PYL-102: PRINCIPLES OF ELECT. MATERIALS

Practice Problems

1. The effective mass of the hole is five times the effective mass of an electron. Calculate the Fermi level position of a semiconductor with a bandgap of 0.7eV at room temperature.
2. E vs. K relation for an electron in the conduction band of a hypothetical n-type tetravalent semiconductor is given by

   i. $E = ak^2 + \text{ constant}$

Cyclotron resonance for electron occurs at $\omega_c = 1.8 \times 10^{11} \text{rads}^{-1}$ in a magnetic field of B=0.1 Weber/m^2. Find the value of a.

3. Relation between bandgap and temperature for Si is given by

$$E_g = 1.17\text{eV} - 4.73 \times 10^{-4} \frac{T^2}{T + 636}$$

   Find a concentration of electrons in the conduction band of intrinsic (undoped) Si at T = 77 K if at 300 K ni = 1.05 × 10^10 cm^{-3}

4. The approximate value of p-n junction current under forward bias is given by $I = I_0 \exp(eV/k_BT)$. Show that the incremental resistance R_e (= ΔV/ΔI) is inversely proportional to current?

5. Using general equation for p, show that (dp/dE) is maximum in the valence band at $E_v - E = (k_BT)/2$.

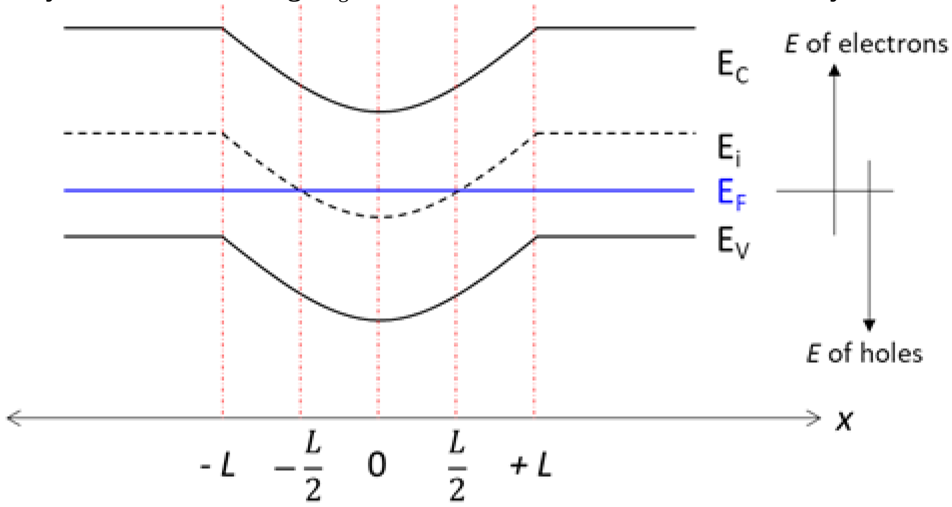
6. The mobilities of electrons and holes in intrinsic Ge are 0.39 and 0.19 m^2/V-s respectively. Determine the intrinsic carrier concentration and conductivity of Ge at 300 K if the band gap of Ge is 0.67 eV and the effective masses of electrons and holes are $0.55m_0$ and $0.37m_0$ respectively, m_0 being the electronic rest mass. How many dopants must be added per cubic metre of Ge to increase its conductivity by a factor of 10^4?

7. Show that the product of electron and hole concentrations in a semiconductor is constant at a given temperature. How is the energy gap determined from the measurement of electrical conductivity of a semiconductor?

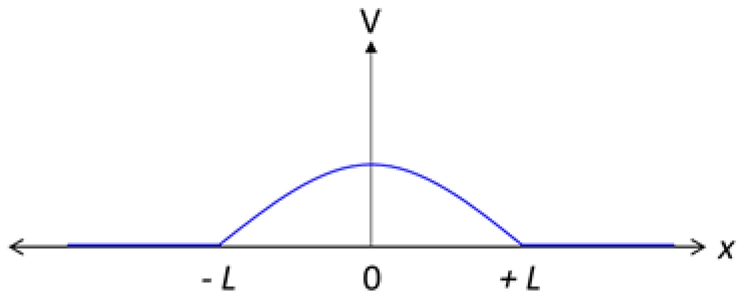
8. The conductivity of a semiconductor changes when the concentration of electrons is varied by changing the position of impurity level. Show that it passes through a minimum when the concentration of electrons becomes $n_i \sqrt{\mu_p/\mu_n}$ where n_i is the intrinsic carrier concentration, μ_n and μ_p represent the mobilities of electrons and holes respectively. Determine the minimum value of conductivity.

9. Calculate the temperatures at which *p-n* junctions made with Si, Ge and GaN will lose their rectifying characteristics.
   Assume that, in all cases the acceptor and the donor concentration: $N_a = N_d = 10^{14}$ cm^{-3}, E_g are independent of the temperature and are 1.12, 0.66 and 3.44 eV for Si, Ge and GaN, respectively.
   Intrinsic carrier concentrations at room temperature are $ni_{Ge} = 2 \times 10^{13}$, $ni_{Si} = 10^{10}$, and $ni_{GaN} = 10^{-9}$ cm^{-3}. The effective mass of the electron and holes for the three materials are: ($m_n^* = 1.18m_0$, $m_p^* = 0.59m_0$) for Si, ($m_n^* = 0.57m_0$, $m_p^* = 0.37m_0$) for Ge and ($m_n^* = 0.22m_0$, $m_p^* = 0.61m_0$) for GaN, where m_0 is the rest mass.

10. In a certain semiconductor, consider the following energy band diagram. Sample is maintained at 300 K with $E_i - E_F = E_g/4$ at $x = \pm L$ and $E_F - E_i = E_g/4$ at $x = 0$. The notations carry the usual meaning. $E_g = 1.42$ eV, $n_i = 10^{10}$ cm^{-3}, hole mobility: 400 cm^2/V s



Red vertical lines are for eye guidance.
Besides, the electrostatic potential (V) inside the semiconductor as a function of x is given by: (potential smoothly changes at ±L)



(i) Sketch the electric field inside the semiconductor as a function of x. Hint: $E_x = -(dV/dx)$ and there is no discontinuity at ±L.

(ii) Calculate the resistivity of the (x>L) portion of the semiconductor.

(iii) Identify whether the semiconductor is under equilibrium, or there is an external electric field applied. justify.

(iv) Determine the electron and hole current density (J_n and J_p respectively) at $x = \pm L/2$.

11. Find the built-in potential for a p-n Si junction at room temperature if the bulk resistivity of Si is 5.5 Ω cm. Electron mobility in Si at RT is 1100 cm^2/Vs; $\mu_n/\mu_p = 3.1$; $n_i = 1.4 \times 10^{10}$ cm^{-3}. Consider, at room temperature all donors and acceptors are ionized.

Calculate the total depletion-layer width for applied bias voltages V = −5 V, 0, and +0.1 V. Consider $\varepsilon_{Si} = 11.9$.