

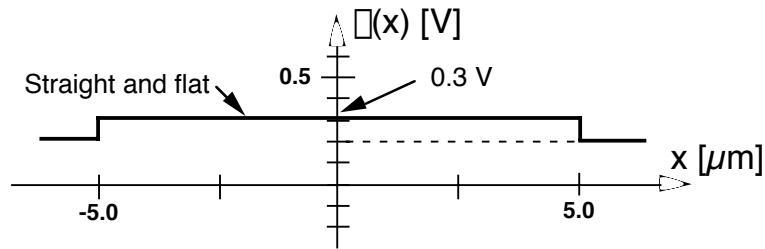
6.012 Electronic Devices and Circuits
 Answers for Exam No. 1 - Spring 2000
 (Ave = 75, σ = 13.5, n = 130)

Problem 1:

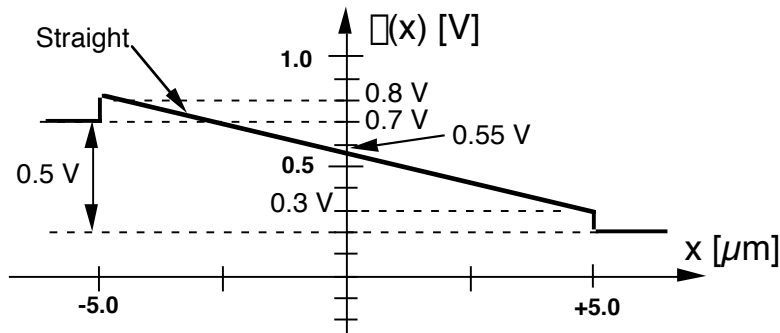
a) The sample is n-type so $n_0 = 10^{15} \text{ cm}^{-3}$ and $p_0 = n_i^2/n_0 = 10^5 \text{ cm}^{-3}$.

b) $\phi_n = (kT/q) \ln(n_0/n_i) = 15 \times 0.06 \text{ V} = 0.30 \text{ V}$

c)



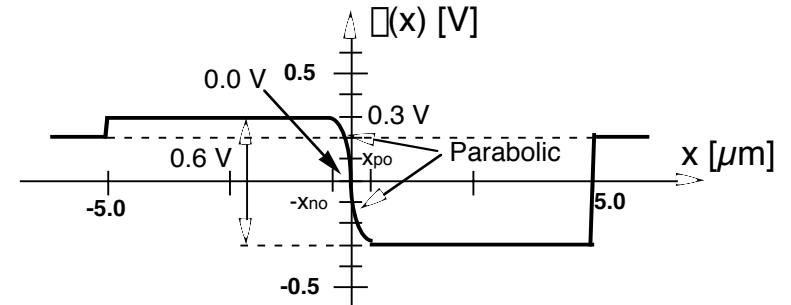
d)



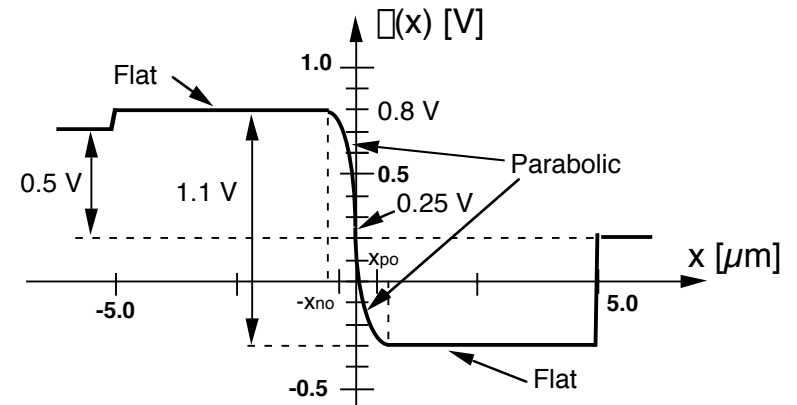
e) The electric field is $0.5 \text{ V}/10^{-3} \text{ cm} = 500 \text{ V/cm}$, so

$$J_e^{\text{dr}} = q \mu_e n_0 E = 1.6 \times 10^{-19} \times 1.6 \times 10^3 \times 10^{15} \times 5 \times 10^2 = 128 \text{ A/cm}^2$$

f) $J_n^{\text{dr}} = 0$ (i.e., negligibly small)



g)



Problem 2:

a) $D_e = kT \mu_e / q = 1600/40 = 40 \text{ cm}^2/\text{s}$

$$L_e = (D_e \tau)^{1/2} = (4 \times 10^1 \times 10^{-5})^{1/2} = 2 \times 10^{-2} \text{ cm} = 200 \mu\text{m}$$

