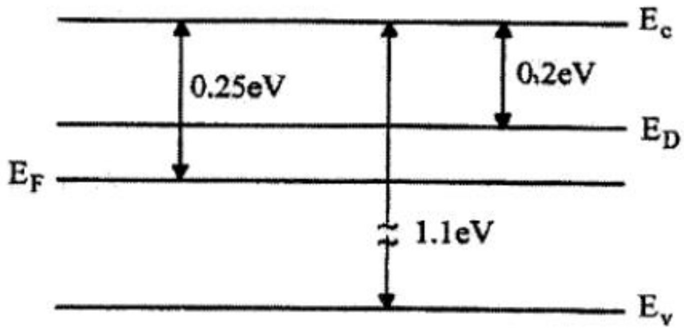
# Unit I Question Bank

1. a) A Si substrate at room temperature is doped with $2.70 * 10^{16}/cm^3$ donor atoms. Determine the electron and hole concentrations of the sample and the type of the substrate. [Given: $n_i = 1.5 * 10^{10}/cm^3$ , $Nc = 6.0953 * 10^{19}/cm^3$ , Eg = 1.1 eV]
   (b) If the above sample is over doped with $5 * 10^{16}/cm^3$ acceptor atoms, what will be the new electron and hole concentrations for the substrate? What will be the type of the substrate after acceptor doping?
2. Consider a Ge crystal at room temperature doped with $5 * 10^{15}/cm^3$ As atoms. Find the equilibrium electron, the hole concentrations, and the position of the Fermi level w.r.t intrinsic energy level ($E_i$ ) and conduction energy band ($E_c$). Draw the energy band diagram also.
3. A Ge sample is doped with $10^{14}/cm^3$ As atoms/$cm^3$ . What will be the equilibrium hole concentration? What is the relative position of Fermi level w.r.t intrinsic energy level? [Given: ni = $2.5x10^{13}/cm^3$ ]
4. A new semiconductor has $Nc = 10^{19}$ $cm^{-3}$ , $N_v = 5 * 10^{18}$ $cm^{-3}$, and Eg = 2 eV. If it is doped with $10^{17}$ donors (fully ionized), calculate the electron, hole, and intrinsic carrier concentrations at 627°C. Sketch the simplified band diagram, showing the position of EF.
5. A 2 cm long piece of Si with cross-sectional area of 0.1 $cm^2$ is doped with donors at $10^{15}$ $cm^{-3}$, and has a resistance of 90 ohms. The saturation velocity of electrons in Si is $10^7$ cm/s for fields above $10^5$ V/cm. Calculate the electron drift velocity, if we apply a voltage of 100 V across the piece. What is the current through the piece if we apply a voltage of $10^6$ V across it?
6. Calculate the drift current density for a given semiconductor. Consider silicon at T = 300 K doped with arsenic atoms at a concentration of $N_d = 8 \times 10^{15}$ $cm^{-3}$ . Assume mobility values of $\mu_n = 1350$ $cm^2$ /V–s and $\mu_p = 480$ $cm^2$ /V–s. Assume the applied electric field is 100 V/cm
7. Consider n-type GaAs at T = 300 K doped to a concentration of $N_d = 10^{16}$ $cm^{-3}$. Assume mobility values of $\mu_n = 7000$ $cm^2$ /V–s and $\mu_p = 300$ $cm^2$ /V–s. Determine the applied electric field that will induce a drift current density of 200 A/$cm^2$.
8. Calculate the diffusion current density for a given semiconductor. Consider silicon at T = 300 K. Assume the electron concentration varies linearly from $n = 10^{12}$ $cm^{-3}$ to $n = 10^{16}$ $cm^{-3}$ over the distance from x = 0 to x = 3 µm. Assume $D_n = 35$ $cm^2$ /s
9. Predict the effect on mobility and resistivity of Si crystal at room temperature if every millionth of Si atom is replaced by an atom of indium (In). Given, the concentration of Si atoms is $5 * 10^{28}/m^3$ , the intrinsic carrier concentration is $1.5 * 10^{10}/cm^3$ , the intrinsic conductivity of Si is 0.00044 S/m, the intrinsic resistivity of Si is R = 2300 Ω.m, and the mobility of electrons and holes are 0.135 $m^2$ /V-sec and 0.048 $m^2$ /V-sec, respectively.
10. An abrupt Si p-n junction has $N_a = 10^{18}$ $cm^{-3}$ on one side and $N_d = 5 * 10^{15}$ $cm^{-3}$ on the other . (a) Calculate the Fermi level positions at 300 K in the p and n regions. (b) Draw an equilibrium band diagram for the junction and determine the contact potential $V_0$ from the diagram. (c) Compare the results with mathematical expression.

(D) The junction described in has a circular cross section with a diameter of 10 mm. Calculate $x_{n0}$, $x_{p0}$, $Q_+$, and $\mathscr{E}_0$ for this junction at equilibrium (300 K). Sketch $\mathscr{E}(x)$ and charge density.

