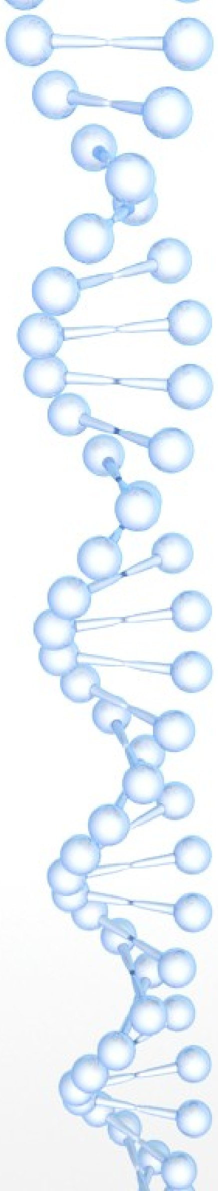
Tutorial 7

Semiconductor



Formulae

$$KE = \frac{1}{2} m v^2$$

$$I = n e v_d A$$

$$P(E) = \frac{1}{1 + e^{\frac{(E - E_F)}{kT}}}$$

Numerical 1

Calculate the speed of conduction electron in copper having its kinetic energy equal to Fermi energy of 7.0 eV. Also calculate the drift velocity if a current of 5 A is flowing in a copper wire with a cross section of 0.5 mm^2. Free electron density in copper is 8.5×10^{28} $/m^3$ and the charge on the electron is 1.6×10^{-19} C. Which velocity is greater? Why? Comment on the results

Solution

$$KE = \frac{1}{2} m v^2 \quad \Rightarrow 7\,eV = \frac{1}{2} m v^2 \quad \Rightarrow 7 \times 1.6 \times 10^{-19}\,J = \frac{1}{2} \times 9.1 \times 10^{-31} v^2$$

$$I = n e v_d A \qquad \Rightarrow 5 = 8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times v_d \times 0.5 \times 10^{-6}$$

Numerical 2

Find the probability with which an energy level 0.02 eV below Fermi level will be occupied at room temperature of 300 K and 1000 K. What do the results signify?

$$P(E)=\frac{1}{1+e^{\frac{(E-E_F)}{kT}}}$$

As the energy level is below the Fermi level, $(E-E_F)=-0.02$

$$k=1.38\times10^{-23}\frac{J}{K}=8.63\times10^{-5}\frac{eV}{K}$$

Thus, at T = 300 K,

At T = 1000 K ?

$$P(E)=\frac{1}{1+e^{\frac{-0.02}{8.63\times10^{-5}\times300}}}=0.68=68\,\%$$

Numerical 3

Find the probability of an electron occupying an energy level 0.02 eV above the Fermi level at 300 K and 1000 K. What do the results signify?

$$\left(E - E_F\right) = +0.02$$

Numerical 4

At any given nonzero temperature, what is the probability of occupancy for a state whose energy is equal to Fermi energy?

$$P(E) = \frac{1}{1 + e^{\frac{(E - E_F)}{kT}}}$$

If $T \neq 0\,K$ and $E = E_F$

$$P(E = E_F) = \frac{1}{1 + e^{\frac{(E_F - E_F)}{kT}}} = 0.5 = 50\,\%$$

Numerical 5

Find the temperature at which there is 1 % probability that a state with energy 0.5 eV above Fermi energy will be occupied. What does the result signify?

$$P(E) = \frac{1}{1 + e^{\frac{(E - E_F)}{kT}}}$$

$$0.01 = \frac{1}{1 + e^{\frac{5793}{T}}}$$

$$\Rightarrow \frac{1}{0.01} = \frac{1 + e^{\frac{5793}{T}}}{1}$$

$$\Rightarrow 99 = e^{\frac{5793}{T}}$$

$$\Rightarrow \ln 99 = \frac{5793}{T}$$

$$\Rightarrow 4.595 = \frac{5793}{T} \Rightarrow T = 1261\,K$$

Numerical 6

Calculate the free electron density in copper, if each copper atom donates one electron to the conduction band. (Properties of copper: Density = 8.96 gm/cc, atomic weight 63.5 and Avogadro's number = 6.02×10^{23} atoms/mole)

63.5 gm of copper contains 6.023×10^{23} atoms

$$\Rightarrow 1\text{gm of copper contains } \frac{6.023\times10^{23}}{63.5}\frac{atoms}{gm}$$

$$\Rightarrow 8.96\,\frac{gm}{cc}\text{ of copper contains } \frac{6.023\times10^{23}}{63.5}\left(\frac{atoms}{gm}\right)\times 8.96\left(\frac{gm}{cc}\right)$$

$$= 8.5 \times 10^{22}\,\frac{atoms}{cc}$$

$$= 8.5 \times 10^{22}\,\frac{electrons}{cc}$$ as each copper atom donates 1 electron in conduction band

