Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B4**
Type:	***Open* Book, *Open* Notes**

Problem Weighting--- **T2-0...20**
T2-1...25 (a-5, b-10, c-10)
T2-2...30 (10 each part)
T2-3...15 (5 each part)
T2-4...20 (N_D-8, V_{bi}-4, Φ_B-8)
(10 points extra credit possible)

T2 – 0

MATLAB TAKE-HOME PROBLEM

DUE: To be handed in immediately before the sit-down test.

WEIGHTING: **T2-0...**20% of the overall test grade.

PROBLEM:

Complete Problem 6.21 (a)–(c) on pp. 297–299 of the SDF[†] text. *OMIT* parts (d)–(f). *CHANGE* the upper limit on the plotted region as specified in part (b) from 10^{-2}A to 10^{-1}A. *PREFERABLY* place the four required plots in part (c) on a single page. Your submitted solution must contain the answer to part (a) and the MATLAB program script used to produce the plots in part (c).

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

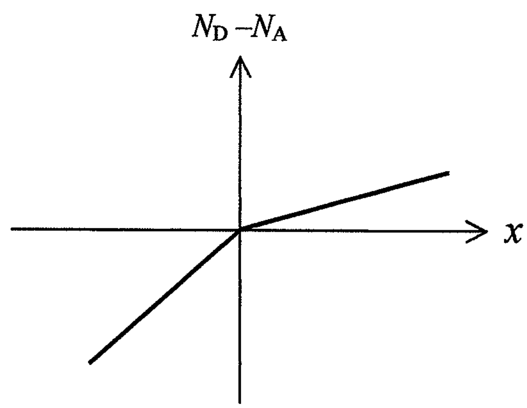
T2 – 1

[Outcome–(iv)]

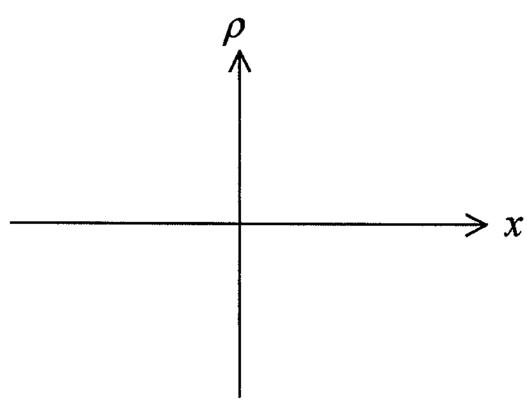
A *pn* junction diode has the asymmetrical linearly-graded doping profile pictured below. Note that

$$N_D - N_A = \begin{cases} ax & \ldots x \le 0 \\ bx & \ldots x \ge 0 \end{cases}$$

where $a > 0$, $b > 0$, and $a \neq b$.



(a) Invoking the depletion approximation, sketch the charge density ρ versus x inside the diode.



(b) Starting from Poisson's equation, obtain an analytical solution for the electric field, $\mathcal{E}$, inside the depletion region.

(Continued)

(c) It can be shown that

$$V(x)=\begin{cases}\dfrac{qa}{6K_S\varepsilon_0}\left(2x_p^3+3x_p^2x-x^3\right) & \ldots -x_p\le x\le 0\\[2ex] (V_{bi}-V_A)-\dfrac{qb}{6K_S\varepsilon_0}\left(2x_n^3-3x_n^2x+x^3\right) & \ldots 0\le x\le x_n\end{cases}$$

Establish an expression for the depletion width W inside the diode. [If $a = b$, does your W expression reduce to Eq. (5.45) in the text?]

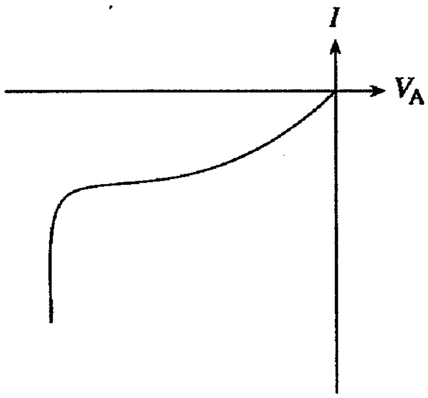
T2 – 2

[Outcome–(iv)]

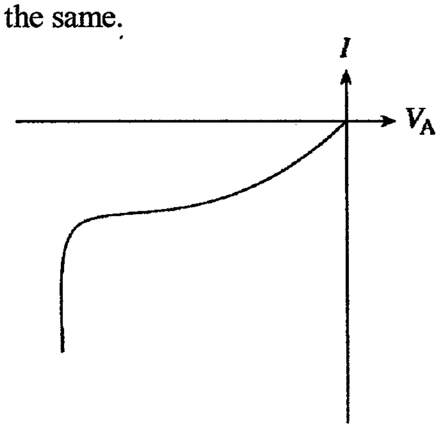
The reverse bias current-voltage (I–V_A) characteristic derived from a wide-based p^+–n Si step-junction diode maintained at room temperature is sketched below. Answer the following questions by adding a *dashed line* to the figure. In each case, also *EXPLAIN* how you arrived at your answer. If the answer is *no effect* (a dashed line the same as the given characteristic) write *no effect* and explain how you arrived at your answer.

