MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.012 ELECTRONIC DEVICES AND CIRCUITS

Problem Set No. 3

Issued: September 19, 2001 **Due:** September 26, 2001

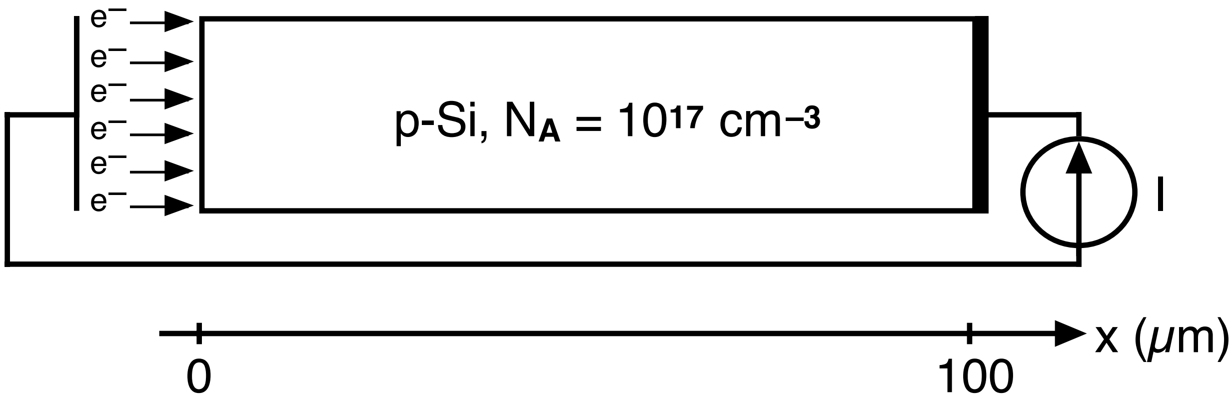
Reading Assignments:

Lecture 6 (9/23/01)	-	Chap. 7 (7.1,7.2)
Lecture 7 (9/25/01)	-	Chap. 7 (7.3, 7.4.1a)
Lecture 8 (9/30/01)	-	Chap. 8 (8.1)
Lecture 9 (10/2/01)	-	Chap. 8 (8.2.1a)
Lecture 10 (10/7/01)	-	Chap. 7 (7.5 to end [good quiz review])

The first hour exam is scheduled for Wednesday night, October 8, from 7:30 to 9:30 pm in Room 34-101. Please let me know as soon as possible (by e-mail) if you have a conflict so we can resolve it as painlessly as possible. The exam is closed book and will cover the material through 9/26/01 and Problem Set #4 (through p-n diodes).

Problem 1 - This problem concerns a bar of p-type silicon, $N_A = 10^{17}$ cm^{-3}, irradiated on its left end with a uniform electron beam having an electron flux of 10^{19} cm^{-2}s^{-1} as illustrated below.*

As shown, the sample is 100 μm long and has an ohmic contact on its right end; this contact is connected to the electron source to complete the circuit as indicated. In this sample the hole mobility, μ_h, is 600 cm^2/V-s; the electron mobility, μ_e, is 1600 cm^2/V-s; the electron diffusion length, L_e, is 10 μm; and the intrinsic carrier concentration at room temperature, n_i, is 10^{10} cm^{-3}.



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* In case you are concerned: The electron beam hitting the left end of the bar behaves like an injecting contact. The injected electrons do not have sufficient energy to generate more hole-electron pairs; also, no holes can leave the left end of the bar.

(a) What is the electron current density just inside the bar at the left end, i.e. what is $J_e(0^+)$? Show your work and/or explain your answer.

(b) Write a formula for n'(x) in terms of n'(0) and then determine the value of n'(0).

(c) Write an expression for the electron current density, $J_e(x)$, valid for $0 < x < 100$ μm.