Numerical 7

Resistance of copper wire of diameter 1.03 mm is 6.51 ohm per 300 m. The concentration of free electrons in copper is 8.4×10[28] /m[3]. If the current is 2 A, find the mobility of free electrons

Diameter of copper wire = 1.03 mm = 1.03×10^{-3} m

Radius = $\frac{1.03\times10^{-3}}{2} = 5.15 \times 10^{-4}\, m$

Area $\pi r^2 = 3.14 \times (5.15 \times 10^{-4})^2 = 8.33 \times 10^{-7} m^2$

We know that $\rho = \frac{RA}{l} = \frac{6.51\times8.33\times10^{-7}}{300} = 1.81 \times 10^{-8}\, \Omega.m$

$$\sigma = \frac{1}{\rho} = \frac{1}{1.81 \times 10^{-8}} = 5.5 \times 10^{7}\, \frac{mho}{m}$$

We have

$$\sigma = ne\mu$$

$$\Rightarrow \mu = \frac{\sigma}{ne} = \frac{5.5 \times 10^{7}}{8.4 \times 10^{28} \times 1.6 \times 10^{-19}} = 4.11 \times 10^{-3}\, \frac{m^2}{V.s}$$

Numerical 8

Calculate the conductivity of pure/intrinsic silicon if free electron concentration is 1.5×10^{10} /cm^3 and mobility of electrons and holes are 1500 cm^2/V.s and 500 cm^2/V.s respectively

$$\sigma_i = e\, n_i \left(\mu_e + \mu_h\right)$$

$$n_i = 1.5\times10^{10}/cm^3 = 1.5\times10^{16}/m^3$$

$$\mu_e = 1500\,\frac{cm^2}{V.s} = 0.15\,\frac{m^2}{V.s} \wedge \mu_h = 500\,\frac{cm^2}{V.s} = 0.05\,\frac{m^2}{V.s}$$

$$\sigma_i = 1.6\times10^{-19}\times1.5\times10^{16}\times\left(0.15+0.05\right) = 4.8\times10^{-4}\,mho/m$$

Numerical 9

Intrinsic silicon is doped with phosphorus with the atomic ratio of 10^8 (Si) : 1 (P). Calculate the conductivity of N type of silicon thus formed

Properties of silicon: Density = 2.3290 g/cm^3
Atomic weight =28.085
Avogadro's number = 6.02×10^{23}

conductivity = $\sigma_N = n_e e \mu_e$

Numerical 10

A strip of copper having thickness 0.5 mm is placed in a magnetic field of magnitude 0.75T. A current of 100 mA is sent through the strip. What is the Hall potential difference that will appear across the width of the strip? The carrier concentration of electrons in copper is 8.47×10^{28} electrons/m^3

$$V_H = \frac{1}{nq} B I \frac{1}{t}$$

Numerical 11

A copper specimen having length 1m, width 1cm, and thickness 1mm is conducting with 1A along its length and is applied with a magnetic field of 1T along its thickness. It experiences Hall effect and a Hall voltage 0.074μV appears along its thickness. Calculate the Hall coefficient, electron concentration and the mobility of electrons in copper. Conductivity of copper is $5.8\times10^{7}\ (\Omega m)^{-1}$.

$$V_H = \frac{1}{nq} IB\frac{w}{A} = R_H IB\frac{w}{A}$$

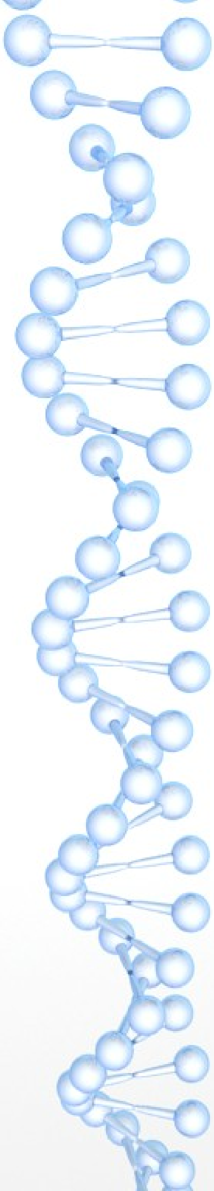
$$R_H = \frac{1}{nq}$$

$$\mu = \sigma R_H$$

Numerical 12

N type semiconductor having length 1cm, width 1mm and thickness 0.1mm is made to conduct with 1mA current and is placed in the magnetic field acting along it's thickness. The Hall voltage is measured to be 3.44×10^{-7}V. Calculate the magnetic field, if the Hall coefficient of the specimen is $-3.44\times10^{-8}\,m^3/C$.

$$V_H = \frac{1}{nq} IB \frac{w}{A} = R_H IB \frac{w}{A} = R_H IB \frac{1}{t}$$



THANK YOU