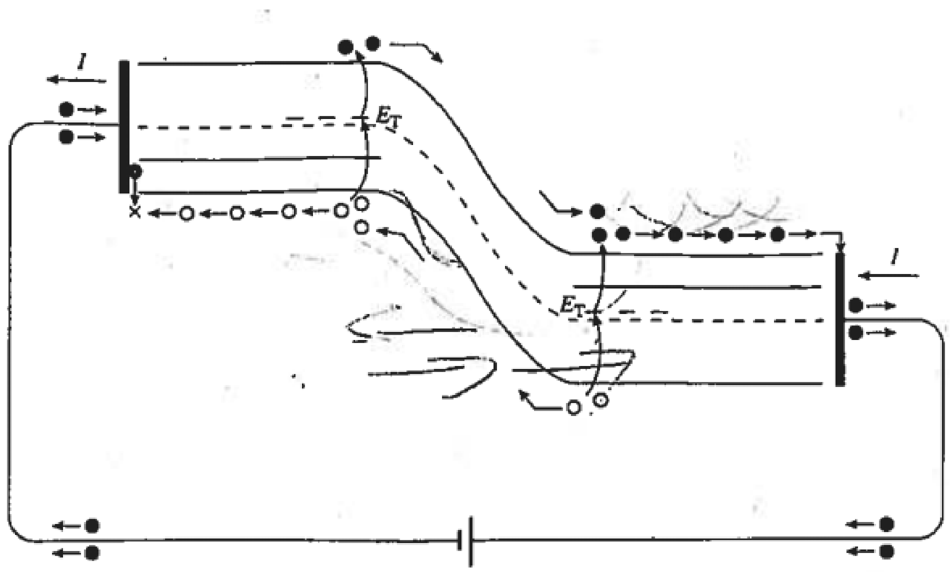
Alexandria University
Faculty of Engineering
Electrical Engineering Department

ECE 336: Semiconductor Devices
Sheet 4

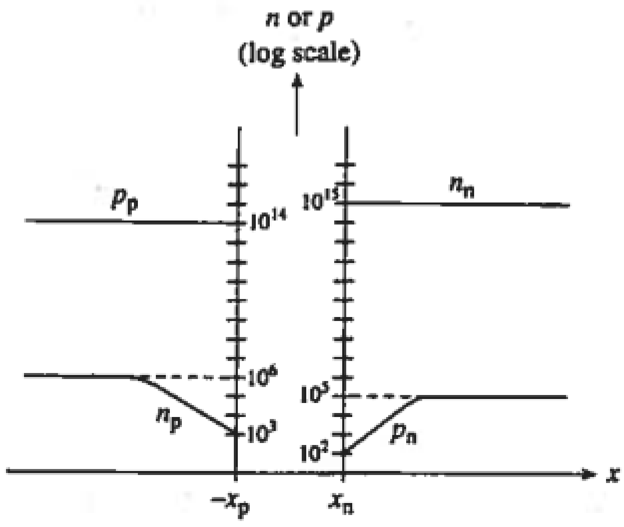
Chapter 6:

1. Sketch the energy band diagram for an ideal p+ - n step junction showing carrier activity near the depletion region when:
   a. $V_A = 0$
   b. $V_A > 0$
   c. $V_A < 0$

2. Construct a composite energy band/circuit diagram analogous to fig. 6.2 that provides an overall view of carrier activity of forward biased pn junction diode.



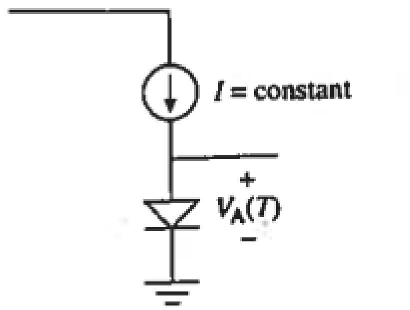
3. Consider an n+ p silicon step junction ($N_A = 10^{15}/cm^3$, $\tau_n = 10^{-6}$ sec, $A = 10^{-3}$ cm^2) to be ideal, perform calculations to determine typical current levels expected from the device under different temperature and biasing conditions.
   a. Compute the ideal diode current at T = 300K when
      i. V_A = -50V
      ii. V_A = -0.1V
      iii. V_A = 0.1V
      iv. V_A = 0.5V
   b. Assuming τ_n does not vary significantly with temperature, repeat part (a) for T= 500K.
4. The figure below is dimensioned plot of the steady state carrier concentrations inside a step pn junction diode maintained at room temperature.