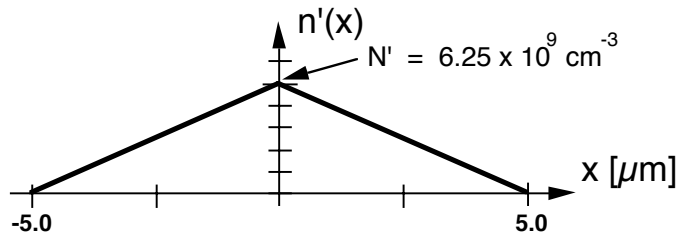
b) With uniform constant illumination, G , the excess minority carrier population is $G \tau$; thus $n'(x) = 10^{13} \text{ cm}^{-3}$.

c) The population decays as $\exp(-x/L_e)$; thus

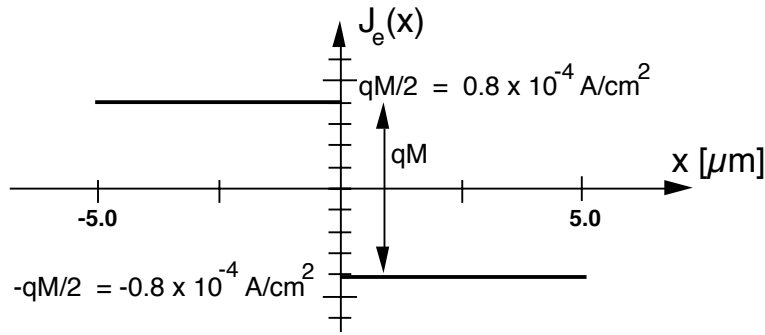
$$n'(x,t) = 10^{13} \exp(-x/L_e) \text{ cm}^{-3}$$

d) $n'(x)$ will be essentially the same as it was in Part b. Prove this to yourself if it isn't yet intuitively obvious.

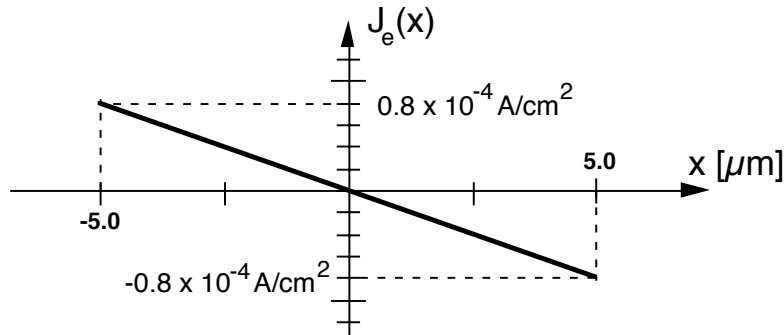
e)



f)



g)



h) Faster now, because there will now be considerable additional recombination at the ohmic contacts, reducing the effective lifetime significantly.

Problem 3:

a) Diode B, because the depletion width is wider in more lightly doped diodes.

b) Diode A, because the magnitude of the electric field is greater in more heavily doped diodes.

c) Diode B, because it will take more bias to increase the field to the breakdown level (see b above).

d) i) In Diode A, x_p is a tenth x_n , or $0.02 \mu\text{m}$, and in Diode B, x_p is ten times x_n , or $2.0 \mu\text{m}$.

ii) Diode B. The voltage drops on the n-sides are the same. And, since most of the potential step in a diode is on the more lightly doped side, the step on the p-side of B is bigger than that on the p-side of A.

e) i) p is originally 10^3 cm^{-3} on the n-sides, so it has increased 9 orders of magnitude. Thus n will increase this much also at the edge of the depletion region on the p-side, and all of this will be excess:

Diode A: $n'(-x_p) = n(-x_p) = 10^9 \times 10^2 = 10^{11} \text{ cm}^{-3}$

Diode B: $n'(-x_p) = n(-x_p) = 10^9 \times 10^4 = 10^{13} \text{ cm}^{-3}$

ii) The ratio is $D_n w_p N_{Ap} / D_e w_n N_{Dn}$. We find this is 3.75 in Diode A, and 0.375 in Diode B.

iii) Neglecting the depletion regions, as we are told to do, the integrals are $q[p'(x_n) + n'(-x_p)] 5 \times 10^{-4} / 2$. For Diode A this is $4.4 \times 10^{-11} \text{ coul/cm}^2$; for B it is ten times larger, i.e. $4.4 \times 10^{-10} \text{ coul/cm}^2$.

iv) In e-i we said p increased nine orders of magnitude; thus the applied bias is $9 \times 0.06 \text{ V} = 0.54 \text{ V}$.