Roll No.:......................

National Institute of Technology, Delhi

Name of the Examination: B. Tech: Mid Semester Examination: Delayed Autumn 2022

Branch	**: ECE**	**Semester**	**: I**
Title of the Course	**: Basics of Electronics and Electrical Engineering**	**Course Code**	**: ECB 101**

Time: 1.5 Hours **Maximum Marks: 25**

- **Questions are printed on BOTH sides. Answers should be CLEAR AND TO THE POINT.**
- **All parts of a single question must be answered together. ELSE QUESTIONS SHALL NOT BE EVALUATED.**

Use following data if not given in a problem: $\varepsilon_o = 8.85 \times 10^{-14}$ F/cm, $\varepsilon_r(SiO_2) = 3.9$, $\varepsilon_r(Si) = 11.8$, At room temperature for Si [$\mu_n = 1350 cm^2/V{\cdot}S$, $\mu_p = 480\ cm^2/V{\cdot}S$, $n_i = 1.5 \times 10^{10}/cm^3$, $E_g = 1.12$ eV], $k = 8.62 \times 10^{-5}$ eV/K, $\tau_n = \tau_p = 1 \mu s$, $E_g(Ge) = 0.7$ eV, $n_i(Ge) = 2.5 \times 10^{13}/cm^3$.

1.	Find the expressions for equilibrium electron concentration and equilibrium hole concentration for a semiconductor sample at the condition of maximum conductivity at a particular temperature. [$n_i = p_i$ = intrinsic carrier concentrations; $\mu_n = \mu_p$ = mobilities for carriers.	**[3M]**
2.	The bandgap of an unknown semiconductor material is 1.95 eV. Determine the wavelength of the electromagnetic radiation in *nm* and write down the *color* of the electromagnetic radiation emitted upon the direct recombination of electrons-holes in that semiconductor sample.	**[2M]**
3.	Sketch and label the energy band diagram, i.e., the valence band (E_V), conduction band (E_C), Fermi energy level (E_F), and intrinsic energy level (E_i), for a Si semiconductor sample at room temperature for following every case. [E_g (Si) = 1.12 eV at room temperature, $n_i = 1.5 \times 10^{10}/cm^3$, and KT = 0.026 eV] (a) Intrinsic. (b) Doped with $10^{17}/cm^3$ Phosphorous dopant. (c) What is the type of semiconductor material in case (b)? (d) Doped with $10^{17}/cm^3$ Boron dopant. (e) What is the type of semiconductor material in case (d)?	**[7M]**

4.	Assume the Fermi-energy level (E_F) for a particular semiconductor material is 6.25 eV, and the semiconductor material follows the Fermi-Dirac distribution. Calculate the temperature at which there is a 1 percent probability that an energy state is 0.30 eV below the E_F and will contain no electron.	**[2M]**
5.	Calculate the position of Fermi-energy level (E_F) for a semi-ideal semiconductor material w.r.t the center of band gap (E_g) in eV, where effective masses for electrons and holes are different and given as $m_n^* = 1.08 \times m_0$ and $m_p^* = 0.56 \times m_0$.	**[3M]**
6.	A Si sample at T=300K contains an acceptor impurity concentration, $N_A = 10^{16}/\ cm^3$. Determine the concentration of the donor impurity to be added so that the above Si sample becomes n-type and the E_F becomes 0.20 eV below the conduction band edge (E_C). [$N_C = 2.8 \times 10^{19}\ /cm^3$; $K.T = 0.0259$ eV]	**[3M]**
7.	Answer the changes in each of the following parameters in a semiconductor material in terms of "increasing" or "decreasing," as the case may be when temperature increases in each of the following cases. (a) Conductivity (b) Mobility due to impurity. (c) Width of the conduction band. (d) Bandgap (e) Intrinsic carrier concentration	**[5M]**

Useful Equations

$$\epsilon_r = \frac{\epsilon(\omega)}{\epsilon_0}$$

$$V \equiv \int_{x0}^{x} €_x . dx$$

$$€_x = \frac{-V}{x-x0} = \frac{-V}{d} \text{ ; d = (x-x0)}$$

$$J = \frac{N.q.v}{L.A} = N.q.\ V\ (volume)$$
$$= \rho\ (Charge\ Density).V$$

$$f \sim \frac{W2 - W1}{h}$$

λ = h/mv = h/p, where p = mv

$$\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{1.24}{Eg\ (eV)}\ \mu m$$

$$E = \frac{1}{2} m.v2 = \frac{p2}{2m} = \frac{\hbar 2}{2m} k^2,\ since\ p = \hbar.k$$

$$\text{n}= p = n_i \propto \exp[-\frac{E_g}{2.K.T}]$$

$$f(E) = \frac{1}{1 + exp\frac{(E-EF)}{KB.T}}$$

$$J_{p,\,drift} = q.p.v_{dp}$$

$$J_{drift} = J_{p,drift} + J_{n,drift} = q.\ [\mu_n.n + \mu_p.p].E$$

$$\frac{I}{A} = \sigma(\frac{V}{L}) \text{ or } V = \left(\frac{L}{\sigma.A}\right).I = \left(\frac{\sigma.L}{A}\right).I = I.R$$

$$n_0 = \int_{Ec}^{\infty} f(E)N(E)dE = N_C.\exp[\frac{-(E_C - E_F)}{KT}]$$

$$p_0 = \int_{Ec}^{\infty} [1 - f(E)].N(E)dE$$
$$= N_V.\exp[\frac{-(E_F - E_V)}{KT}]$$

$$N_C = 2.\left[\frac{2.\pi m_n*.K.T}{h^2}\right]^{3/2} \quad ; N_V = 2.\left[\frac{2.\pi m_p*.K.T}{h^2}\right]^{3/2}$$

$$n_i^2 = n_0.p_0$$

$$n_i = N_C.\exp[\frac{-(E_C-E_i)}{K.T}]$$

$$p_i = N_V.\exp[\frac{-(E_i - E_V)}{K.T}]$$

$$n_0 = N_C.\exp[\frac{-(E_C-E_F)}{K.T};\quad p_0 = N_V.\exp[\frac{-(E_F-E_V)}{K.T}]$$