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

National Institute of Technology, Delhi

Name of the Examination: B. Tech

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

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 QUESTION SHALL NOT BE EVALUATED.**

Use following data 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.

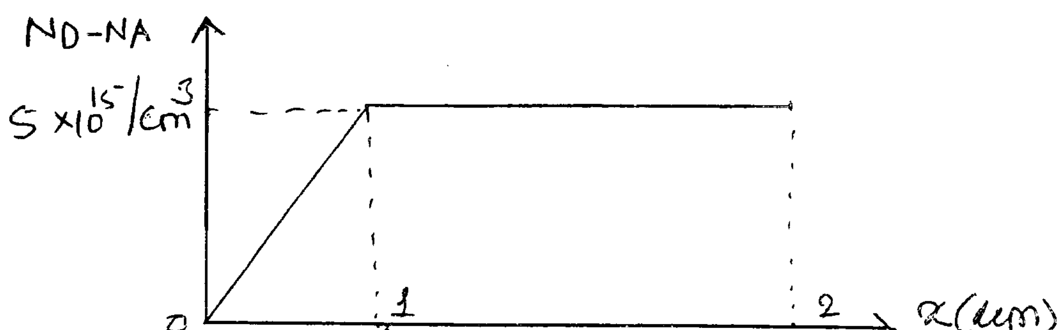
1. In a Si semiconductor sample, the doping profile is given by the following acceptor impurity profile: $N_A = 10^{14}.exp(-a.x^2)$. For $x \geq 0$ and assume, $a = \frac{2}{(\mu m^{1/2})}$. **[4M]**

(a) Find the expression/ equation for the electric field for this sample at above condition.

(b) Then from part (a), calculate the values for the electric filed at x=a/2 and at x=a distances in unit of V/cm only.

2. In a Si semiconductor sample, the doping profile is expressed in terms of the following figure. **[3M]**

(a) At x =0 μm, what is the type of the extrinsic semiconductor material and why?
(b) At x =1 μm, what is the type of the extrinsic semiconductor material and why?
(c) At x =1 μm, what should be the position of Fermi level (E_F) w.r.t to intrinsic Fermi level (E_i) for this semiconductor material?



3. Consider a Ge crystal, at room temperature doped with 5x10^{17} /cm^3 As atoms. [n_i=2x10^{13}/cm^3] **[3M]**

(a) Find the equilibrium hole concentration for the sample.
(b) Find the position of Fermi level (E_F) w.r.t to intrinsic Fermi level (E_i) for this semiconductor material.
(c) Find the position of Fermi level (E_F) w.r.t to bottom of Conduction band (E_C) for this semiconductor material.
(d) Draw the consolidated energy band diagram including all above.

4. A Si bar 0.001 cm long and 100 μm^2 cross sectional area is doped with 10^{18} /cm^3 donor atoms. If due to the application of 10 V bias, 10^7 Amp/m^2 current density develops, then **[4M]**

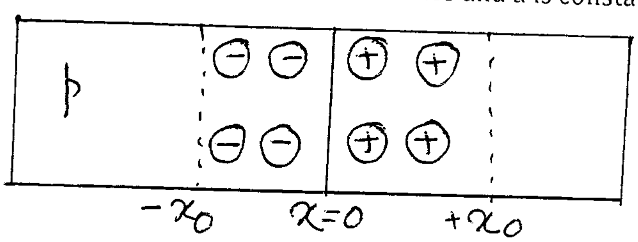
   (a) What will be the conductivity of the Si bar after applying above bias?

   (b) What will be the mobility of the Si bar after applying above bias?

   (c) Calculate the electric field developed across the sample.

