PHYSICS - II

Tutorial - 10

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1. From Mass Action Law →

$$n\cdot p = n_i^2$$

$$n = \frac{n_i^2}{p} = \frac{2.25\times10^{20}}{2.25\times10^{15}}$$

$$= \boxed{10^5/cm^3}$$

2. At 300K, $2kT = 2\times 8.614\times10^{-5}\times 300\, eV = 0.052\,eV$

Now intrinsic concentration of charge carrier i.e

$$n_i = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2} \cdot (m_e^* m_h^*)^{3/4} \exp\left(-\frac{E_g}{2kT}\right)$$

$$\exp\left(\frac{E_g}{0.052}\right) = \frac{1.713\times10^{24}}{2.29\times10^{18}} = 0.748\times10^6$$

or

$$E_g = 0.052[\ln(0.748) + 6\ln 10]$$

$$\boxed{E_g = 0.7eV}$$

3. Given $E_c - E_F = 0.44eV$ below conduction band,

$T = 300k$, $kT = 0.026eV$, $N_0' = 3N_0$, $E_c - E_F' = ?$

for an n-type semiconductor, the electron density is given by →

$$n = N_0 = N_C \exp\left(-\frac{E_c - E_F}{kT}\right)$$

$$n' = 5N_0 = N_C \exp\left(-\frac{E_c - E_F'}{kT}\right)$$

Now

$$\exp\left(-\frac{E_c - E_F'}{kT}\right) = 5\exp\left(-\frac{E_c - E_F}{kT}\right)$$

$$\exp\left(-\frac{E_c - E_F'}{kT} + \frac{E_c - E_F}{kT}\right) = 5$$

$$E_c - E_F' = E_c - E_F - kT\ln 5 = 0.44 - 0.026\ln 5$$

$$= \boxed{0.398eV}$$

4. Given - $n_i = 1.5\times10^{16}/m^3$, $\mu_e = 0.13\, m^2V^{-1}s^{-1}$, $\mu_h = 0.05\, m^2v^{-1}s^{-1}$
impurity atom = 1 atom/ 10^8 silicon atoms, density (Si) →
$2.33\times10^3\, kg/m^3$, atomic weight (Si) = 28.09.

$$\sigma_i = n_i e(\mu_e + \mu_h) = 0.432\times10^{-3}\,\Omega^{-1}m^{-1}$$

No. of Si atoms per unit volume is given by →

$$n = \frac{\rho N}{M} = \frac{2.33\times10^3 \times 6.026\times10^{26}}{28.09}$$

$$= 5\times10^{28}/m^3$$

Now density of donor atoms (impurity) will be

$$N_D = \frac{5\times10^{28}}{10^8} = 5\times10^{20}/m^3$$

Therefore the extrinsic conductivity

$$\sigma_{en} = N_D e \mu_e$$

$$= 5\times10^{20}\times1.6\times10^{-19}\times0.13$$

$$\boxed{\sigma_{en} = 10.4\,\Omega^{-1}m^{-1}}$$

5. Given! $E = 100\, V/m$, $R_H = -0.0125\, m^3/C$, sample is n-type semiconductor $\mu_e = 0.36\, m^2v^{-1}s^{-1}$.

For n-type semiconductor, the Hall coefficient is

$$R_H = \frac{1}{ne} \quad \text{or} \quad n = \frac{1}{eR_H} = \boxed{5\times10^{20}/m^3}$$

Further, electron conductivity is given by $\sigma_e = ne\mu_e$
& $\sigma_e = J/E$

Therefore $J = \sigma_e E$

$$= ne\mu_e E$$

$$= 5\times10^{20}\times1.6\times10^{-19}\times0.36\times100$$

$$= 2880\, A/m^2$$

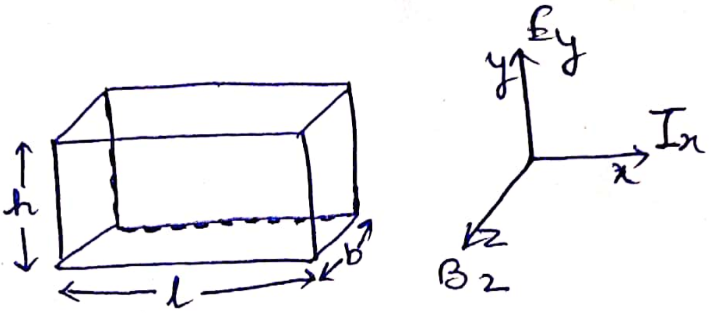
$$\boxed{J = 2880\, A/m^2}$$

6. Given -

$l = 0.2\,cm = 0.2 \times 10^{-2}\,m,$

$b = 0.12\,cm = 0.12 \times 10^{-2}\,m$

$h = 0.02\,cm = 0.02 \times 10^{-2}\,m$



$V_a = 1.0$ Volts, $I_x = 2.5 \times 10^{-3}\,A$

$B_z = 0.5\,T$, $n = ?$

$R_H = \dfrac{E_y}{J_x B_z}$ where $E_y = \dfrac{V_H}{h}$ and $J_x = \dfrac{I_x}{b.h}$

$\therefore R_H = \dfrac{V_H b}{I_x B_z} = -\dfrac{1}{ne}$ (for n-type)

$= -\dfrac{1}{pe}$ (for p-type)

Assuming the charge carriers to be electrons

$$n = \frac{I_x b_z}{V_H b e} = \frac{2.5 \times 10^{-3} \times 0.5}{10^{-2} \times 0.12 \times 10^{-2} \times 1.6 \times 10^{-19}}$$

$$\boxed{n = 6.5 \times 10^{20} / m^3}$$

Now. $E_x = \dfrac{V_a}{l}$, $\therefore \sigma_x = \dfrac{J_x}{E_x} = \dfrac{I_x / bh}{V_a / l} = \dfrac{I_x l}{bh V_a}$

$$\sigma_x = \frac{2.5 \times 10^{-3} \times 0.2 \times 10^{-2}}{0.12 \times 10^{-2} \times 0.02 \times 10^{-2} \times 1}$$

$$\boxed{\sigma_x = 20.8\,\Omega^{-1}\,m^{-1}}$$

Hence,

$$\mu_e = \frac{\sigma_x}{ne} = \frac{20.8}{6.5 \times 10^{20} \times 1.6 \times 10^{-19}}$$

$$\boxed{\mu_e = 0.2\,m^2\,V^{-1}\,s^{-1}}$$