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

National Institute of Technology, Delhi

Name of the Examination: Mid Semester Examination (B. Tech)

Branch	**: ECE**	**Semester**	**: III**
Title of the Course	**: Solid State Devices**	**Course Code**	**: ECB 201**

Time: ~~3~~ 2 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 QUESTION SHALL NOT BE EVALUATED.**

Use following data only if not given in a problem: ε_o = 8.85x10^{-14}F/cm, ε_r (SiO_2) = 3.9, ε_r (Si) = 11.8, At room temperature for Si [μ_n = 1350cm^2/V·S, μ_p = 480 cm^2/V·S, n_i = 1.5x10^{10}/cm^3, E_g = 1.12 eV], k = 8.62 x10^{-5} eV/K, $\tau_n = \tau_p$= 1μs, E_g(Ge) = 0.7 eV, n_i (Ge)= 2.5x10^{13} /cm^3.

1. In a photoelectric effect experiment, the threshold wavelength for the ejection of photo electrons from zinc is 2863.81 Å. [1+2]

   (a) Calculate the work function for zinc (Zn).

   (b) Also calculate the velocity required for the photo electrons by light of wavelength 2600 Å other than threshold.

2. For H atom, show that, [2+1]

   (a) The possible radii in meters are given by:

   $$r = \frac{h^2 \varepsilon_0 n^2}{\pi m q^4}$$; where, n is any integer but not zero. Show that for n=1, (ground state), the radius is 0.53 Å.

   (b) Show that The energy levels in joules are given by,

   $$W_n = \frac{mq^4}{8h^2 \varepsilon_0{}^2} \cdot \frac{1}{n^2}$$

3. (a) The distance between the plates of a plane parallel capacitor is 1 cm. An electron starts at rest from the negative plate. If a direct voltage of 1,000 V is applied, how long will it take for the electrons to reach the positive plate? [1]

   (b) If a 60 H_z sinusoidal voltage of peak value 1,000 V is applied, how long will the time of transit be? Assume that the electron is released with zero velocity at the instant of time when the applied voltage is passing through zero. [Hint: sinθ = θ - θ^3/3! + θ^5/5!- ....]. [2]

4. Consider two energy levels E_1, E_{ev} above the Fermi level and E_2, E_{ev} below the Fermi level. P_1 and P_2 are respectively the probabilities of E_1 being occupied by an electron and E_2 being empty. Then which one option will be true from below options? Show with proper calculation and justification. [3]

(a) $P_1>P_2$; (b) $P_1=P_2$; (c) $P_1<P_2$ (d) P_1 and P_2 depends on number of free electrons.

5. A bar of n-type Si with a cross-sectional area of 1mm x 1mm, length of 1 cm is connected to a 2 V battery and is carrying a current of 2 mA at 300 K temperature.

   (a) Calculate the thermal equilibrium electron and hole concentrations in the bar. [2+1]

   (b) Calculate the dopant concentration assuming that only donors with energy level 0.148 eV is away from the conduction band. [μ_n=1300 cm^2/V-sec].

6. Consider a homogenous AlAs sample at T=300 K temperature with acceptor concentration of $10^{17}/cm^3$. A light source is turned at t=0, producing excess carriers at a rate of $10^{20}/cm^3$ uniformly. [2+1+1]

   (a) Derive the expression for the excess carrier recombination rate as a function of time.

   (b) If the maximum steady state excess carrier concentration is $10^{14}/cm^3$, determine the minority carrier lifetime value at maximum.

   (c) Determine the time at which the excess minority carrier concentration will be equal to half of the steady state value.

7. Write **true (T) or false (F)** only against each statement. [6x1] = 6

   (a) Work function for metal is the energy difference between Fermi level and vacuum level.

   (b) Effective density of states function in conduction band is a hypothetical density of electron states at bottom of conduction band.

   (c) Donors and acceptors are mobile ions in nature.

   (d) Drift motion may be a consequence of diffusion process.

   (e) Lattice scattering is observed at lower temperature, due to which mobility increases.

   (f) Excess carriers are generated at equilibrium.

Useful Equations

$$r=\frac{h^2\varepsilon_0 n^2}{\pi m q^4} \qquad KE=h\nu_0-\frac{ch}{\lambda_0} \qquad \rho=\frac{R.A}{L}$$

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

At Equilibrium, $n_0=\int_{E_c}^{\infty} f(E)N(E)dE = N_c f(E_c) = N_c e^{-(E_c-E_F)/kT}$

$$N_c = 2\left(\frac{2\pi m_n^* kT}{h^2}\right)^{3/2} \qquad n_0 = n_i e^{(E_F-E_i)/kT}$$

$$N_V = 2\left(\frac{2\pi m_p^* kT}{h^2}\right)^{3/2} \qquad p_0 = n_i e^{(E_i-E_F)/kT};\ n_0 p_0 = n_i^2$$

$$p_0 = N_V[1-f(E_V)] = N_V e^{-(E_F-E_V)/kT}$$

$$n_i = N_C e^{-(E_C-E_i)/kT}$$

$$p_i = N_V e^{-(E_i-E_F)/kT} n_i = \sqrt{N_C N_V} e^{-(E_g)/2kT} = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2} (m_n^* m_p^*)^{3/4} e^{-(E_g)/2kT}$$

$$n = N_C e^{-(E_C-F_n)/kT} = n_i e^{(F_n-E_i)/kT} \qquad p = N_V e^{-(F_p-E_i)/kT} = n_i e^{(E_i-F_p)/kT}$$

$$np = n_i^2 e^{(F_n-F_p)/kT}$$

$$\frac{d\xi(x)}{dx} = \frac{d^2V(x)}{dx^2} = \frac{\rho(x)}{\epsilon} = \frac{q}{\epsilon}(p-n+N_d^+-N_a^-)$$

$$\xi(x) = -\frac{dV(x)}{dx} = \frac{1}{q}\frac{dE_i}{dx} \qquad \frac{I_x}{A} = J_x = q(n\mu_n + p\mu_p)\xi_x = \sigma\xi_x \qquad L=\sqrt{D_\tau} \qquad \frac{D}{\mu} = \frac{kT}{q}$$

$$\frac{\partial p(x,t)}{\partial t} = \frac{\partial \delta p}{\partial t} = -\frac{1}{q}\frac{\partial J_p}{\partial x} - \frac{\delta p}{\tau_p}$$

$$\frac{\partial \delta n}{\partial t} = \frac{1}{q}\frac{\partial J_n}{\partial x} - \frac{\delta n}{\tau_n}$$

$$\frac{d^2\delta n}{dx^2} = \frac{\delta n}{D_n\tau_n} = \frac{\delta n}{L_n^2} \qquad \frac{d^2\delta p}{dx^2} = \frac{\delta p}{L_p^2}$$