5. Consider a Si sample kept at room temperature having band gap E_g = 1.12 eV. If the Fermi level E_F, is located exactly at the middle of the band gap for this sample, then what will be the probability of finding an electron at $E = E_C + 2KT$? **[2M]**

6. Derive the expression for the electric field across a linearly graded *pn* junction diode having physical contact at x=0. The space charge profile is given as $\rho(x) = qax$, where, x is the distance with $|x| = \pm x_0$ from x = 0 on either of the sides and a is constant. **[2M]**



7. In a CRO/ DSO, sweep rate frequency is 100 Hz with 2 full sinusoidal cycles observed in the screen. What will be the frequency of the voltage applicable at the input vertical parallel plates? **[1M]**

8. Quantum Mechanics is supported by which mathematical equation? **[1M]**

9. Write true (T)/false (F) only against each of the following: **[0.5 x 10 = 5M]**

   (a) Slow luminescence process is known as fluorescence.
   (b) Any drift, diffusion or combination of two in a semiconductor results in current proportional to the gradients of the two quasi-Fermi levels.
   (c) Depletion approximation is related to carrier depletion within space charge region.
   (d) Carbon (C) is an indirect band gap semiconductor.
   (e) Junction potential decreases with increasing temperature.
   (f) Junction width decreases with increasing temperature.
   (g) Conductivity of a semiconductor decreases with increasing temperature.
   (h) Band gap (E_g) increases with increasing temperature.
   (i) Band gap increases with increasing doping.
   (j) Lattice controlled mobility decreases with increasing temperature.

<u>**Useful Equations**</u>

Fermi-Dirac distribution: $f(E) = \frac{1}{e^{(E-E_F)/kT}+1} \approx e^{(E_F-E)/kT}$ for $E \gg E_F$

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

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

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

$n_i = N_c e^{-(E_c-E_i)/kT}$, $\quad p_i = N_v e^{-(E_i-E_v)/kT}$ $\quad n_i = \sqrt{N_c N_v}\, e^{-E_g/2kT} = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2}(m_n^* m_p^*)^{3/4} e^{-E_g/2kT}$

$n = N_c e^{-(E_c-F_n)/kT} = n_i e^{(F_n-E_i)/kT}$

$p = N_v e^{-(F_p-E_v)/kT} = n_i e^{(E_i-F_p)/kT}$ $\qquad np = n_i^2 e^{(F_n-F_p)/kT}$

$$\frac{d\mathscr{E}(x)}{dx} = -\frac{d^2V(x)}{dx^2} = \frac{\rho(x)}{\epsilon} = \frac{q}{\epsilon}(p - n + N_d^+ - N_a^-) \qquad \mathscr{E}(x) = -\frac{dV(x)}{dx} = \frac{1}{q}\frac{dE_i}{dx}$$

$\frac{I_x}{A} = J_x = q(n\mu_n + p\mu_p)\mathscr{E}_x = \sigma\mathscr{E}_x$ $\qquad \frac{p_p}{p_n} = \frac{n_n}{n_p} = e^{qV_0/kT}$ $\qquad W = \left[\frac{2\epsilon(V_0 - V)}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)\right]^{1/2}$

Diffusion length: $L = \sqrt{D\tau}$ $\qquad$ Einstein relation: $\frac{D}{\mu} = \frac{kT}{q}$

Continuity: $\frac{\partial p(x,t)}{\partial t} = \frac{\partial \delta p}{\partial t} = -\frac{1}{q}\frac{\partial J_p}{\partial x} - \frac{\delta p}{\tau_p}$ $\qquad \frac{\partial \delta n}{\partial t} = \frac{1}{q}\frac{\partial J_n}{\partial x} - \frac{\delta n}{\tau_n}$

For steady state diffusion $\quad \frac{d^2\delta n}{dx^2} = \frac{\delta n}{D_n\tau_n} = \frac{\delta n}{L_n^2}$ $\qquad \frac{d^2\delta p}{dx^2} = \frac{\delta p}{L_p^2}$

Equilibrium $\quad V_0 = \frac{kT}{q}\ln\frac{p_p}{p_n} = \frac{kT}{q}\ln\frac{N_a}{n_i^2/N_d} = \frac{kT}{q}\ln\frac{N_a N_d}{n_i^2}$