a. Is the diode forward or reverse biased? Explain how you arrived at your answer.
b. Do low level injection conditions prevail in the quasineutral regions of the diode? Explain how you arrived at your answer.
c. What are the p-side and n-side doping concentrations?
d. Determine the applied voltage V_A.

5. A voltage $V_A = 23.03(KT/q)$ is being applied to a step junction diode with n- and p- side dopings of $N_A = 10^{17}/cm^3$ and $N_D = 10^{16}\ /cm^3$, respectively. $n_i = 10^{10}\ /cm^3$. Make a dimensioned log(p and n) versus x sketch of both the majority and minority concentrations in the quasineutral regions of the device. Identify points 10 and 20 diffusion lengths from the depletion region edges on your sketch.

6. It was confirmed that the I-V characteristics of the pn junction diode are very sensitive to temperature. It should not be too surprising then that there are silicon diodes sold commercially as temperature sensors. To use the diode to measure temperature, it is typically forward biased with a constant current source and V_A is monitored as a function of T as shown in the figure below. Make the assumption the diode is being operated in the forward bias range where $I = I_0 e^{qVA/KT}$. Also take the intended range of operation to be $0<T<100C$.



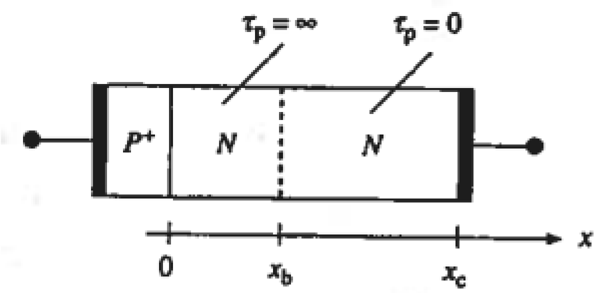
a. With I as an input variable. Compute and plot V_A versus T for $0<T<100C$.
b. Considering the sensitivity (dV_A/dT) of the sensor, would it be preferable to monitor the temperature using $I = 10^{-4}$ A or $I = 10^{-3}$ A? support your answer.

7. Given a planar p+n Si step junction diode with an n-side doping of $N_D = 10^{15}/cm^3$ and T = 300k, determine
a. The approximate V_{BR} of the diode.
b. The depletion width of the breakdown voltage.

c. The maximum magnitude of the electric field in the depletion region at the breakdown voltage.

8. The diffusion component of the current is expected to dominate in Si diodes at sufficiently elevated temperatures. What is sufficiently elevated temperature? To answer this question suppose one has p+n step junction diode where $N_D = 10^{16}/cm^3$, $\tau_0 = \tau_p$' and $L_p = 10^{-2}$ cm for 300K<T<500K. Determine the temperature where $I_{Diff} = I_{R-G}$ at a reverse bias of $V_{bi} – V_A = V_{BR} /2$.

9. Consider p^+ -n step junction diode in the figure below. Not that τ_p = inf. For $0<x<x_b$ and $\tau_p = 0$ for $x_b <x<x_c$. Excluding biases that would cause high-level injection of breakdown, develop an expression for the room-temperature I-V characteristic of the diode. Assume depletion width (W) does not exceed x_b for all biases of interest.



10. Reconsider the previous problem with some modifications. Take τ_p to be nonzero but still sufficiently small so that $L_p << x_c – x_b$. Assuming that the depletion width (W) does not exceed x_b for all biases of interest, and that excluding biases that would cause high-level injection or breakdown, derive an expression for the room temperature I-V characteristics of the diode.