EEE118 Homework.

1. $L = 2m$, $A = 1mm^2 = 1\times10^{-6} m^2$ $\quad \rho_0 = 2.82\times10^{-8}\,\Omega m$.

$$R = \rho_0 \frac{L}{A} \quad ①$$

$$\Rightarrow R = \frac{2.82\times10^{-8}\cdot 2}{1\times10^{-6}} = 0.0564\,\Omega = 56.4\,m\Omega$$

$$\rho = \rho_0\left(1 + a\left(T - T_0\right)\right] \quad ② \quad a = 0.0039\,K^{-1}$$

$$R = \rho\frac{L}{A} \Rightarrow \frac{R\cdot A}{L} = \rho \quad ③ \qquad R = 0.1\,\Omega$$

$$\Rightarrow ② + ③ \Rightarrow \frac{0.1\times1\times10^{-6}}{2} = 2.82\times10^{-8}\left(1 + 0.0039\left(T - 20\right)\right]$$

$$\Rightarrow \frac{0.1\times1\times10^{-6}}{2\times2.82\times10^{-8}} = 1 + 0.0039\left(T - 20\right)$$

$$\Rightarrow 1.77305 = 1 + 0.0039\left(T - 20\right)$$

$$\Rightarrow 0.77305 = 0.0039\left(T - 20\right)$$

$$\Rightarrow 198.218 = T - 20$$

$$\Rightarrow T = 218.22\,^\circ C = 491.37\,K$$

2. $n_i = 1\times10^{16}\,m^{-3}$

$$n_i = C T^{3/2} \exp\left(-\frac{W_g}{2K_BT}\right) \qquad W_{g_{Si}} = 1.1\,eV.$$

$$T_{R.T} = 293.15\,K.$$

$$\Rightarrow C = \frac{n_i}{T^{3/2}\cdot\exp\left(-\frac{W_g}{2K_BT}\right)} = \frac{1\times10^{16}}{293.15^{3/2}\cdot\exp\left(-\frac{1.1\times1.6\times10^{-19}}{2\times1.381\times10^{-23}\times293.15}\right)}$$

$$= \frac{10^{16}}{5019.2\times\exp\left(-21.737\right)}$$

$$= 5.49\times10^{21}\,m^{-3} = 5.5\times10^{21}.$$

$$\Rightarrow \text{at } T = 350K \qquad n_i = 5.5\times10^{21}\times350^{3/2}\cdot\exp\left(-\frac{1.1\times1.6\times10^{-19}}{2\times1.381\times10^{-23}\times350}\right)$$

$$= 5.49\times10^{21}\times6547.9\times\exp\left(-18.206\right)$$

$$= 4.454\times10^{17}\,m^{-3}.$$

In semiconductors, the band gap is big but small enough for few electrons to take a leap to the conduction band and conduct electricity to some extend. However with increase in temperature they get charged with thermal energy which is sufficient to overcome the energy barrier and leap to the conduction band and thus, their conductivity increases, i.e the carrier concentration increases.

3. $I = 20\,mA = 20\times10^{-3} A$

$V = 0.2V$

$e = 1.6\times10^{-19}\,C$

$J_0 = 9\,A\,m^{-2}$ but $J_0 = \frac{I_0}{A \to \text{area}}$.

$$I = I_0\left(\exp\left(\frac{eV}{K_BT}\right)-1\right)$$

$$20\times10^{-3} = 9 \cdot A \cdot \left[\exp\left(\frac{1.6\times10^{-19}\times0.2}{1.381\times10^{-23}\times293.15}\right)-1\right]$$

$$\Rightarrow 20\times10^{-3} = 9 \cdot A\left[\exp(7.9044)-1\right].$$

$$\Rightarrow A = \frac{20\times10^{-3}}{9\times2708.05}$$

$$\Rightarrow A = 8.21\times10^{-7}\,m^2 = 0.821\times10^{-6}\,m^2 = 0.821\,mm^2$$

4. $$C = A\left(\frac{e\varepsilon}{2(V_0-V)}\cdot\left(\frac{N_aN_d}{N_a+N_d}\right)\right]^{1/2}$$

$N_a = N_d$

$$\Rightarrow C = A\left[\frac{e\varepsilon}{2(V_0-V)}\cdot\frac{N_a^2}{2N_a}\right]^{1/2} = A\left(\frac{e\varepsilon}{2(V_0-V)}\cdot\frac{N_a}{2}\right)^{1/2} = K$$

$10N_a = N_d$

$$\Rightarrow C = A\left[\frac{e\varepsilon}{2(V_0-V)}\cdot\frac{10N_a^2}{11N_a}\right]^{1/2} = A\left(\frac{e\varepsilon}{2(V_0-V)}\cdot\frac{10N_a}{11}\right]^{1/2}$$

$$= C = A\left[\frac{e\varepsilon}{2(V_0-V)}\cdot\frac{N_a}{2}\cdot\frac{2\times10}{11}\right]^{1/2} = A\left(\frac{e\varepsilon}{2(V_0-V)}\cdot\frac{N_a}{2}\right)^{1/2}\cdot\left(\frac{20}{11}\right)^{1/2}$$

$$= 1.348\,K$$

5. $a = 2\mu m = 2\times10^{-6}m$, $L_g = 3\mu m = 3\times10^{-6}m$

$\rho = 3\times10^{-3}\,\Omega m$, $V_p = 3V$ $I = 1A$

$$I_d = \frac{Z\cdot a\cdot V_p}{\rho L_g\cdot 3} \Rightarrow 1 = \frac{Z\times2\times\cancel{10^{-6}}\times\cancel{3}}{3\times10^{-3}\cdot3\times\cancel{10^{-6}}\cdot\cancel{3}} \Rightarrow Z = \frac{9\times10^{-3}}{2} = 4.5\,mm.$$

6. $$\gamma = \frac{I_{E_e}}{I_{E_e}+I_{E_h}} = \frac{500}{500+1} = 0.998 \quad , B = 0.98$$

current transfer ratio, $a = \gamma\times B = 0.998\times0.98 = 0.978$

$$\beta = \frac{a}{1-a} = \frac{0.978}{1-0.978} = 44.45.$$