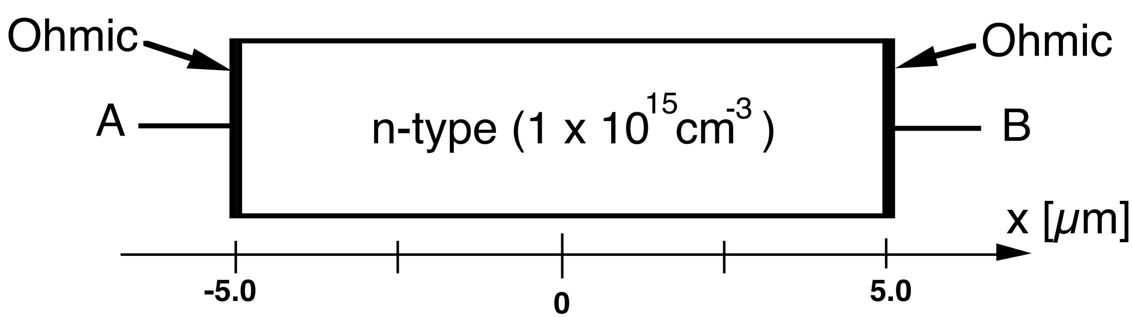
(d) Write an expressioin for the hole current density, $J_h(x)$, valid for $0 < x < 100$ μm.

(e) Write an expression for the electric field, $E_x(x)$, valid for $0 < x < 100$ μm.

(f) What is the voltage drop from end to end in this sample? Note: this is the same as the change in electrostatic potential between x = 0 and 100 μm.

Problem 2 - Do Problem 6.1, parts a and b only, in the course text.

Problem 3 - The n-type silicon sample illustrated below is 10 microns (μm) long and has metal ohmic contacts, A and B, on either end. The net donor concentration



is 1×10^{15} cm^{-3}; the electron mobility, μ_e, is 1600 cm^2/V-s; and the hole mobility, μ_h, is 600 cm^2/V-s. The electrostatic potential of the metal relative to intrinsic silicon is 0.2V, and the intrinsic carrier concentration at room temperature is 10^{10} cm^{-3}.

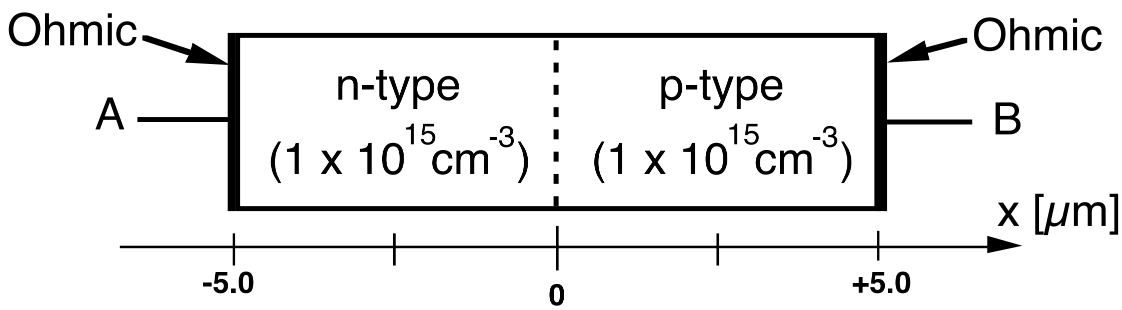
a) What are the thermal equilibrium (i.e., no light, v_{AB} = 0 V) hole and electron concentrations and electrostatic potential, $ø_n$, in this silicon?

b) Sketch the electrostatic potential, ø(x), with v_{AB} = 0 V, going from the metal on the left, through the silicon, and into the metal on the right. Dimension your sketch; label any significant features.

c) Assume now that v_{AB} = 0.5 V. Sketch the electrostatic potential, ø(x), with v_{AB} = 0.5 V, going from the metal on the left, through the silicon, and into the metal on the right (where you should assume the value of ø is unchanged, i.e. 0.2 V). Dimension your sketch and label any significant features, including ø(0).

e) When v_{AB} = 0.5 V, what are the electron and hole drift current densities, J_e^{dr} and J_h^{dr}, respectively, at x = 0 μm

Next consider a sample similar to our original sample, except that it is doped p-type with a net acceptor concentration of 1×10^{15} cm^{-3} in the region from x = 0 μm to x = +5 μm as shown below. **Note**: This is a diode with the p-side to the right.



f) Sketch the electrostatic potential, ø(x), going from the metal on the left, through the silicon, and into the metal on the right, with v_{AB} = 0 V. Dimension your sketch and label any significant features, including the value of ø(0).

g) The diode is now <u>reverse biased</u> by v_{AB} = 0.5 V. Sketch the electrostatic potential, ø(x), now, going from the metal on the left, through the silicon, and into the metal on the right. Keep ø in the metal to the right of x = 5 μm at the value it had in Part f. Dimension your sketch and label any significant features, including the value of ø(0).

Problem 4 - Do Problem 7.1 in the course text.

Problem 5 - Do Problem 7.5 in the course text.