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National Institute of Technology, Delhi

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

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

Time: 3 Hours **Maximum Marks: 50**

- **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: $\varepsilon_o = 8.85\text{x}10^{-14}$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, $n_i = 1.5\text{x}10^{10}$/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. Assume KT = 0.026 V

1. **(a)** A doped Si sample A of thickness 3mm, shows a hall voltage of V_y = 5mV for current density J_x = 500 Amp/m^2 under a magnetic field of B_z = 1 Wb/m^2. **[3+2+1]**

(i) Find the type of the semiconductor sample A.

(ii) Doping concentration of the semiconductor sample A.

(iii) Sketch and label the energy band diagram of the semiconductor sample A.

(b) If another Si sample B, of the same physical dimension, is tested under the same current density, magnetic field, and the Hall Voltage applied with same magnitude, but opposite polarity, then

(i) Sketch the energy band diagram of the sample B.

(ii) Mention the Type of the Semiconductor sample B.

(c) Now sketch and label the combined energy band diagram for samples A and B, (if samples A and B are joined together to make a pn junction), which are at atomic contact levels grown on Single crystal at thermal equilibrium.

2. A Si sample is doped with acceptor impurity of the given profile $N_A = 10^{14}.\exp(-ax^2)$. For $x \geq 0$ assume a=2/$(um)^{1/2}$ **[4]**

(a) Find the expression and value for the electric field at x = a/2.

(b) Find the expression and value for the electric field at x = a.

3. The current equation for a p-n junction for V> $\frac{3KT}{q}$ is given as I=I_0. Exp $[\frac{q.v}{kT}]$ **[3]**

Where, I_0 = A. exp $[\frac{-1.12eV}{kT}]$.

Calculate the suitable forward bias voltage required at 320°K for this diode to maintain the same current as available in this diode at 300°K for 0.5 V of forward Bias.

4. Consider an uniformly doped GaAs junction at T=300°K, at Zero bias only 20% of the total space charge region/depletion region is to be in the p-region. The contact potential $V_0 = 1.20V$ for Zero bias determine **[3]**

(a) Acceptor concentration (N_A) and (b) Donor concentration (N_D).

Assume, $n_i = 1.8 \times 10^{16}/cm^3$.

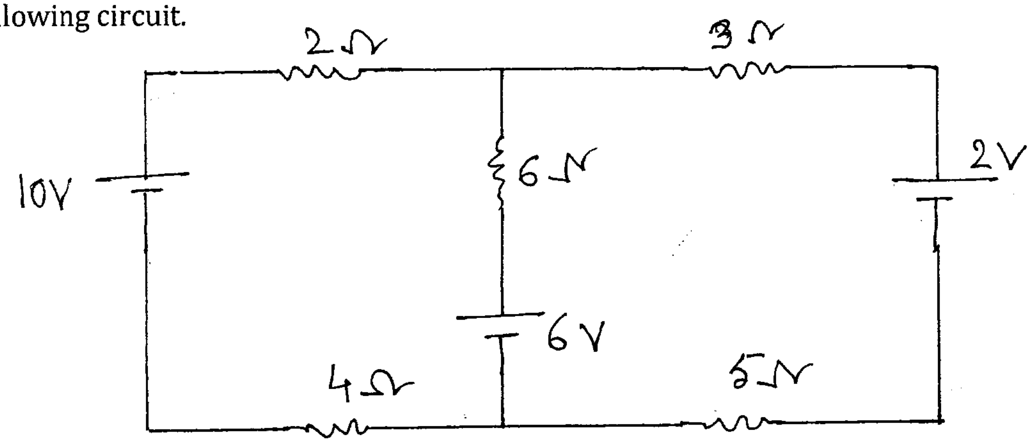
5. Consider a Si p-n Junction at T = 300°K with a p-type doping concentration of $N_A = 10^{18}/cm^3$. Determine the n-type doping concentration such that the maximum electric field is $|E_{max}| = 3 \times 10^5\ V/cm$ at reverse bias of 25V. **[3]**

