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→ Numericals:

1. Calculate the conductivity of silicon doped with 10^{21} atoms m^{-3} of boron if the mobility of holes is $0.048\, m^2 V^{-1} s^{-1}$

$\sigma = ne\mu_h$

$= 10^{21} \times 1.6 \times 10^{-19} \times 0.048$

$= 0.768 \times 10^2 = 7.68\ ohm^{-1} m^{-1}$

2. Calculate the resistivity of intrinsic germanium if the intrinsic carrier density is $2.5 \times 10^{19} m^{-3}$ assuming electron and hole mobilities of 0.38 and 0.18 $m^2 V^{-1} s^{-1}$ respectively.

$\rho = \frac{1}{\sigma} = \frac{1}{ne(\mu_e + \mu_h)}$

$= \frac{1}{2.5 \times 10^{19} \times 1.6 \times 10^{-19} (0.38 + 0.18)}$

$= \frac{1}{4 \times \cancel{10^{-19}} \times \cancel{10^{+19}} (0.56)}$

$= \frac{1}{2.24} = 0.446\ ohm\, m$

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3. Calculate the conductivity of germanium with the given data. what is the effect of doping germanium with donar - type impurity to the extent of one atom per 10^8 germanium atoms?

Given : $n_i = 2.4 \times 10^{19} m^{-3}$

$\mu_e = 0.38\ m^2 v^{-1} s^{-1}$, $\mu_h = 0.19\ m^2 v^{-1} s^{-1}$

no of atoms: 4.4×10^{28}

$e = 1.6 \times 10^{-19}\ C$

$\sigma_1 = n_i e (\mu_e + \mu_h)$

$= 2.4 \times 10^{19} \times 1.6 \times 10^{-19} (0.38 + 0.19)$

$= 3.84 (0.57)$

$= 2.227 = \underline{2.23\ ohm^{-1} m^{-1}}$

4. The electrical conductivity of an intrinsic semi conductor increases from 19.96 ohm^{-1}m^{-1} to 79.44 ohm^{-1}m^{1} when the temp is increased from 60 to 100°c. Find the band gap energy of semi conductor.

$\sigma = K \cdot exp(E_g / 2Kt)$

$$\frac{\Delta(\ln \sigma)}{\Delta(1/T)} = \frac{-E_g}{2k}$$

$$E_g = \frac{-(\ln\sigma_2 - \ln\sigma_1) \times 2 \times K}{(1/T_2 - 1/T_1)}$$

$$= -\frac{(-4.3750 + 2.9937)}{(3.003 - 2.681)\times 10^{-3}} \times 2 \times 1.38\times 10^{-23}$$

$$= \frac{1.3813}{0.322\times 10^{-3}} \times 2.76\times 10^{-23}$$

$$= 11.839 \times 10^{-20}$$

$$= 1.1839 \times 10^{-19}$$

$$= \frac{1.1839\times 10^{-19}}{1.6\times 10^{-19}} = 0.739 \approx 0.74\ eV$$

5. Intrinsic (silicon) semiconductor has a carrier concentration of $1.1\times 10^{16}\ m^{-3}$. If the mobilities of electrons and holes are 0.17 and 0.035 $m^2 V^{-1} s^{-1}$ respectively at room temperature, compute the resistivity of silicon.

$$\sigma_i = n_i e(\mu_e + \mu_h)$$

$$= 1.1\times 10^{16} \times 1.6\times 10^{-19}(0.17 + 0.035)$$

$$= 1.76\times 10^{-3}(0.205)$$

$$= 0.3608 \times 10^{-3}$$

$$= 3.608\times 10^{-4}\ ohm^{-1} m^{-1}$$

Resistivity $= \frac{1}{\sigma} = \rho = \frac{1}{3.608\times 10^{-4}} = 2.77\times 10^{4}$ ohm

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6. The compound galluim arsenide has an intrinsi-c conductivity of 10^{-6} ohm^{-1}m^{-1} at 20°C. How many electrons have jumped the forbidden energy gap?

