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

National Institute of Technology, Delhi

Name of the Examination: B. Tech: Mid Semester (Autumn 2018-2019) Examination

Branch	**: ECE**	**Semester**	**: III**
Title of the Course	**:Solid State Devices**	**Course Code**	**: ECB 201**
Time: 2 Hours		**Maximum Marks: 25**	

Note:

- **Questions are printed on BOTH sides. Answers should be CLEAR ANDTO THE POINT.**
- **All parts of a single question must be answered together and in the same sequence as given in question paper. ELSE QUESTION SHALL NOT BE EVALUATED.**

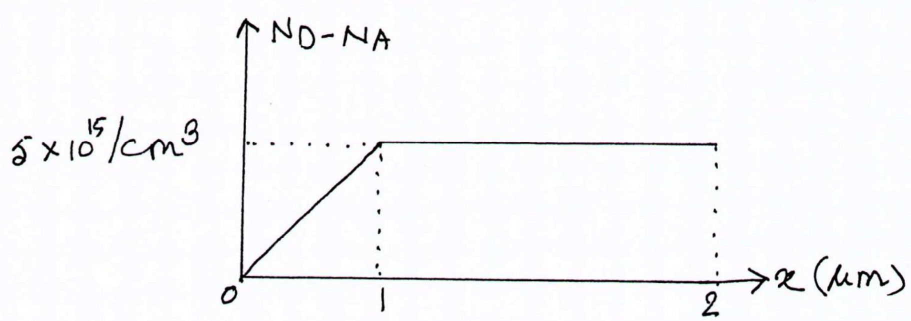
Q1. Sketch and label the E_V,E_F, and E_C for the following Si samples at room temperature. [$E_g|Si$ = 1.12 eV at room temperature, n_i = 1.5x10^{10}/cm^3 and kT = 0.026 eV] **[1 +2+2]**

(a) Intrinsic Si.

(b) Si Doped with 10^{17}/cm^3 P dopant.

(c) Si Doped with 10^{17}/cm^3 B dopant.

Q2. In a Si semiconductor sample, the doping profile is given in figure 1: **[3+2]**



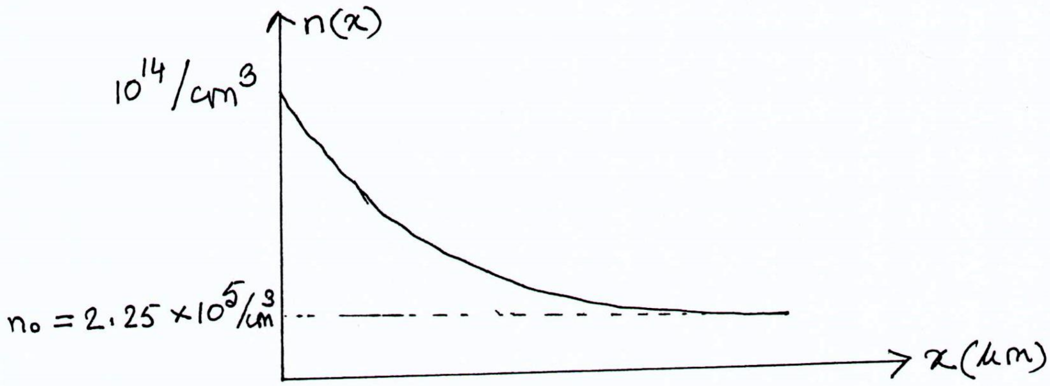
Sketch and label the energy band diagram from x = 0 to x = 2 μm, of the above sample with proper labeling and calculation, direction of electric field, if any, in the region from x = 0 to 2 μm.

Q3. In a given semiconductor sample excess carriers are injected at x = 0 due to external light illumination and profile of the excess carriers n(x) of the sample w.r.t. x is given below in figure 2. [n_i = 1.5x10^{10}/cm^3; kT = 0.0259 eV]. **[1+ 1+ 3]**

(a) Predict the doping type and calculate the doping concentration of the sample.

(b) Calculate total minority carrier concentration at x = Lp.

(c) Sketch and label the energy band diagram, if the sample is uniformly illuminated. Mark the Fermi levels also.



Q4. A Si sample, doped with $10^{16}/cm^3$ donor impurity, is exposed by light at x = 0 to generate excess EHP of amount $10^{14}/cm^3$. Excess carriers travel 1 cm distance in 0.4 msec time under a field of 2 V/cm. **[2 +4+1]**

(a) Sketch and label majority and minority carrier profiles i.e. n(x) and p(x) in the sample w.r.t. distance x.

(b) Calculate p(x) and n(x) at x = 2Lp.

(c) Calculate diffusion current density at x = 0, at x = Lp and x = 2Lp.

(d) Calculate mobility for majority and minority carriers [D_p = 25 cm²/sec; D_n = 50cm²/sec; $\tau_n = \tau_p$ = 10 nsec].

Q5. (a) A doped Si sample of thickness 3 mm shows a Hall voltage of V_y = 3 mV for current density J = 300 A/m² under a magnetic field of B_z = 1 Wb/m². [kT = 0.0259 eV]. **[2+1]**

(b) Find the type of the semiconductor and doping concentration.

(c) Draw the energy band diagram with proper labeling and calculation.

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

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

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

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

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

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

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

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

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

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

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

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

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