6. Determine the equilibrium carrier concentrations, n_0 *and* p_0 for a Si sample at T=300°K ,if the fermi energy is 0.22eV above the valance band energy. **[3]**

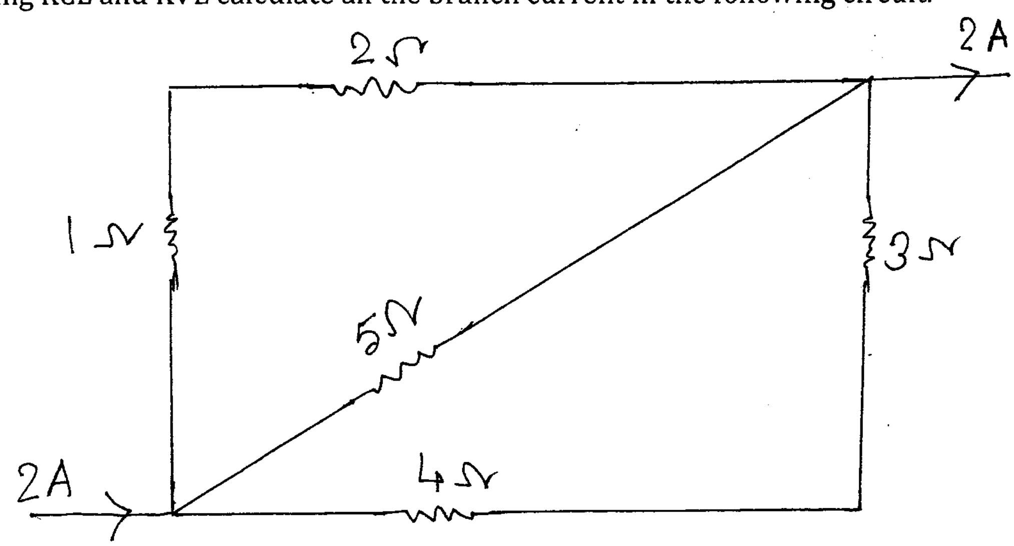
Given: $N_c = 2.8 \times 10^{19}/cm^3$, $N_V = 1.04 \times 10^{19}/cm^3$, $E_g|_{Si}$ = 1.12eV at T=300°K.

7. Si is doped with B to the concentration of $4 \times 10^{17} atoms/cm^3$. Assume $n_i = 1.5 \times 10^{10}/cm^3$ and $\frac{KT}{q}$ = 25mV at 300°K, then what will be the shift in E_F compared with undoped Si ? **[3]**

8. Using mesh current method calculate the current flowing in the resistor 6Ω in the following circuit. **[2]**



9. Using KCL and KVL calculate all the branch current in the following circuit. **[4]**

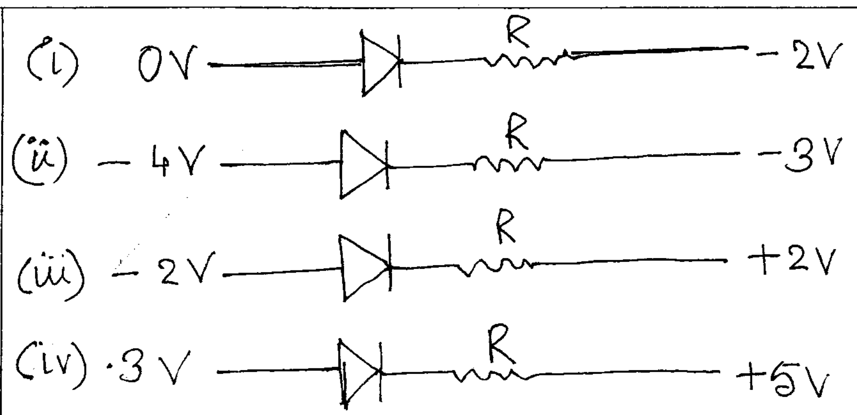


10. For a Si Bar having the length of 4um, doped n-type at $10^{17}/cm^3$. Calculate the current for an applied voltage of 2V having a cross-sectional area of 0.01cm². If the voltage is now raised at 1000V, then what will be the change in current? Electron and hole Mobilities are 1350 $cm^2/V-sec$ and 400 $cm^2/V-sec$, respectively for the low electric field. For higher field, the saturation velocity is $10^7\ cm/sec$. **[4]**