[Given : $\mu_e = 0.88\ m^2 V^{-1} s^{-1}$ and $\mu_h = 0.04\ m^2 V^{-1} s^{-1}$]

$$n_i = \frac{\sigma}{e}(\mu_e + \mu_h) \qquad \frac{\sigma}{e(\mu_e + \mu_h)}$$

$$= \frac{1 \times 10^{-6}}{1.6 \times 10^{-19}} \cdot (0.88 + 0.04)$$

$$= \cancel{0.625 \times 10^{13} (0.92)}$$

$$= \frac{1 \times 10^{-6}}{1.6 \times 10^{-19} (0.92)} = 6.79 \times 10^{12}\ m^{-3}$$

7. The resistivity of Ge at 20°C is 0.5 ohm m. What will be its resistivity at 40°C if band gap of Ge is 0.7eV?

$$= \frac{\Delta(\ln \rho)}{\Delta(1/T)} = \frac{E_g}{2K}$$

$$E_g = \frac{\Delta(\ln \rho)}{\Delta(1/T)} \times 2k$$

$$\Delta \ln(\rho) = \frac{E_g}{2K} \times \Delta(1/T)$$

$$= \frac{0.7 \times 1.6 \times 10^{-19} \times (1/313 - 1/293)}{2 \times 1.38 \times 10^{-23}}$$

$\cancel{1/12(3.19 - 3.41) \times 10^{-3}}$

$$\ln \rho_{40} = \ln \rho_{20} = -0.885$$

$$= -0.693 - 0.885$$

$$= -1.578$$

$$\rho_{40} = 0.206 \text{ ohm m}$$

8. An intrinsic Semiconductor has an energy gap of 0.7eV. Calculate probability of occupation of the lowest level in conduction band at 0°, 50°, 100°

- Lowest level in Conduction Band

$$(E - E_f) = 0.35 eV$$

probability

$$F(E) = \frac{1}{1 + \exp((E - E_F)/KT)}$$

1. The critical temperature and critical magnetic field for superconducting lead are 7.2 K and 800 ~~guss~~ gauss respectively. What will be the temperature upto which lead will be in superconductivity state in a magnetic field of 400 guass

$\Rightarrow$ $T_c = 7.2$

$H_c(0) = 800K$

$H_c(T) = 400 K$

$$H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

$$400 = 800\left[1 - \frac{T^2}{51.84}\right]$$

$$\frac{1}{2} - 1 = -\frac{T^2}{51.8}$$

$- 0.5$ $\quad$ $25.9 = T^2$

$$T = 5.09K$$

2) Supercoducting ~~lime~~ tin has a critical magnetic field of 217 gauss at 2K. If the critical temperature for superconducting transition for tin is 3.7 K, find the critical magnetic field at 3K?

$$H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

$$H_c(T_1) = H_c(0)\left[1 - \left(\frac{T_1}{T_c}\right)^2\right] \quad - (1)$$

$$H_c(T_2) = H_c(0)\left[1 - \left(\frac{T_2}{T_c}\right)^2\right] \quad - (2)$$

$$\frac{H_c(T_1)}{H_c(T_2)} = \frac{T_c^2 - T_1^2}{T_c^2 - T_2^2}$$

$$= \frac{(3.7)^2 - (2)^2}{(3.7)^2 - (3)^2}$$

$$= \frac{13.69 - 4}{13.69 - 9} = \frac{9.69}{4.69}$$

$$\frac{217}{H_c(T_2)} = \underline{\underline{2.066}}$$

$$H_c(T_2) = 105.02 \text{ Gauss}$$

3) The transition temperature for Pb is 7.2K. However at 5K it is loses the superconducting property if subjected a magnetic field of 3.3×10^4 A/m. Find the maximum value of H which will allow the

metal to retain its superconductivity at 0K

→ $T_c = 7.2K$ $\qquad H_c(T) = 3.3 \times 10^4$

$T = 5K$

$$H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

$$3.3 \times 10^4 = H_c(0)\left[1 - \left(\frac{5}{7.2}\right)^2\right]$$

$$= H_c(0)\left[1 - \frac{25}{51.84}\right]$$

$$3.3 \times 10^4 = H_c(0)[1 - 0.48]$$

$$3.3 \times 10^4 = H_c(0)[0.52]$$

$$H_c(0) = 6.34 \times 10^4 \, A/m$$

4) The critical field of Nb is 1×10^5 A/m at 8K, and 2×10^5 A/m at 0K. Calculate the Transition temperature of the element.

