Draw a qualitative energy band diagram if the *pin* diode in equilibrium, forward bias, and reverse bias. Under what bias can this device be used as a photo detector? Explain the reasons for your answer.

2. Show that the change in emitted wavelength λ with T from an LED is approximately given by

$$\frac{d\lambda}{dT} = -\frac{hc}{E_g^2}\left(\frac{dE_g}{dT}\right)$$

   where E_g is the band gap. Consider a GaAs LED with E_g of 1.42 eV and $dE_g/dT = -4.5 \times 10^{-4}\ eVK^{-1}$. What is the change in the emitted wavelength if the temperature change is 10 °C?

3. A solar cell at room temperature is under an illumination of 500 Wm^{-2} and has a short circuit current, I_{sc}, of 150 mA and an open circuit voltage, V_{oc}, of 0.53 V. What are the short circuit current and the open circuit voltage when the light intensity is doubled? What are the values when the intensity is halved?

4. (a) A Si solar cell of area 1 cm^2 is connected to drive a load R and the $I-V$ characteristics for an illumination of 500 Wm^{-2} is shown in figure 1. Suppose the load R is 20 Ω and the light intensity is 1 kWm^{-2}. What is the voltage in the circuit if current is 24 mA? What is the power delivered to the load? What is the efficiency of the solar cell in this circuit? The I-V characteristics are plotted in the figure below

   (b) What should the load be to obtain maximum power transfer from the solar cell to the load at 1 kWm^{-2} illumination? What is this load at 500 Wm^{-2}.

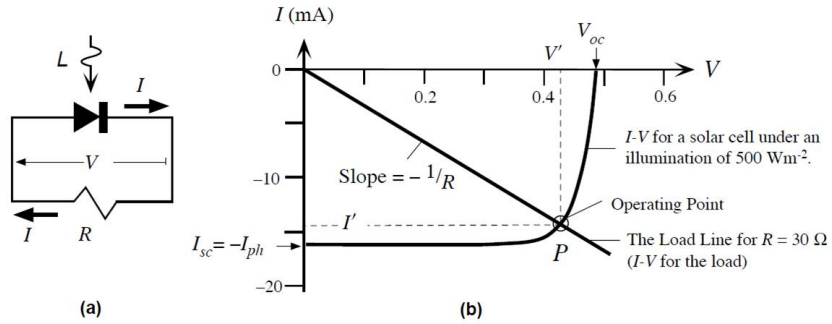

Figure 1: (a) Schematic of a solar cell equivalent circuit. (b) I-V curve under illumination of 500 Wm^{-2}. Adapted from *Principles of Electronic Materials - S.O. Kasap*

(c) Consider using a number of such cells to drive a calculator that needs a minimum of 3 V and draws 3 mA at 3-4 V. It is to be used at a light intensity of 500 Wm^{-2}. How many solar cells would you need and how should they be connected?

5. A photoconductor with dimensions $L = 6\ mm$, $W = 2\ mm$, and $D = 1\ mm$ is placed under uniform illumination. The absorption of light increases the current by 2.83 mA. A voltage of 10 V is applied across the device. As the radiation is suddenly cut off, the current falls, initially at the rate of 23.6 As^{-1}. The electron mobility is 3600 $cm^2V^{-1}s^{-1}$.

   (a) Find the equilibrium density of electron-hole pairs generated under radiation

   (b) The minority-carrier lifetime

   (c) The excess density of electrons and holes remaining 1 ms after the radiation is turned off