11. Consider two energy level E_1, Fev above E_F and E_2 Eev below E_F in a semiconductor material. 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 of following option will be correct, prove with proper calculations (*without proving through calculations answer is not acceptable*). **[2]**

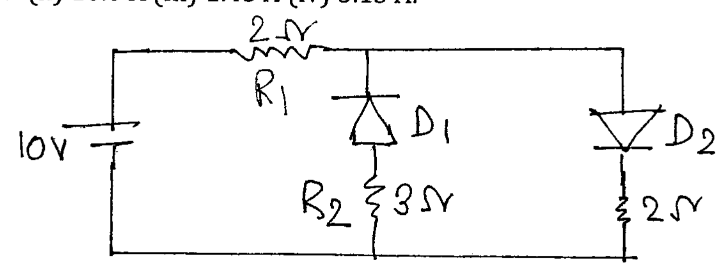
(a) $P_1 > P_2$.
(b) $P_1 = P_2$
(c) $P_1 < P_2$.

12.	Please choose/ fill up the correct answer against the question and write only the appropriate answer in your answer sheet. **(a)** For a FB diode, the contact potential ________, as temperature increase. (i) Decreases (ii) Remains Constant (iii) Increases. **(b)** The "Wide end Arrow" in the schematic symbol of a pn junction diode indicates__________. (i) Ground (ii) Direction of Electron Flow (iii) Cathode (iv) Anode. **(c)** Which statement best describes a "Real Insulator." (i) A material with many free electrons (ii) A material doped to have some free electrons (iii) A material with few free electrons (iv) No description fits. **(d)** Effectively how many valence electrons are there in each atom within a Si crystal? (i) 2 (ii) 4 (iii) 8 (iv) 16. **(e)** What factor(s) does the barrier potential of a pn junction diode depend on: (i) Type of semiconductor material (ii) The amount of doping (iii) The temperature (iv) All the above (v) Type of semiconductor material, doping but not temperature. **(f)** Which one of the following represents forward bias circuit?	**[1+1+1+2+2+2+2+2]**



(g) The given circuit has two ideal diodes connected as shown in the figure below. The current flowing through the resistance R1 will be:

(i) 2.5 A (ii) 10.0 A (iii) 1.43 A (iv) 3.13 A.



(h) Pure Si at 500K has equal no. of electron and hole concentrations of $1.5 \times 10^6/m^3$. Doping by Indium (In) increases the hole concentration to $4.5 \times 10^{22}/m^3$. The type of the doped semiconductor will be:

(i) n-type with electron concentration $5 \times 10^{22}/m^3$. (ii) p-type with electron concentration $2.5 \times 10^{23}/m^3$ (iii) n-type with electron concentration $2.5 \times 10^{10}/m^3$ (iv) p-type with electron concentration $5 \times 10^9/m^3$.

Useful Equations

$$\in_r = \frac{\in(\omega)}{\epsilon_0}$$

$$V \equiv \int_{x0}^{x} €_x.dx$$

$$€_x = \frac{-V}{x-x0} = \frac{-V}{d} \text{ ; d = (x-x}_0\text{)}$$

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

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

λ = h/mv = h/p, where p = mv

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$V = \frac{J}{q.p_0}.B.t$$

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

$$V_0 = K.T.ln\left(\frac{N_A.N_B}{n_i 2}\right)$$

$$I = I_0.\left[exp.\left(\frac{V}{\eta K.T}\right) - 1\right]$$

$$I = q.A.\left[\frac{D_p}{L_p}.p_n + \frac{D_n}{L_n}.n_p\right].\left[exp\left(\frac{q.V}{K.T}\right) - 1\right]$$

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

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