→ $H_c(T) = 1 \times 10^5$ A/m

$H_c(0) = 2 \times 10^5$ A/m

$T = 8K$

$T_c = ?$

$$H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

$$1 \times 10^5 = 2 \times 10^5\left[1 - \left(\frac{8}{T_c}\right)^2\right]$$

$$\frac{1\times10^5}{2\times10^5} = 1 - \frac{64}{(T_c)^2}$$

$$0.5 = \frac{1-64}{T_c^2}$$

$$(T_c)^2 = \frac{1-64}{0.5}$$

$$T_c = 11.31$$

1. The hall co-efficient of a specimen of a doped silicon is found to be $3.66\times10^{-4}\ m^3/c$. The restivity of the specimen is $8.93\times10^{-3}\ \Omega\,m$. Find the mobility and density of the charge carriers

Given : $R_H = 3.66\times10^{-4}\ m^3/c$

$\rho = 8.93\times10^{-3}\ \Omega\,m$

n = density of charge carriers.

$$n = \frac{1}{R_H e} = \frac{1}{3.66\times10^{-4}\times1.6\times10^{-19}}$$

$$= 0.1707\times10^{+23}$$

$$= 1.707\times10^{22}$$

$$\mu_e = \frac{\sigma}{ne} = R_H\sigma = R_H\cdot\frac{1}{\rho} = \frac{3.66\times10^{-4}}{8.93\times10^{-}}$$

$\mu_e = 0.041\ m^2/Vs$

2. A semiconductor sample of thickness $1.2 \times 10^{-4} m$ is ~~phased~~ placed in a magnetic field of 0.2 T acting perpendicular to its thickness. Find the hall voltage generated when a current of 100 mA passes through it. Assume the ~~charge~~ ~~con~~ carrier concentration is $10^{23} m^{-3}$

Given: $t = 1.2 \times 10^{-4} m$ $\quad I = 100\ mA$

$B = 0.2T$ $\quad e = 1.6 \times 10^{-19}$

$V_H = ?$

$n = 10^{23} m^{-3}$

$$V_H = \frac{3\pi B I}{8\ net} = \frac{3 \times 3.14}{8} \cdot \frac{0.2 \times 100 \times 10^{-3}}{10^{23} \times 1.6 \times 10^{-19} \times 1.2 \times 10^{-4}}$$

$$= \frac{9.42 \times 20 \times 10^{-3}}{8 \times 1.92 \times \cancel{10^{23}} \times \cancel{10^{-23}}} = \frac{188.4 \times 10^{-3}}{15.36}$$

$$= 12.26 \times 10^{-3}$$

3. The Hall Co-efficient of a semiconductor is $3.22 \times 10^{-4}\ m^3/C$. Its resistivity is $9 \times 10^{-3}\ \Omega\ m$. Calculate mobility and carrier concentration

$$n = \frac{1}{R_H e} = \frac{1}{3.22 \times 10^{-4} \times 1.6 \times 10^{-19}}$$

$$= \frac{1}{5.152 \times 10^{-23}} = 0.1940 \times 10^{23}$$

$$= 1.94 \times 10^{22}$$

$$\mu_e = R_H \cdot \frac{1}{\rho} = \frac{1.94 \times 10^{22} \cdot 1}{9 \times 10^{-3}}$$

$$= 0.02156 \times 10^{-3} \, m^2/Vs$$

4. A Si plate of thickness 1 mm, breadth 1 cm, and length 10 cm is placed in a magnetic field of 0.5T, acting perpendicular to axis. If 1A current flows along its length, calculate the Hall Voltage developed, if hall co-efficient is $3.66 \times 10^{-4} m^3 C^{-1}$

$$V_H = R_H \cdot \frac{BI}{t} = 3.66 \times 10^{-4} \frac{\times 0.5 \times 1}{\cancel{3}.1 \times 10^{-3}}$$

$$= 3.66 \times 10^{-4} \times 0.5 \times 10^{+3}$$

$$= 1.83 \times 10^{-1}$$

$$V_H = 0.183 \cancel{\times 10^{-8}}$$

$$V_H = 0.183 \, V$$

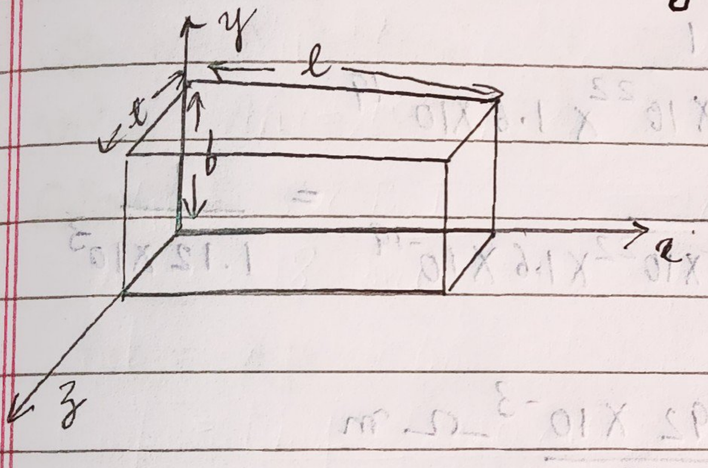
5. Calculate the Hall Voltage across ~~is~~ a semiconduc[tor] with following data

