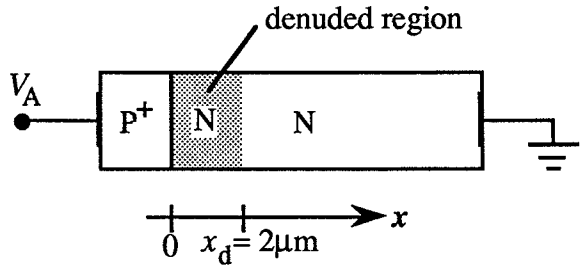
Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B8**
Type:	***Open* Book, *Open* Notes**

Problem Weighting is noted adjacent to each problem.

T2 - 1

As pictured below, a Si p^+-n step junction diode maintained at 300K is built with a denuded (decrease R–G center) region extending from $x = 0$ to $x = x_d = 2\mu m$. The R–G center concentration (N_T) is 10 times greater in the $x > x_d$ portion of the n-side. $\tau_{p0} = 10^{-5}$ sec is the minority carrier lifetime in the denuded region, $N_D = 10^{16}/cm^3$ on the n-side of the junction, and the diode area $A = 10^{-3}$ cm^2.



GENERAL

[5] (a) What is the minority carrier lifetime in the $x > x_d$ portion of the n-side? (Use the symbol $\tau_{p\infty}$ for the hole lifetime in this region.)

[5] (b) What effect will the denuded region and the associated variation in lifetime have on the capacitance exhibited by the diode under reverse bias conditions? Explain.

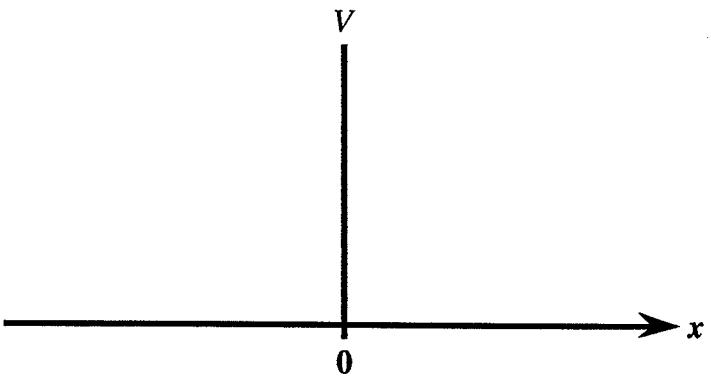
[5] (c) What is the breakdown voltage (V_{BR}) of the diode? Cite your reference.

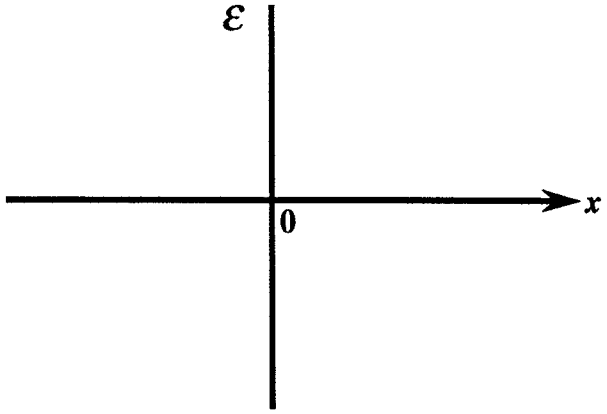
ELECTROSTATICS

[10] (d) Sketch the equilibrium energy band diagram for the diode assuming $E_F = E_v$ in the quasi-neutral region on the p^+-side of the diode. Label E_c, E_i, E_v, and E_F.

[10] (e) Based on the energy band diagram sketched in part (d), confirm that the built-in voltage across the junction is $V_{bi} \cong 0.92\text{V}$.

[10] (f) Sketch the general form of the potential (V) and electric field ($\mathcal{E}$) inside the diode. Make sure your sketches reflect the p^+-n nature of the diode.





[10] (g) What applied voltage (V_A) is necessary to expand the n-side depletion-region edge to $x = x_d$?

(Continued)

CURRENT COMPONENTS

ANSWER ONLY ONE OF PARTS (h) and (i). DO NOT ANSWER BOTH.

[20] (h) Assuming $\tau_o = \tau_{p0}$ for $0 \leq x \leq x_d$ and $\tau_o = \tau_{p\infty}$ for $x \geq x_d$, solve for the R-G current, $I_{R\text{-}G}$, flowing in the given diode under *reverse bias* conditions. Make a sketch of the reverse-biased current versus voltage based on your result.

(Continued)

ANSWER ONLY ONE OF PARTS (h) and (i). DO NOT ANSWER BOTH.

[20] (i) As in the standard diode, the diffusion or "ideal diode" current flowing in the given diode can be computed from

$$I_{\text{Diff}} \cong AJ_{\text{P}}(x_{\text{n}}) \cong -qAD_{\text{P}} \left.\frac{d\Delta p_{\text{n}}}{dx}\right|_{x_{\text{n}}}$$

where $x = x_{\text{n}}$ is the *n*-side depletion region edge.

Indicate (i) the equation or equations one must solve,

(ii) the *general* solutions of the noted equations, and

(iii) the boundary conditions

necessary to complete the $I_{\text{Diff}} - V_{\text{A}}$ derivation for the GIVEN diode. You may assume the device is a "wide-base" diode.

(DO NOT waste time actually completing the I_{Diff} derivation.)

T 2 - 2

[13] (a) Let Q_B be the charge associated with the *excess* minority carriers existing in the quasi-neutral base of a BJT under a given bias condition. It is readily established that

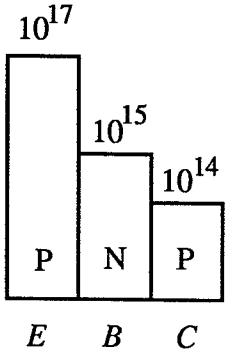
$$I_{B2} = \frac{Q_B}{\tau_B}$$

where I_{B2} is the base current component associated with minority carrier recombination in the base. τ_B is of course the minority carrier lifetime in the base.

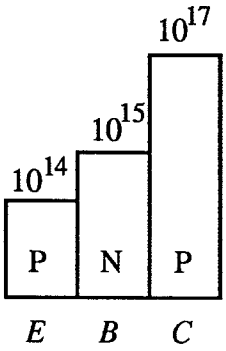
If $V_{CB} = 0$, develop an expression for I_{B2} in terms of the applied emitter-base voltage (V_{EB}). Assume a PNP transistor and $W_B << L_B$. Record your work.

(Continued)

(b) Two transistors (BJTs) are identical except the emitter and collector region dopings are interchanged. The doping profiles of transistors A and B are shown below.



Transistor **A**



Transistor **B**

Which transistor will exhibit:

[4] (i) The greater emitter injection efficiency? Explain. (1-point for answer; 2-points for explanation.)

[4] (ii) The greater sensitivity to base-width modulation under forward active mode opertion? Explain.

[4] (iii) The greater V_{CB0}? Explain.