ROUGHLY indicate how the (I–V_A) characteristic would be modified if:

(a) The nondegenerate n-side doping (N_D) was *INCREASED* by a factor of 2 while all other parameters remained the same.

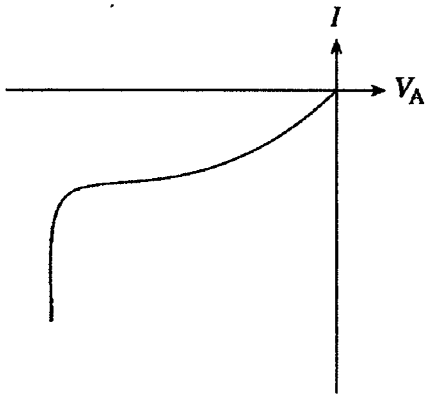


(b) The R–G center concentration (N_T) was *INCREASED* by a factor of 2. All other parameters remain the same.



(CONTINUED)

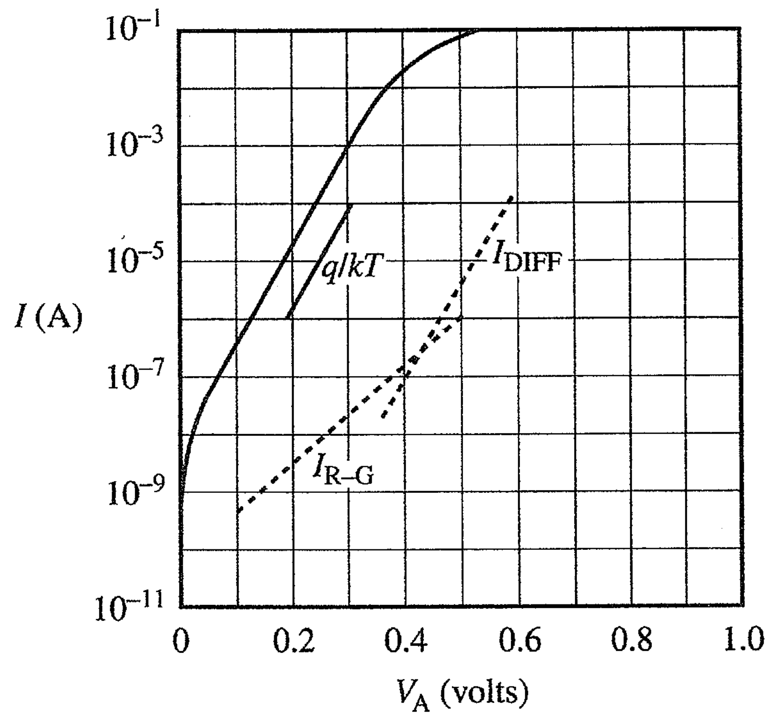
(c) The diode temperature was *INCREASED* from 300K to 325K. Assume the carrier lifetimes (τ_n, τ_p, τ_0) in the diode are unaffected by the increase in temperature.



T2 – 3

[Outcome–(v)]

A blow-up of text Fig. 14.6(a) is reproduced below. The solid line in the figure is a plot of the measured forward-biased *I–V* characteristics derived from a MBR040 Schottky diode.



(a) What is the cause of the non-linear plot region near $V_A = 0$?

(b) Determine the approximate value of the diode "saturation" current, I_S. Record how you arrived at your answer.

(c) Determine the approximate value of the diode series resistance, R_S. Record how you arrived at your answer.

T2 – 4

[Outcome–(v)]

A least squares fit to $(1/C)^2$ versus V_A data derived from a 1N5819 Schottky diode maintained at 300K yields:

$$(1/C)^2 = 3.08 \times 10^{19} - (7.64 \times 10^{19})\, V_A$$

where V_A has units of volts and $(1/C)^2$ has units of $(1/F)^2$. Take the semiconductor in the diode to be *n*-type Si and assume the cross-sectional area of the diode is $A = 1.61 \times 10^{-3}$ cm^2. From the given information determine (a) N_D, (b) V_{bi}, and (c) the Φ_B characterizing the diode.