HW #~~4~~ 5

1.

$\rho = 50\ \Omega.cm$ @ $T = 300\,K$

$\rho = 5\ \Omega.cm$ @ $T = 330\,K$

assume μ is T independent.

$\rho = (qn\mu_n + qp\mu_p)^{-1}$

semiconductor described here is assumed to be intrinsic:

$n = p = n_i = \sqrt{N_c N_v}\ \exp\left(\frac{-E_g}{2KT}\right)$

$$\Rightarrow \frac{\rho(T=300^K)}{\rho(T=330^K)} = \frac{n_i(T=330^K)}{n_i(T=300^K)} = \exp\left[-E_g\left(\frac{1}{2K330} - \frac{1}{2K300}\right)\right] = 10$$

$\overset{Ln}{\Rightarrow} E_g \simeq 1.31\ eV$

2.

$$\frac{1}{\mu} = \frac{1}{\mu_1} + \frac{1}{\mu_2} + \frac{1}{\mu_3}$$ & $\mu_3 \ll \mu_1 \,\&\, \mu_2 \Rightarrow \mu = \mu_3 \cong 15\ cm^2/V.S$

3.

$\sigma = qn_o\mu_n + qP_o\mu_p$

$n_oP_o = n_i^2$ & $\sigma_i = qn_i(\mu_n + \mu_p)$ (a)

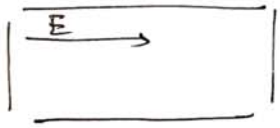
$$\frac{\partial\sigma}{\partial p_o} = -\frac{qn_i^2\mu_n}{P_o^2} + q\mu_p \xrightarrow{\frac{\partial\sigma}{\partial p_o}=0} P_o = n_i\sqrt{\frac{\mu_n}{\mu_p}}$$

$$\sigma = \frac{qn_i^2}{P_o}\mu_n + qP_o\mu_p = qn_i\sqrt{\mu_n\mu_p} + qn_i\sqrt{\mu_n\mu_p}$$

$$\overset{(a)}{\Longrightarrow} \sigma = \frac{2\sigma_i}{(\mu_n + \mu_p)}\sqrt{\mu_n\mu_p}$$

ofcourse it has been assumed that μ_n & μ_p have been the same for the intrinsic semiconductor as well.

4. $E = 12\ V/cm$ $\quad 0 \le x \le 50\ \mu m$



$J = 100\ A/cm^2$

n-type : $J = qn\mu_n \mathcal{E} + qD_n \frac{dn}{dx}$ (c) & $\frac{D_n}{\mu_n} = \frac{KT}{q}$ (a)

This means you can neglect the hole current component!

@ $x = 0$: $J_{drift} = J_{\cancel{diff}} \Rightarrow n^{(0)}\mu_n \mathcal{E} = D_n \left.\frac{dn}{dx}\right|_{x=0}$ (b)

$T = 300^K$ & $\mu_n = 8000\ cm^2/V.s \xrightarrow{(a)} D_n = \mu_n \times 25.8^{mV}$
$= 206.4\ cm^2/s$

$\overset{(b)}{\Longrightarrow} \left.\frac{dn}{dx}\right|_{x=0} = \frac{12}{25.8^{mV}}\ n(0)$ (d)

$\overset{(c)}{\Longrightarrow} 1.6\times10^{-19} \times n(x) \times 8000 \times 12 + 1.6\times10^{-19} \times 206.4 \times \frac{dn}{dx} = 100$

$\Rightarrow 15.36\times10^{-15}\ n(x) + 33\times10^{-18}\ \frac{dn}{dx} = 100$

$\Rightarrow n(x) = \frac{100}{15.36\times10^{-15}} + K \exp\left(\frac{-X}{\frac{33\times10^{-18}}{15.36\times10^{-15}}}\right) = 6.5\times10^{15} + K\exp\left(\frac{-x}{2.15\times10^{-3}}\right)$

$\left.\frac{dn}{dx}\right|_{x=0} = \frac{-K}{2.15\times10^{-13}} \xrightarrow{(d)} \frac{-K}{2.15\times10^{-3}} = \left(6.5\times10^{15} + K\right) \times \frac{12}{25.8^m}$

$\Rightarrow K \simeq -3.25\times10^{15} \Rightarrow \boxed{n(x) = 6.5\times10^{15} - 3.25\times10^{15} \exp\left(\frac{-X}{2.15\times10^{-3}}\right)}$

4. Contd

(b)

$$n(0) \simeq 3.25 \times 10^{15}\ cm^{-3} \quad \& \quad n(x = 50^{\mu m} = 5\times10^{-3}\ cm) \simeq 6.18\times10^{15}\ cm^{-3}$$

Attention: all the units have been in cm.

