Numericals on Unit 2&3

Q1. Consider that in an n-type GaAs semiconductor at 300K temperature, the e⁻ concentration varies linearly from 1×10^{18} to 7×10^{17} cm^{-3} over a distance of 0.10 cm. So, Calculate the diffusion current density if e⁻ diffusion coefficient is $D_n = 225\ cm^2/s$.

Soln 1. Diffusion Current density is

$$J_{diff} = e D_n \frac{dn}{dx} \approx e D_n \frac{\Delta n}{\Delta x}$$

So, as per value

$$J_{diff} = 1.6\times10^{-19} \times 225 \times \frac{(1\times10^{18} - 7\times10^{17})}{0.10}$$

$$= 108\ A/cm^2 \quad \underline{Ans}$$

Q2. Consider a p-type Si sample for which the hole diffusion coefficient is $9\ cm^2/sec$. If the hole concentration varies from $10^{16}\ cm^{-3}$ to $10^{13}\ cm^{-3}$ over a length of $1\ \mu m$, then find out the diffusion current density.

Soln 2- Diffusion current density is given by

$$J_{diff} = p D_p \frac{dp}{dx} \approx p D_p \frac{\Delta p}{\Delta x}$$

$$= 1.6\times10^{-19} \times 9 \times \frac{(10^{16} - 10^{13})}{1\times10^{-6}\times100} = 143.86\ A/cm^2$$

$\underline{Ans.}$

(2)

Q3. Find the position of fermilevel E_F at room temperature ($=27°c$) for Germanium crystal having 5×10^{22} atoms/m^3.

<u>Ans 3</u>. Given $T = 27°c = 300K$ and $n_e = 5 \times 10^{22}$ atoms/m^3

$$n_e = 2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2} e^{(E_F - E_c)/kT}$$

$$= e^{(E_F - E_c)/kT} = \frac{n_e}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}}$$

$$= e^{(E_F - E_c)/kT} = \frac{5 \times 10^{22}}{2\left[\frac{2 \times 3.14 \times 9.1 \times 10^{-31} \times 1.38 \times 10^{-23} \times 300}{(6.62 \times 10^{-34})^2}\right]^{3/2}}$$

$$= e^{(E_F - E_c)/kT} = \frac{5 \times 10^{22}}{25.115 \times 10^{24}}$$

$$e^{-(E_c - E_F)/kT} = 0.1991 \times 10^{-2}$$

$$e^{-(E_c - E_F)/kT} = 502.296 \quad \text{or} \quad E_c - E_F = \log 502.296$$

$$\frac{E_c - E_F}{kT} = 6.2192 \quad \text{or} \quad E_c - E_F = 0.161\,eV$$

Q4- For an intrinsic Semiconductor having band gap $E_g = 0.7eV$ Calculate the density of holes and electrons at room temperature ($= 27°C$). Given $h = 6.62 \times 10^{-34}$, $m = 9.1 \times 10^{-31}$, $\pi = 3.14$ & $k = 1.38 \times 10^{-23}$

Soln 4- Given $E_g = 0.7eV$

In intrinsic semiconductor the concentration of electrons and holes are same. So

$$n_e = n_h = 2\left[\frac{2\pi kTm}{h^2}\right]^{3/2} e^{(E_F - E_C)/kT}$$

The fermi level lies exactly in between the middle of Conduction and valence band.

$$E_F = \frac{E_C + E_V}{2}$$

$$E_F - E_C = \frac{E_C + E_V}{2} - E_C = \frac{-(E_C - E_V)}{2} = \frac{-E_g}{2}$$

$$\therefore n_e = n_h = 2\left[\frac{2\pi kTm}{h^2}\right] e^{-E_g/2kT}$$

$$= 2 \times \left[\frac{2 \times 3.14 \times 1.38 \times 10^{-23} \times 300 \times 9.1 \times 10^{-31}}{6.62 \times 10^{-34}}\right] e^{-\left[\frac{0.7}{2 \times 0.026}\right]}$$

$$= 3.6 \times 10^{19} / m^3.$$

Q5- A single solar cell (10cm × 10cm) produces a voltages of 0.5V and a current upto 0.25A. If the solar insulation is 800 W/m³, find the efficiency of solar cell?

Soln 5- Surface Insulation (S.I.) = 800 W/m², V = 0.5V, I = 2.5A, η = ?

$$\eta = \frac{P_{out}}{P_{in}} \times 100$$

where P_{out} = Voltage (V) × Current (I)

P_{in} = S.I × area.

$$\eta = \frac{VI}{SI \times area} = \eta = \frac{0.5 \times 2.5}{800 \times 10^{-2}}$$

$$= \frac{1.25}{8}$$

$$\eta = 0.1562 = 15.62\%$$

Q6 - Solar insulation on a rectangular module (1.5m × 2.0m) of photo voltaic cell is 550 W/m². If the efficiency of cell is 12%. What is the power output of the module?

Soln 6- $$\eta = \frac{P_{out}}{P_{in}} \times 100$$

$$\eta = \frac{P_{out}}{Area \times S.I} = 0.12 = 12\%$$

$$0.12 = \frac{P_{out}}{550 \times 3} = 0.12 \times 550 \times 3$$

$$= 198 W.$$

Q7. Calculate the drift velocity of e- in an aluminium wire of diameter 0.9 mm carrying current of 6A. Assume that 4.5×10^{28} el./m³ are available for conduction.

Sol^n - $I = 6A$, $n = 4.5\times10^{28}$ el/m³ & radius $(r) = \frac{d}{2} = \frac{0.9\times10^{-3}}{2}$

$= 4.5\times10^{-4}$ m

$$J = \frac{I}{A} = \frac{6.0}{\pi\times(4.5\times10^{-4})^2}$$

(Current Density)

$$= \frac{6.0}{3.14\times(4.5\times10^{-4})^2} = 9.44\times10^6 \, A/m^2$$

$$\text{\& drift velocity } v_d = \frac{J}{ne} = \frac{9.44\times10^6}{4.5\times10^{28}\times1.6\times10^{-19}}$$

$$= 1.311\times10^{-3} \text{ m/sec.}$$