Numericals - Unit-I

Q1- Calculate the probability that an energy level 2kT above the fermi energy is occupied by an electron?

Soln 1- $f(E) = \dfrac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}$

or $f(E) = 1/[1+\exp(2kT/kT)] = 1/[1+\exp(2)] = \dfrac{1}{1+7.38}$

$\Rightarrow 1/8.38 \Rightarrow 0.1193$ Ans.

Q2- Calculate the intrinsic concentration of charge carriers at 300K given that $m_e^* = 0.12 m_o$, $m_h^* = 0.28 m_o$ and the value of brand gap = 0.67eV ?

Soln 2- $m_e^* = 0.12 m_o = 0.12 \times 9.1 \times 10^{-31} = 1.092 \times 10^{-31}\ kg\,m^{-3}$

$m_h^* = 0.28 m_o = 0.28 \times 9.1 \times 10^{-31} = 2.548 \times 10^{-31}\ kg\,m^{-3}$

Intrinsic carrier concentration is given by,

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

$$2\left[\frac{2\pi kT}{h^2}\right]^{3/2} = 2\left[\frac{2\pi \times 1.38\times10^{-23} \times 300}{6.626\times10^{-34}}\right]^{3/2}$$

$$= 2(1.4421 \times 10^{70})$$

$$= 2.884 \times 10^{70}$$

$$(m_e^* m_h^*)^{3/4} = (1.092\times10^{31} \times 2.548\times10^{-31})^{3/4}$$

$$= 6.813 \times 10^{-47}$$

$$\exp\left[\frac{-E_g}{2k_BT}\right] = \exp\left[-\left(\frac{0.67\times1.6\times10^{-19}}{2\times1.38\times10^{-23}\times300}\right)\right]$$

$$= \exp(-12.9468)$$

$$= 2.3838 \times 10^{-6}$$

Numericals – UNIT 1

Q1 - Evaluate the fermi function for an energy kT above the fermi energy?

Soln 1 - $f(E) = \frac{1}{1+\exp(E-E_F/kT)} = \frac{1}{1+\exp\left(\frac{E_F+kT-E_F}{kT}\right)}$

$$= \frac{1}{1+\exp(kT/kT)} = \frac{1}{1+e} = \frac{1}{1+2.73} = 0.269$$

Q2 - In a solid, consider the energy level lying 0.01eV below fermi level. What was the probability of this level not being occupied by electron?

Soln 2 - Energy difference $= E_F - E = 0.01\,eV$

Thermal Energy at room temperature, $kT = 0.026\,eV$

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

$$f(E) = \frac{1}{1+e^{-0.01eV/0.026eV}}$$

$$= \frac{1}{1+e^{-0.3846}}$$

$$= 0.595$$

Thus $p = 1-f(E) = 1-0.595 = 0.405$

Q2 - Calculate the probalities for an electronic state to be occupied at 20°c, if the energy of these states lies 0.11eV above and 0.11eV above the fermi level!

(2)

Soln2 - Probability of occupying an energy level E,

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

Probability of occupying an energy level 0.11eV above fermi level

$$f(E) = \frac{1}{1+e^{0.11eV/kT}} = \frac{1}{1+e^{4.2307}} = 0.0126$$

Probability of occupying an energy level 0.11eV below fermi level

$$f(E) = \frac{1}{1+e^{-0.11eV/kT}} = \frac{1}{1+e^{-4.2307}} = 0.987$$

6) Find the position of fermi level E_F at room temperature (27°c) for germanium crystal using 5×10^{22} atoms/m³

Soln 6 $T = 27°C = 300K$ & $n_c = 5\times10^{22}/m^3$

$$n_c = 2\left[\frac{2\pi mkT}{h^2}\right]^{3/2} e^{(E_F-E_c)/kT}$$

$$e^{(E_F-E_c)/kT} = \frac{n_c}{2\left(\frac{2\pi mkT}{h^2}\right)^{3/2}}$$

$$e^{(E_F-E_c)/kT} = \frac{5\times10^{22}}{2\left[\frac{2\times3.14\times9.1\times10^{-31}\times1.381\times10^{-23}\times300}{(6.62\times10^{-34})^2}\right]^{1/2}}$$

$$= \frac{5\times10^{22}}{25.115\times10^{23}}$$

$$e^{(E_F-E_c)/kT} = 0.1991\times10^{-2}$$

$$e^{(E_c-E_F)/kT} = 502.296 \text{ or } E_c-E_F = \ln 502.296$$

$$\frac{E_c-E_F}{kT} = 6.2192 \text{ or } E_c-E_F = 0.161\text{ eV.}$$