UNIT-I - Problems

1. Calculate the conductivity of intrinsic germanium at 300K using the following data.

$n_i = 2.4 \times 10^{19} /m^3$

$\mu_e = 0.39 \; m^2 v^{-1} s^{-1}$

$\mu_h = 0.19 \; m^2 v^{-1} s^{-1}$

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

$= 2.4 \times 10^{19} \times 1.6 \times 10^{-19} (0.39 + 0.19)$

$\sigma = 2.2272 \; (\text{ohm m})^{-1}$

2. Find the resistance of an intrinsic germanium rod 1cm long, 1mm wide, 1mm thick at 300K, for Ge, $n_i = 2.5 \times 10^{19}/m^3$

$\mu_e = 0.39 \; m^2 \; v^{-1} s^{-1}$

$\mu_h = 0.19 \; m^2 \; v^{-1} s^{-1}$ at 300k.

$L = 1cm = 1 \times 10^{-2} m$

$A = w \times t = 10^{-3} \times 10^{-3} = 10^{-6} m^2$

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

$\sigma = \frac{1}{\rho}, \quad \rho = \frac{1}{\sigma} = \frac{1}{n_i e(\mu_e + \mu_h)}$

$$\rho = \frac{RA}{L}$$

$$R = \frac{L}{n_i e(\mu_e + \mu_h) A}$$

$$R = 4.31 \times 10^{3} \text{ ohm}$$

3. Calculate the drift velocity of electrons in copper and current density in wire of diameter 0.16 cm which carries a steady current of 10 A.

Given $n = 8.46 \times 10^{28} \text{ m}^{-3}$

Diameter of the wire = $d = 0.16\text{cm}$

current flowing = 10 A

$$J = \frac{I}{A} = \frac{10}{\pi r^2}$$

$$J = \frac{10}{\pi (d/2)^2} \quad [\because r = d/2]$$

$$= \frac{10}{3.14 \times (0.16 \times 10^{-2}/2)^2}$$

$$J = 4.979 \times 10^{6} \text{ Am}^{-1} \quad \boxed{J = ne v_d}$$

$$v_d = J/ne = \frac{4.97 \times 10^{6}}{8.46 \times 10^{28} \times 1.6 \times 10^{-19}}$$

$$v_d = 3.67 \times 10^{-4} \text{ ms}^{-1}$$

4. Find the lowest energy of an electron Confined in one dimensional potential box separated by distance 0.1 nm.

$l = 0.1\,nm \qquad n = 1$

$$E_n = \frac{n^2h^2}{8ml^2} = \frac{(1)^2 \times (6.62\times10^{-34})^2}{8\times9.1\times10^{-31}\times(0.1\times10^{-9})^2}$$

$$E_1 = 6.0198\times10^{-19}\,J$$

5. An electron is bound in one dimensional infinite well of width $1\times10^{-10}\,m$. Find the energy value in the ground state, first and second excited states.

$$E_n = \frac{n^2h^2}{8ml^2} \qquad \text{ground state } n=1$$

$h = 6.625\times10^{-34}\,Js$

$m = 9.1\times10^{-31}\,kg$

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

I excited state $n=2$

II excited state $n=3$

$$E_1 = \frac{(1)^2\times(6.625\times10^{-34})^2}{8\times9.1\times10^{-31}\times(1\times10^{-10})^2} = \frac{43.89\times10^{-68}}{72.8\times10^{-31}\times10^{-20}}$$

$$E_1 = \frac{0.6028\times10^{-68}\times10^{51}}{1.6\times10^{-19}} = 0.376\times10^{-17}\times10^{19} = 37.6\,eV$$

$\boxed{E_1 = 37.6\,eV}$ $\qquad E_2 = (2)^2\times37.6 = 150.4\,eV$

$E_3 = (3)^2\times37.6 =$

6. Obtain the value of $F(E)$ for $E-E_F = 0.01$ eV at 200k with fermi distribution function.

$$F(E) = \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)} = \frac{1}{1+\exp\left(\frac{0.01\times1.6\times10^{-19}}{1.38\times10^{-23}\times 200}\right)}$$

$E-E_F = 0.01$ eV $= 0.01\times1.6\times10^{-19}$

$T = 200$ k

$k = 1.38\times10^{-23}$

$$= \frac{1}{1+\exp\left[\frac{0.016\times10^{-19}}{276\times10^{-23}}\right]}$$

$$= \frac{1}{1+\exp\left[5.797\times10^{-5}\times10^{-19}\times10^{23}\right]}$$

$$= \frac{1}{1+\exp\left[5.79\times10^{-1}\right]} = \frac{1}{1+\exp(0.579)}$$

$$= \frac{1}{1+1.784} = \frac{1}{2.784} = 0.359$$

$$\boxed{F(E) = 0.359}$$

7. The fermi level for Potassium is 2.1ev. Calculate the velocity of the electron at the fermi level.

$$E_F = \frac{1}{2} m v_F^2$$

$$v_F = \left(2E_F/m\right)^{1/2}$$

$$= \left[\frac{2 \times 2.1 \times 1.602 \times 10^{-19}}{9.1 \times 10^{-31}}\right]^{1/2}$$

$$v_F = 8.6 \times 10^5 \ m/s$$

8. Evaluate the fermifunction for energy k_BT above the fermi energy

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

$$E - E_F = k_BT$$

$$F(E) = \frac{1}{1+e^1} = \frac{1}{1+2.7183}$$

$$F(E) = 0.2689$$