ECE 25500: Homework II

Current Flow and PN Junctions

Due on: Sep. 6$^{\text{th}}$, 2019 *by* 5:00 PM

Note: Scan your work (there is a scanner in the EE computer lab for student use) and submit it on Blackboard by the deadline indicated above. Late homework is **not** accepted. Make sure that the scan is readable. Please email the course GTA at `rchatrie@purdue.edu` if you have any questions about this assignment.

Problem 1 (pts) : Suppose that a silicon semiconductor device has a p-type layer of width W. Suppose further that electron carriers are injected into the layer from one side resulting in the minority carrier distribution $n_p(x)$ shown in **Fig.** below. The excess minority carrier concentration at $x = 0$ is $n_p = 10^{14}$ cm^{-3}, and that at $x = W$ is $n_p = 0$ cm^{-3}. Let $\mu_n = 600$ cm^2/V $\cdot$ s, $T = 300$ K, and $W = 100$ nm.

(a) Compute the electron current density in A/cm^2 (with the correct sign).

(b) Compute the average velocity of an electron at $x = 0$ (with the correct sign. **Hint:** the current density if proportional to the average velocity $J_n(x) = -qn(x)\nu_n(x)$).

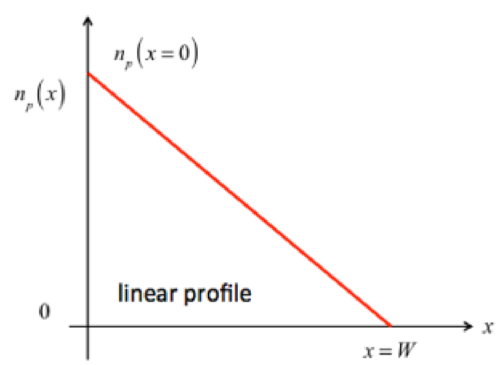

Fig.1

Problem 2 (pts) : Consider a uniformly doped n-type silicon resistor with $N_D = 3 \times 10^{17}$ cm^{-3}. Suppose the resistor is 10 µm long, that the temperature is $T = 300$ K, and that the electron mobility is $\mu_n = 500$ cm^2/V $\cdot$ s. Suppose further that 1.5 V is applied at $x = 10$ µm and $x = 0$ µm is grounded.

(a) What the average electron velocity in the $+x$ direction in units of cm/s?

(b) What is the direction of the electron drift current?

Problem 3 **(pts)** **:** Consider the equilibrium energy band diagram shown in **Fig.2** below for a silicon semiconductor at $T = 300$ K and for which $n_i = 10^{10}$ cm^{-3}. The semiconductor is doped p-type with $N_A = 10^{18}$ cm^{-3} so that $p_B = 10^{18}$ cm^{-3} in the bulk region where $x \gg 0$.

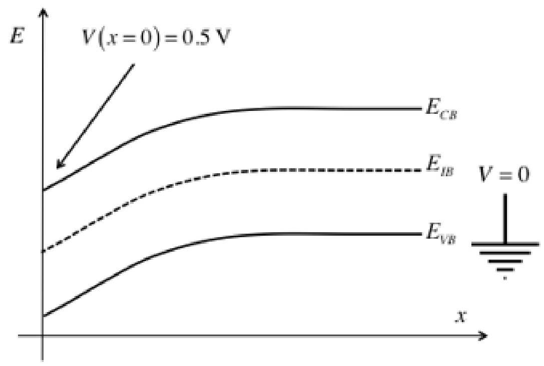

Fig.2

(a) What is the equilibrium electron density at $x = 0$?

(b) What is the equilibrium hole density at $x = 0$?

(c) What is the space charge density in C/cm^3 at $x = 0$?

Problem 4 **(pts)** **:** Consider a PN junction whose p-type side is doped with $N_A = 10^{15}$ cm^{-3} and whose n-type side is doped with $N_D = 10^{18}$ cm^{-3}. Assume that the temperature $T = 300$ K.

(a) Suppose that the junction is made of silicon with $n_i = 10^{10}$ cm^{-3}. Compute its built-in potential V_{bi}.

(b) Suppose that the junction is made of galium-arsenide with $n_i = 2 \times 10^6$ cm^{-3}. Compute its built-in potential V_{bi}.

(c) Compare your answers to the band-gap energy of the material.

Problem 5 **(pts)** **:** Consider a PN junction made of silicon with its p-type side doped with $N_A = 10^{17}$ cm^{-3} and its n-type side doped with $N_D = 10^{19}$ cm^{-3}. Assume room temperature conditions with $T = 300$ K so that $n_i = 10^{10}$ cm^{-3}. The bulk (not depleted) n-type and p-type regions are 100 nm and 200 nm long respectively. The junction area is 500×500 nm^2. The electron and hole mobilities are 1200 cm^2 V $\cdot$ s and 70 cm^2/V $\cdot$ s respectively.

(a) What the junction's saturation current I_S in A?

(b) What potential must be applied across the junction so that it conducts exactly 10^{-12} A of current?

(c) What potential must be applied across the junction so that it conducts exactly 10^{-5} A of current?

Problem 6 **(pts)** **:** A diode with saturation current $I_S = 2.32 \times 10^{-15}$ A conducts 0.36 mA when forward biased by 0.67 V. What current will it conduct if the bias is increased to 0.79 V? Assume room temperature ($T = 300$ K).

Problem 7 **(pts)** **:** Consider the diode test circuit shown in **Fig.3** below. The load-line of the circuit and the diode's i-v characteristic are plotted together in **Fig.4**.

(a) What is the value of R?

(b) What is the value of I_D?

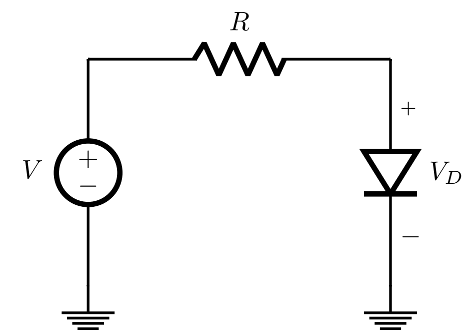

Fig.3

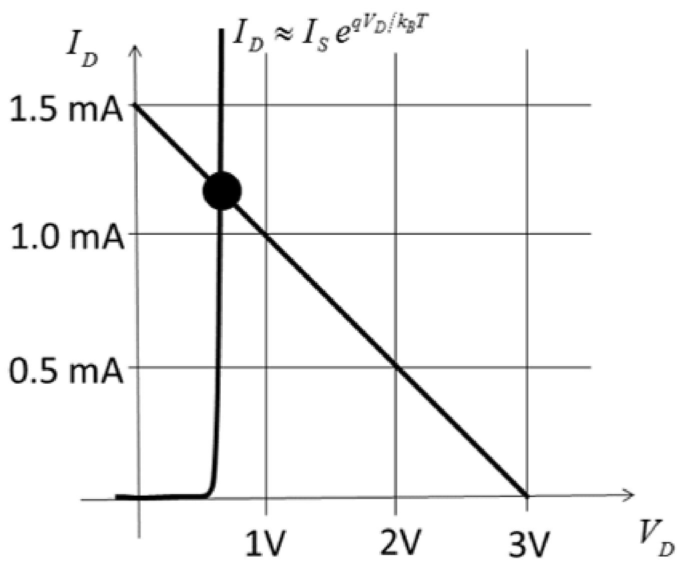

Fig.4