Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B6**
Type:	***Open* Book, *Open* Notes**

Problem Weighting--- **T1-0...20**
T2-1...20 (a-5, b-10, c-5)
T2-2...30 (10 each part)
T2-3...30 (5 each part)
T2-4...10 (2 each part)–extra credit

T2 - 0

MATLAB TAKE-HOME PROBLEM

PROBLEM: 6.12 (both parts) in the SDF[†] text.
Note: The part (a) problem statement says to modify the Prob. 6.7(b) program. Actually, it is probably best to construct a totally new program; you do NOT have to complete Prob. 6.7(b) before answering Prob. 6.12.

DUE: To be handed in before or at the time of the sit-down test.

WEIGHTING: 20% of the overall test grade.

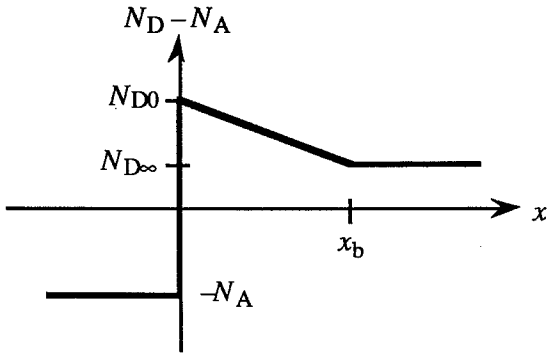
COMMENT: The MATLAB program listing must be included with the problem solution to receive credit.

[†] R. F. Pierret, *Semiconductor Device Fundamentals*, Addison-Wesley, Reading MA, © 1996.

T2 - 1

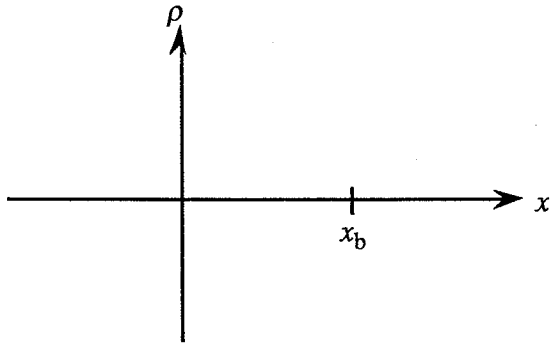
A *pn* junction diode has the doping profile sketched below, where mathematically,

$$N_D - N_A = N_{D0} - (N_{D0} - N_{D\infty})\frac{x}{x_b} \qquad \ldots 0 \le x \le x_b$$



Assume that $x_n < x_b$ for the V_A being applied across the diode. (Reiterating, x_n *is less than* x_b, where x_n is the *n*-edge of the depletion region.)

(a) Invoking the depletion approximation, make a sketch of the charge density inside the diode.



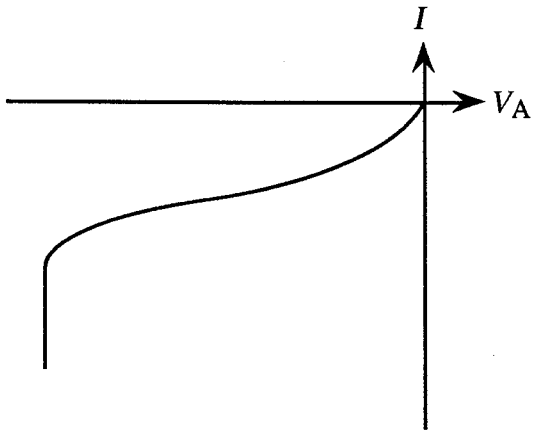
(b) Establish an analytical expression for the electric field, $\mathcal{E}(x)$, in the depletion region on the *n*-side of the junction ($0 \le x \le x_n$, $x_n < x_b$).

(c) Given $x_n = x_b/2$ under equilibrium ($V_A = 0$) conditions, establish an expression for the built-in voltage (V_{bi}) across the *pn* junction. HINT: See the paragraph that starts at the bottom of p. 225 in the text. Also, you will need to make use of the fact that $x_n = x_b/2$ when $V_A = 0$.

T2 - 2

The current-voltage (I–V_A) and junction capacitance (C_J–V_A) characteristics pictured in the following figures are to be considered *experimental data* derived from a p^+-n Si step junction diode maintained at room temperature. In each case, add a *dashed-line* to the characteristic to indicate how the specified change in one of the device parameters would affect the characteristic. TO RECEIVE CREDIT OF ANY TYPE you must EXPLAIN how you arrived at the modified characteristic. You may use equations in your explanations.