11. Boron is implanted into an n-type Si sample ($N_d = 10^{16}$ $cm^{-3}$ ), forming an abrupt junction of square cross section with area = $2 * 10^{-3}$ $cm^2$ . Assume that the acceptor concentration in the p-type region is $N_a = 4 * 10^{18}$ $cm^{-3}$ . Calculate $x_{n0}$, $x_{p0}$, $Q_+$, and $\mathscr{E}_0$ for this junction at equilibrium (300 K). Sketch $\mathscr{E}(x)$ and charge density
12. An abrupt silicon p-n diode at 300 K has a doping of $N_a = 10^{18}$ $/cm^3$ ; $N_d = 10^{15}$ $/cm^3$ . Calculate the built-in potential and the depletion widths in the n and p regions.
13. An abrupt Si p-n junction has $N_a = 10^{17}$ $cm^{-3}$ on the p side and $N_d = 10^{16}$ $cm^{-3}$ on the n side. At 300 K, (a) calculate the Fermi levels, draw an equilibrium band diagram, and find V0 from the diagram; (b) compare the result from (a) with V0 calculated.
14. Consider a $p^+$ n Si diode with $N_a = 10^{18}$ $/cm^3$ and Nd = $10^{16}$ $/cm^3$ . The hole di usion coeffcient in the n-side is 10 $cm^2/s$ and $\tau_p = 10^{-7}$ s. The device area is $10^{-4}$ $cm^2$ . Calculate the reverse saturation current and the forward current at a forward bias of 0.7V at 300k.
15. Calculate the number of holes, electrons and $n_i$ in the unknown semiconductor with $E_F$=0.25eV below $E_C$




16. For a Si $p^+$ n junction of area $2 * 10^{-4}$ $cm^2$ , calculate the depletion width, the peak electric field, and the depletion capacitance under 60 V of reverse bias with the following diode specifications:

| **p side** | **n side** |
|---|---|
| $Na = 10^{19}/cm^3$ | $Nd = 10^{16}/cm^3$ |
| $\tau_p$ = 10 ns | $\tau_n$ = 0.1 ns |
| $\mu_p$ = 800 $cm^2$ /V-sec | $\mu_n$ = 1250 $cm^2$ /V-sec |
| $\mu_n$ = 200 cm2 /V-sec | $\mu_p$ = 1400 cm2 /V-sec |

**17.** For a Si $p^+$ n junction of area $10^{-4}$ $cm^2$. The junction is forward biased by 0.5 V. What is the forward current? What is the current at a reverse bias of −0.5 V?

| **p side** | **n side** |
|---|---|
| $Na = 10^{17}/cm^3$ | $Nd = 10^{15}/cm^3$ |
| $\tau_p$ = 10 µs | $\tau_n$ = 0.1 µs |
| $\mu_p$ = 200 $cm^2$ /V-sec | $\mu_n$ = 1300 $cm^2$ /V-sec |
| $\mu_n$ = 700 cm2 /V-sec | $\mu_p$ = 450 $cm^2$ /V-sec |

18. Determine the current in a pn junction diode. Consider a pn junction at $T = 300$ K in which $I_S = 10^{-14}$ A and $n = 1$. Find the diode current for $v_D = +0.70$ V and $v_D = -0.70$ V
19. In a P-type semiconductor, the Fermi level lies 0.4 eV above the valence band. Determine the new position of the Fermi level if the concentration of acceptor atoms is multiplied by a factor of (a) 0.5, and (b). Assume $kT = 0.025$ eV
20. In a P-type semiconductor, the Fermi level lies 0.4 eV above the valence band at 300 K. Determine the new position of the Fermi level (i) at 450 K, and (ii) if the concentration of acceptor atoms is multiplied by a factor of 2. Assume $kT = 0.03$ eV.
21. The mobilies of electrons and holes in a sample of intrinsic germanium at room temperature are 0.36 $m^2$ /V-s and 0.17 $m^2$ /V-s, respectively. If the electron and hole densities are each equal to $2.5 \times 10^{19}/m^3$ , calculate the conductivity.
22. Compute the conductivity of a silicon semiconductor which is doped with acceptor impurity to a density of $10^{22}$ atoms/$m^3$ . Given that $n_i = 1.4 \times 10^{16}/m^3$ , $\mu_n = 0.145$ $m^2$ /V-s and $\mu_p = 0.05$ $m^2$ /V-s
23. A young designer, aiming to develop intuition, concerning conducting paths within an integrated circuit, examines the end-to-end resistance of a connecting bar 10 μm long, 3 μm wide, 1 μm thick, made of various materials. The designer considers:

    a) intrinsic silicon

    b) n-doped silicon with $N_D = 1 \times 10^{16}/cm^3$

    c) p-doped silicon with $N_D = 1 \times 10^{10}/cm^3$

    d) aluminum with resistivity of 2.8 μΩ·cm

    Find the resistance in each case. For intrinsic silicon, use $\mu_n = 1350$ $cm^2$ /V·s, $\mu_p = 480$ $cm^2$ /V·s, and $n_i = 1.5 \times 10^{10}/cm^3$ . For doped silicon, assume $\mu_n \cong 2.5\ \mu_p = 1200$ $cm^2$ /V·s. (Recall that $R = \rho L/A$.)
24. If for a particular junction, the acceptor concentration is $1 \times 10^{16}/cm^3$ and the donor concentration is $1 \times 10^{15}/cm^3$ , find the junction built-in voltage (barrier voltage). Assume $n_i = 1 \times 10^{10}/cm^3$. Also, find $W_{dep}$ and its extent in each of the p and n regions when the junction is reverse biased with $V_R = 5$ V. At this value of the reverse bias, calculate the magnitude of the charge stored on either side of the junction. Assume the junction area is 400 $\mu m^2$. Also, calculate $C_j$
25. Calculate the minority carrier concentrations at the edge of the space charge regions in a forward-biased pn junction. Consider a silicon pn junction at $T = 300$ K. Assume the doping concentration in the n region is $N_d = 10^{16}$ $cm^{-3}$ and the doping concentration in the p region is $N_a = 6 * 10^{15}$ $cm^{-3}$, and assume that a forward bias of 0.60 V is applied to the pn junction.