- Width – 0.11m, • Thickness = 0.01m, Magnetic field = 0.6T
- Current, I = 10mA • Hall coefficient $R_H = 3.84 \times 10^{-4} m^3 [C^{-1}]$

$$V_H = R_H \cdot \frac{BI}{t} = 3.84 \times 10^{-4} \frac{\times 0.6 \times 10 \times 10^{-3}}{0.01}$$

$$= 2304 \times 10^{-7} = 2.304 \times 10^{-4} \, V$$

6. A rectangular plane sheet of a semiconductor material of dimensions 2 cm along Y direction, and 1 mm along z direction. Hall probs are attached on its surfaces parallel to xz plane and a magnetic field of flux density of 1 Weber/m². is applied along z direction. A current of 3 mA is flowing in it in the X-direction. Calculate the Hall voltage measured by the probs if the Hall Coefficient of the material is $3.66 \times 10^{-4} m^2/c$. Also calculate the charge carrier.



a) $V_H = R_H \cdot \frac{BI}{t}$

$V_H = \frac{3.66 \times 10^{-4} \times 1 \times 3 \times 10^{-3}}{1 \times 10^{-3}}$

$= \frac{10.98 \times 10^{-7}}{1 \times 10^{-3}}$

$V_H = \underline{10.98 \times 10^{-4}} \ V$

$\approx \underline{\underline{1.1}} \ mV$

b) → $R_H = \frac{1}{ne}$

$n = \frac{1}{R_H e} = \frac{1}{3.66 \times 10^{-4} \times 1.6 \times 10^{-19}} = \frac{1.71 \times 10^{23}}{c/m^3}$

7. A sample of Si is doped with 10^{22} Phosphorous atom /m^3. What is its resistivity ? What hall voltage would you expect in the sample of $100\mu m$ thick when the current of 1mA is passed perpendicular to a magnetic field of 0.1T

<u>Given</u> : $\mu_e = 0.7 \, m^2/Vs$

= $\rho = ?$

$$\mu_e = \frac{\sigma}{ne} = \frac{1}{\rho ne}$$

$$0.7 = \frac{1}{\rho \times 10^{22} \times 1.6 \times 10^{-19}}$$

$$\rho = \frac{1}{0.7 \times 10^{22} \times 1.6 \times 10^{-19}} = \frac{1}{1.12 \times 10^{3}}$$

$$\rho = \underline{0.892 \times 10^{-3}} \, \Omega m$$

$$V_H = R_H \cdot \frac{BI}{t} = \frac{1}{ne} \cdot \frac{BI}{t}$$

$$= \frac{1 \times 0.1 \times 1 \times 10^{-3}}{10^{22} \times 1.6 \times 10^{-19} \times 100 \times 10^{-6}}$$

$$= \frac{0.1 \times 10^{-3}}{160 \times 10^{-3}} = 6.25 \times 10^{-4}$$

$$= \underline{0.625 \times 10^{-3} \, V}$$

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or

$$V_H = \frac{3\pi}{8} \frac{1}{ne}$$

$$= \frac{3 \times 3.14 \times 1}{8 \times 10^{22} \times 1.6 \times 10^{-19}}$$

$$= \frac{9.42}{12.8 \times 10^{3}} = \underline{0.73 \times 10^{-3} \, V}$$

8. A current of 3 mA is flowing in a semiconducting material of length 2 cm and width 1 mm. Calculate the Hall voltage, if the Hall coefficient is 3.66×10^{-4} m^3/c. Also calculate charge concentration

Given : B = 1T

$$V_H = R_H \cdot \frac{BI}{t} = \frac{3.66 \times 10^{-4} \times 1 \times 3 \times 10^{-3}}{1 \times 10^{-3}}$$

$$= \frac{10.98 \times 10^{-7}}{10^{-3}}$$

$$= \underline{10.98 \times 10^{-4}}$$

$$\underline{V_H = 1.098 \times 10^{-3} \, V}$$

$$n = \frac{1}{R_H e} = \frac{1}{3.66 \times 10^{-4} \times 1.6 \times 10^{-19}} = \frac{1}{5.856}$$

$$\underline{0.1707 \times 10^{23}}$$