BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE – PILANI, K K BIRLA GOA CAMPUS

FIRST SEMESTER 2022-2023

PHY F426 Mid Semester Exam (closed book) Time: 90 min

Physics of Semiconductor Devices Date: 01/11/2022, Tuesday Time: 4 pm – 5.30 pm

Max. Marks: 40

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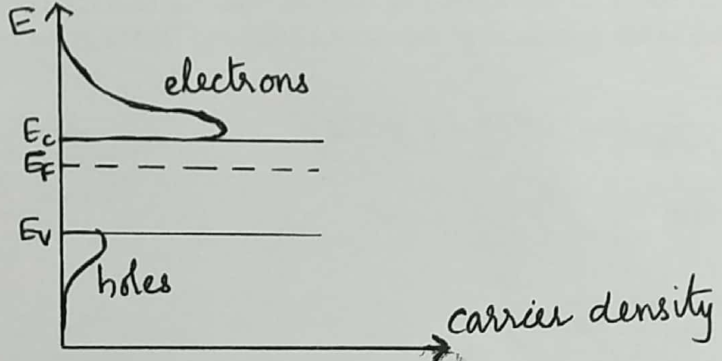
1) What is Brillouin zone? How is Brillouin zone and Brillouin zone boundary important in the context of the energy band gap of semiconducting materials? Explain **[2+3]**

2) What are direct and indirect band gap semiconductors? Explain with examples. Draw and explain the corresponding $E-k$ diagrams. **[4+4]**

3) The concentration of electrons in the conduction band reaches a maximum value at some energy value ΔE above E_c. This energy value is independent of the Fermi level. Find the value of that energy at $T=300\ K$ in terms of E_c. **[4]**



4) Consider silicon at $T = 300\ K$. Determine (a) p_o if $E_i - E_f = 0.35\ eV$. (b) Assuming that p_o from part (a) remains constant, determine the value of $E_i - E_F$ when $T = 400\ K$. (c) Find the value of n_o for part (a). What do you infer from these calculations? **[3+5+2+2]**

5) Consider a semiconductor that is non-uniformly doped with donor impurity atoms $N_d(x)$. Find out the induced electric field in the semiconductor in thermal equilibrium in terms of $N_d(x)$. **[4]**

6) A $2\ cm$ long piece of Si with cross-sectional area $0.1\ cm^2$ is doped with donors at $10^{15}\ cm^{-3}$ and has a resistance of $90\ ohms$. The saturation velocity of electrons in Si is $10^7\ cm/s$ for fields above $10^5\ V/cm$. Calculate the electron drift velocity, if we apply a voltage of $100\ V$ across the piece. What is the current through the piece if we apply a voltage of $10^6\ V$ across it? **[4+3]**

Useful parameters and equations:

Free electron mass = $9.1\text{x}10^{-31}$ kg

Planck's constant, h = $6.63\text{x}10^{-34}\ m^2kg/s$

Boltzmann's constant $k_B = 1.38 \times 10^{-23}\ m^2\ kg\ s^{-2}\ K^{-1}$

$$\left.\begin{array}{l} n_i\ (Si) = 1.5 \times 10^{10}\ cm^{-3} \\ N_c\ (Si) = 2.8 \times 10^{19}/cm^3 \\ N_v\ (Si) = 1.04 \times 10^{19}/cm^3 \\ E_g\ (Si) = 1.12\ eV \end{array}\right\}\ \text{at 300 K}$$

Intrinsic electron concentration,

$$n = 2\left(\frac{2\pi m_e^* k_B T}{h^2}\right)^{3/2} exp\left(\frac{E_F - E_C}{k_B T}\right)$$

For an n-type semiconductor,

$$N_d = n_i\, exp\left(\frac{E_F - E_i}{k_B T}\right)$$

The density of states for an electron of mass m_e^* located near the bottom of the conduction band with reference to the minimum of the conduction band (E_c) is given by

$$D(E)dE = \frac{1}{2\pi^2 \hbar^3}(2m_e^*)^{3/2}(E - E_c)^{1/2}dE$$

FD Distribution,

$$f(E) = \frac{1}{1 + \exp(\frac{E - E_F}{k_B T})}$$

The intrinsic carrier concentration,

$$n_i^2 = N_c N_v \exp\left(\frac{-E_g}{k_B T}\right)$$

The drift -diffusion equations,

$$J_{n,p} = (n,p)q\mu_{n,p}E \pm qD_{n,p}\frac{dn,p}{dx}$$