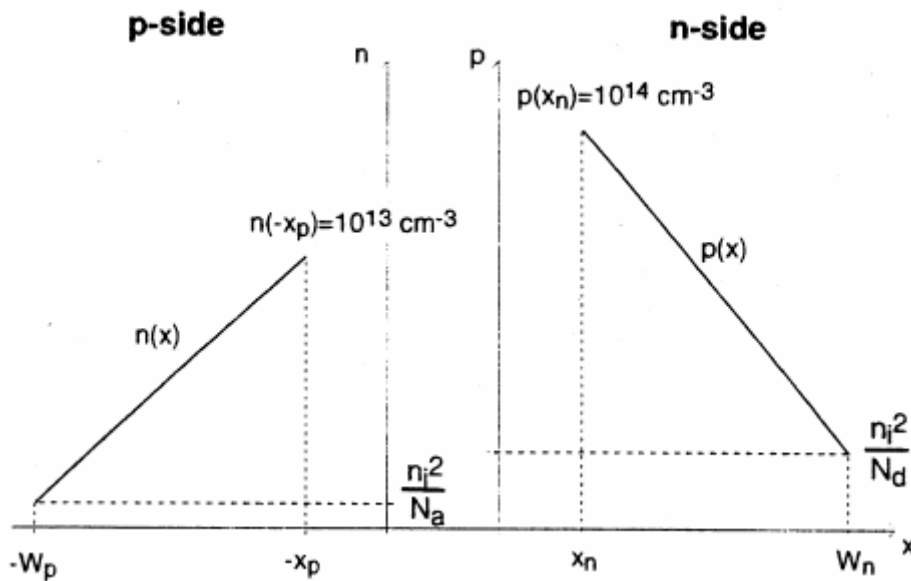


Massachusetts Institute of Technology  
 Department of Electrical Engineering and Computer Science  
 6.012  
 Microelectronic Devices and Circuits  
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 Homework #5  
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Problem 1

Below is a sketch not to scale of the minority carrier distribution across the quasi-neutral regions of a forward biased p-n diode. For this diode,  $W_p - x_p = 4 \mu\text{m}$ ,  $W_n - x_n = 3 \mu\text{m}$ ,  $D_n = 25 \text{ cm}^2/\text{s}$  and  $D_p = 10 \text{ cm}^2/\text{s}$ . The area of the junction is  $10 \mu\text{m}^2$ .

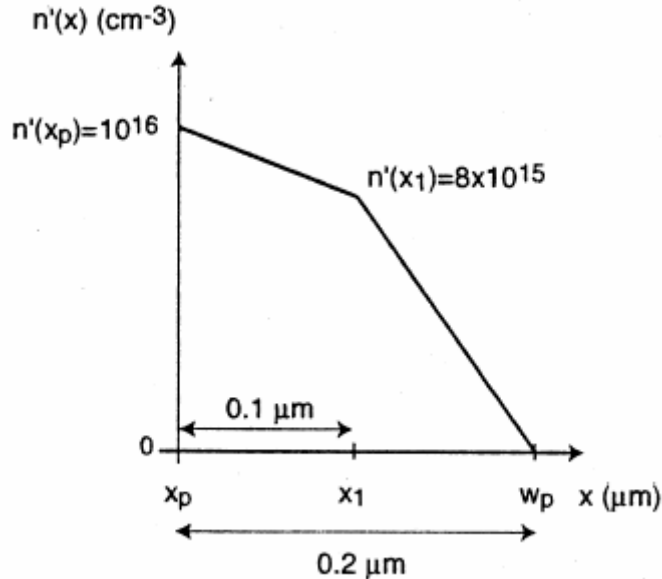


- Calculate the hole current injected into the n-side of the diode.
- Calculate the electron current injected into the p-side of the diode.
- Calculate the diffusion capacitance associated with the carrier storage on the n-side of the diode
- Calculate the diffusion capacitance associated with the carrier storage on the p-side of the diode.
- How much should the voltage across the junction increase if we wish to double the total current through the diode?
- Compute the diffusion capacitance of the diode when we increase the voltage in the manner suggested in the previous question.
- What is the ratio of the doping levels across the junction:  $N_a/N_d$ ?
- In what direction should  $N_a/N_d$  change if we wish to redesign the diode so as to get less diffusion capacitance at the same current level? (Assume that in redesigning the diode  $D_n$ ,  $D_p$ ,  $W_n - x_n$ , and  $W_p - x_p$  do not change). Should  $N_a/N_d$  increase or decrease? Explain.

### Problem 2

Consider an abrupt asymmetric  $n^+p$  junction diode with a junction area of  $100 \mu\text{m}^2$ . All the action in this device is dominated by the lightly-doped p-type region.

Due to processing reasons, the diffusion coefficient of holes across the quasi neutral p-type region is not uniform and changes half way down the n-QNR at a location  $x_1$ . As a result at a current level of  $400 \mu\text{A}$ , the excess minority carrier concentration in the quasi neutral p-type region has the distribution sketched below:



- Calculate the electron diffusion coefficient in both portions of the quasi neutral regions.
- Calculate the total amount of excess minority carrier charge in the diode.
- Calculate the diffusion capacitance of the diode.
- Calculate the electron diffusion velocity at  $x_1^-$  and at  $x_1^+$ .

### Problem 3

A pn junction diode can be used as a tunable capacitor. For a short-base diode with area  $A = 20 \times 20 \mu\text{m}^2$ ,  $N_a = 10^{17} \text{cm}^{-3}$ ,  $W_p = 1 \mu\text{m}$ ,  $N_d = 10^{19} \text{cm}^{-3}$ ,  $W_n = 0.25 \mu\text{m}$ :

- Compute the depletion capacitance for a  $V_D$  of  $-2\text{V}$  and for a  $V_D$  of  $\phi_B / 2$ .
- Compute the diffusion capacitance and the total capacitance for a  $V_D$  of  $-2\text{V}$  and for a  $V_D$  of  $\phi_B / 2$ .
- Compute the conductance for a  $V_D$  of  $-2\text{V}$  and for a  $V_D$  of  $\phi_B / 2$ .

#### Problem 4

You are given a pn junction diode with the device data shown below.

Device Data:

$$N_a = 10^{16} \text{ cm}^{-3}$$

$$N_d = 10^{15} \text{ cm}^{-3}$$

$$\mu_n = 1400 \text{ cm}^2/\text{Vs}$$

$$\mu_p = 500 \text{ cm}^2/\text{Vs}$$

$$A = 50 \text{ }\mu\text{m} \times 50 \text{ }\mu\text{m}$$

$$W_n = W_p = 2 \text{ }\mu\text{m}$$

- a) What is the maximum applied voltage we can place across the diode and still satisfy the Low Level Injection constraint? We define this onset as when the minority carrier concentration equals 1 / 10 of the majority carrier concentration in thermal equilibrium.
- b) Calculate  $x_d$  at  $V_D = 0.54$
- c) Calculate  $I_0$
- d) Calculate the depletion capacitance (in pF) under the applied bias  $V_D = 0.54$
- e) Calculate the diffusion capacitance (in pF) at  $V_D = 0.54$
- f) Calculate  $g_d$