Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B1**
Type:	**Closed Book, Closed Notes**
Note:	**Available Info/Equation Sheets**

Problem Weighting--- **T2-1...24 (6 each part)**
T2-2...28 (a,c,e,g-2; b,d,f,h-5)
T2-3...15 (3 each part)
T2-4...12 (4 each part)
T2-5...21 (a-6, b-6, c-9)

MATLAB *EXTRA-CREDIT* TAKE-HOME PROBLEM

DUE: To be handed in on the Monday after the T2 sit-down test.
(The problem answer is understood to be your own work, completed without the direct or indirect assistance of another person.)

MAXIMUM EXTRA CREDIT: 2% added to the semester test score.

PROBLEM:

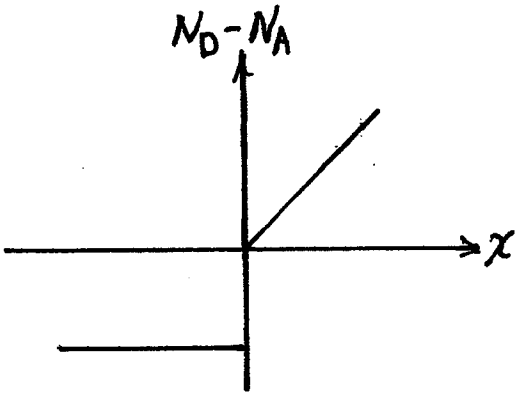
Complete Problem 6.21 (a)–(c) on pp. 297–299 of the SDF[†] text. *OMIT* parts (d)–(f). *CHANGE* the upper limit on the plotted region as specified in part (b) from 10^{-2}A to 10^{-1}A. *PREFERABLY* place the four required plots in part (c) on a single page. Your submitted solution must contain the answer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

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

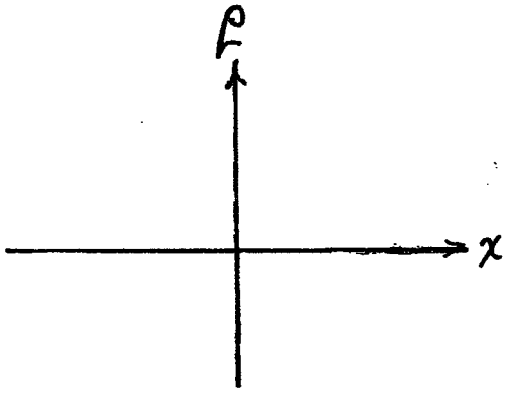
T2 – 1
[Outcome–(iii)]

Score_____/24

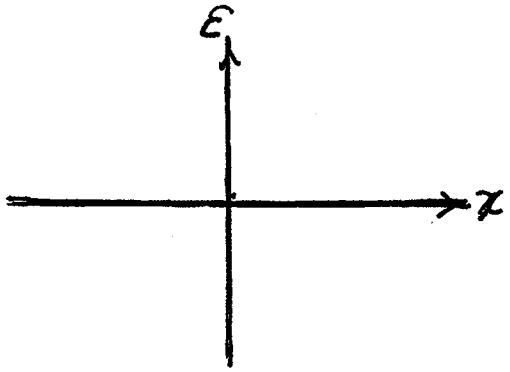
A *pn* junction diode has the doping profile pictured below. Note that $N_D - N_A = ax$ for $x > 0$.



(a) Invoking the depletion approximation, qualitatively sketch the general form of the charge density versus x inside the diode. (No computations are necessary or required.)



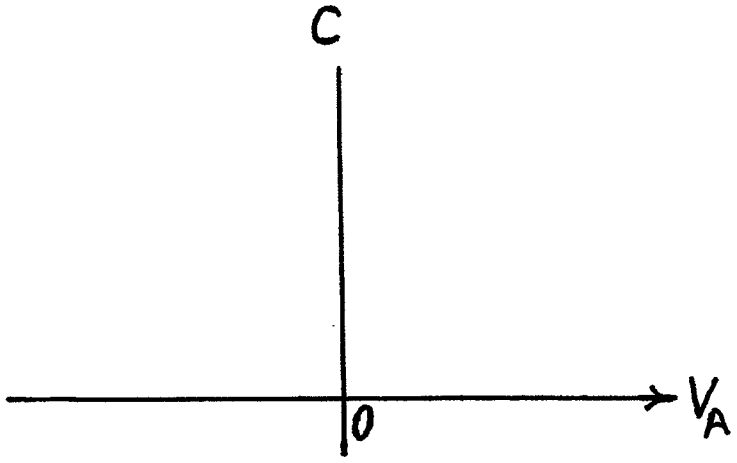
(b) Sketch the general form of the electric field versus x inside the diode. (No computations are necessary or required.)