(c)

$$J_{drift}^{(x=50^{\mu m})} = qn\mu_n \mathcal{E} = 1.6\times10^{-19} \times 8000 \times 6.18\times10^{15} \times 12 \simeq 94.9\ A/cm^2$$

$$J_{diff}(x = 50^{\mu m}) = qD_n \frac{dn}{dx} = 1.6\times10^{-19} \times 206.4 \times \frac{3.25\times10^{15}}{2.15\times10^{-3}} \times \exp\left(\frac{-5\times10^{-3}}{2.15\times10^{-3}}\right)$$

$$\Rightarrow J_{diff}^{(x=50^{\mu m})} \simeq 4.88\ A/cm^2$$

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$$N_d = N_{d_0} \exp\left(\frac{-x}{L}\right) \quad 0 \le x \le L \quad \& \quad L = 0.1^{\mu m} = 10^{-5\,cm}$$

Important conversion

$$N_{d_0} = 5\times10^{16}\ cm^{-3}$$

$$\mu_n = 6000\ cm^2/V.S \quad \& \quad T = 300^K$$

$$\Rightarrow D_n = \mu_n \times \frac{KT}{q} = 6000 \times 25.8\times10^{-3} \simeq 154.8\ cm^2/s$$

a) assume we don't have acceptors and at $T = 300^K$ all dopants are already activated

$$n = N_d = N_{d_0} \exp\left(\frac{-x}{L}\right)$$

$$J_{diff} = -\frac{qD_n N_{d_0}}{L} \exp\left(\frac{-x}{L}\right) = -1.24\times10^{5} \exp\left(\frac{-x}{10^{-5}}\right)\ A/cm^2$$

b) $J_{Total} = J_{drift} + J_{diff} = 0 \Rightarrow \mu_n \mathcal{E} n = -D_n \dfrac{dn}{dx}$

$$\mathcal{E} = -25.8^m \times \frac{1}{N_{d_0} \exp\left(\frac{-x}{L}\right)} \times \left(-\frac{N_{d_0}}{L}\right) \exp\left(\frac{-x}{L}\right) = 2.58\times10^{3}\ V/cm$$

6.

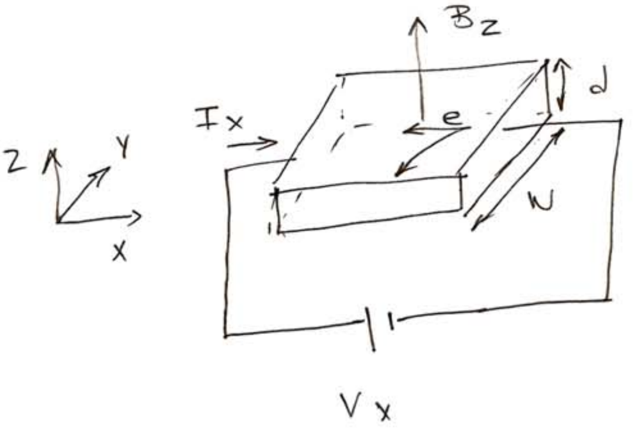
Germanium

n-type $n = 5\times10^{15}\ cm^{-3}$ $T = 300\ K$

$d = 5\times10^{-3}\ cm$, $W = 2\times10^{-2}\ cm$, $L = 10^{-1}\ cm$

$I_x = 250\ \mu A$, $V_x = 100\ mV$, $B_z = 500\ gauss = 5\times10^{-2}\ T$

a)



$\mathcal{E}_Y = \mathcal{E}_H = \dfrac{V_H}{W}$

$I_x = q n v_x \times Wd$

$-q V_x B_z = q E_y \Rightarrow -\dfrac{I_x (Wd)^{-1}}{qn} B_z = \dfrac{V_H}{W} \Rightarrow V_H = -\dfrac{I_x B_z}{q n d}$

Convert all unit to MKS

$$\Rightarrow V_H = -\frac{250^{\mu A} \times 5\times10^{-2}\ T}{1.6\times10^{-19} \times \underbrace{5\times10^{21}}_{m^{-3}} \times 5\times10^{-5}} = -312.5\ \mu V$$

b) $\mathcal{E}_H = \dfrac{V_H}{W} = -1.56\times10^{-2}\ V/cm$

c) $I_x = q n \mu_n \mathcal{E}_x (W \times d)^{+1} = q n \mu_n \dfrac{V_x}{L} (W d)^{+1} \Rightarrow$

$$\mu_n = \frac{I_x L}{q n V_x W d} = \frac{250^{\mu} \times 10^{-3 (m)}}{1.6\times10^{-19} \times \underbrace{5\times10^{21}}_{m^3} \times 2\times10^{-4} \times 5\times10^{-5} \times 0.1}$$

$\Rightarrow \mu_n = 3125\ cm^2/V.s = 312.5\times10^{-3}\ m^2/V.s$

In all calculation pay close attention to units!

$\underline{\underline{7}}$ $T = 300^K$ Silicon

a) $N_d = N_a = 10^{14}\ cm^{-3}$; use Fig 5.3 for μ_n & μ_n

$\Rightarrow \mu_n \simeq 1500\ cm^2/V.s$ & $\mu_n \simeq 450\ cm^2/V.s$

$\sigma = q n_i (\mu_n + \mu_p) \simeq 4.68 \times 10^{-6} (\Omega.cm)^{-1}$

$\uparrow$

$n_i (Si @ 300^K) = 1.5 \times 10^{10}\ cm^{-3}$

b) $N_a = N_d = 10^{18}\ cm^{-3}$

Fig 5.3 : $\mu_n \simeq 200\ cm^2/V.s$ & $\mu_p \simeq 100\ cm^2/V.s$

$\sigma = 1.6 \times 10^{-19} \times 1.5 \times 10^{10} (200 + 100) = 720 \times 10^{-9} (\Omega.cm)^{-1}$