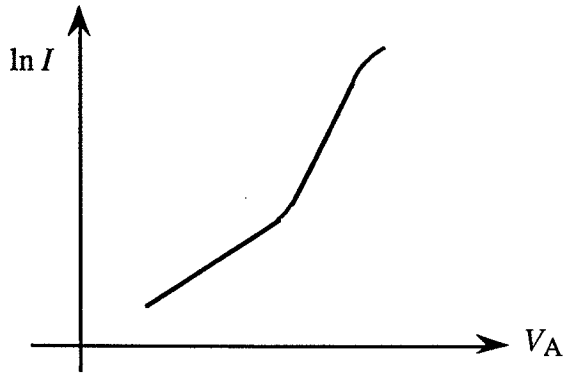
(a) Indicate how the reverse-bias I–V_A characteristic would be modified if N_D were increased by a factor of 2. (All other parameters remain the same.)



EXPLANATION:

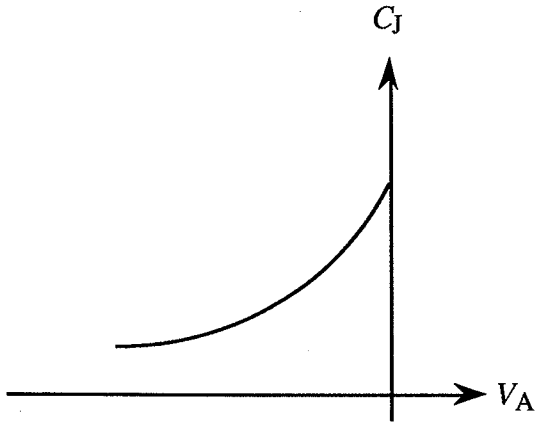
(continued)

(b) Indicate how the forward-bias I–V_A characteristics would be modified if the concentration of R–G centers (N_T) throughout the device were increased by a factor of 2.



EXPLANATION:

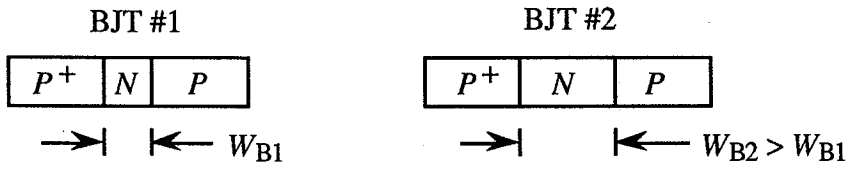
(c) Indicate how the reverse bias C_J–V_A characteristic would be modified if the dielectric constant (K_S) were somehow increased by a factor of 2.



EXPLANATION:

T2 - 3

Two silicon *pnp* BJT's maintained at 300K are identical except the physical width of the base (W_B) is greater in BJT #2. $W_B << L_B$ in both BJT's. Compare the operation of the two BJT's by answering the questions that follow. Assume identical biasing of the two BJT's in working parts (a) through (d).



NOTE: *No explanation → No credit.* You may use equations in your explanations.

(a) Which BJT will exhibit the larger emitter efficiency (γ)?

1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

(b) Which BJT will exhibit the larger base transport factor (α_T)?

1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

(c) Which BJT will exhibit the larger common emitter d.c. current gain (β_{dc})?

1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

(d) Which BJT will exhibit the greater sensitivity to base-width modulation?

1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

(e) Assuming punch-through limits the observed V_{CB0}, which BJT will exhibit the larger V_{CB0}?

1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

(f) Assuming avalanche breakdown of the CB junction limits the observed V_{CB0}, which BJT will exhibit the larger V_{CE0}?

1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

T2 - 4

EXTRA CREDIT

(a) A semiconductor has a band gap of 2.48 eV. Approximately, what is the wavelength of the light to be expected from an LED constructed from the semiconductor?

(b) *Name* two semiconductor materials that are used to make yellow LEDs.

(c) The frequency response of the *p-i-n* photodiode is greatly enhanced over that of a *pn* junction photodiode. Concisely explain why.

(d) *Name* two semiconductor materials that have been employed in producing avalanche photodiodes specifically constructed for use in fiber-optic communications.

(e) The top surface of solar cells are often "textured". What exactly is "texturing" and why is it employed?