(Continued)

(c) Establish **ONE** of the two relationships between x_n and x_p that is needed to determine a solution for the x_n and x_p widths in the given diode. HINT: Consider a requirement associated with the part (a) or part (b) plots.

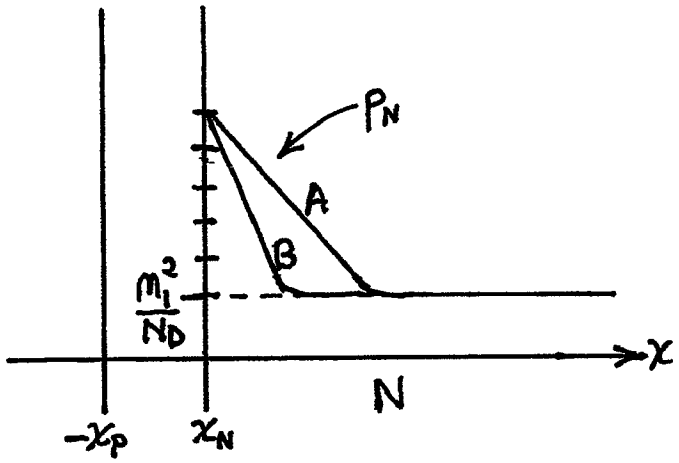
(d) Sketch the expected general form of the C–V characteristic to be expected from the diode. (No computations are necessary or required.)



T2 – 2
[Outcome–(iii)]

Score_____/28

A semilog plot of the minority carrier concentration on the *n*-side of two *ideal p+-n diodes* maintained at room temperature is pictured below. The *n*-side doping (N_D) and the cross-sectional area (A) are the same in both diodes. Assume low-level injection conditions prevail.



Place a circle around the correct answer in parts (a), (c), (e), and (g).

(a) The diodes are (i) forward biased, (ii) zero biased, or (iii) reverse biased?
(b) Explain how one determines the correct answer to part (a).

(c) The magnitude of the bias applied to Diode A is (i) larger than, (ii) the same as, or (iii) smaller than the magnitude of the bias applied to Diode B?
(d) Explain how one determines the correct answer to part (c).

(Continued)

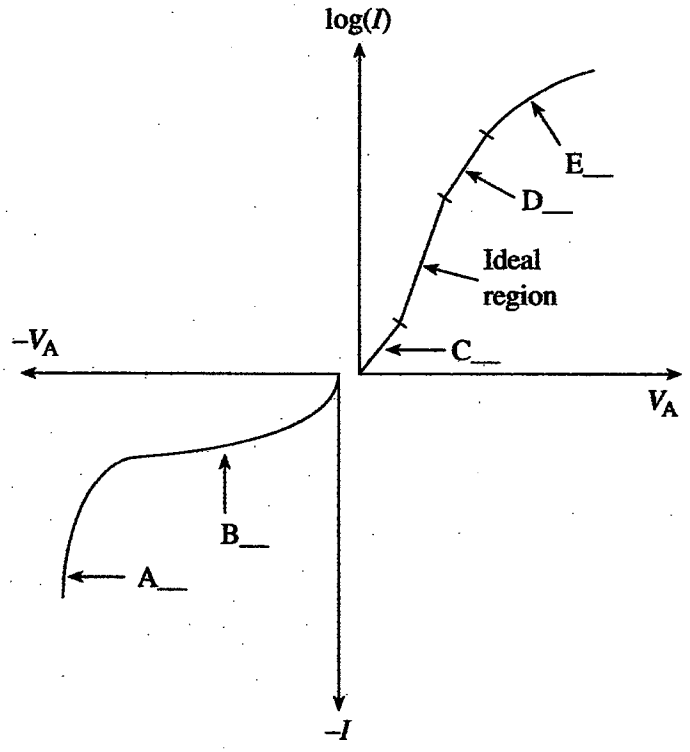
(e) If the diodes were to exhibit reverse bias breakdown by the avalanching process, the breakdown voltage (V_{BR}) of Diode A would be (i) signficantly larger than, (ii) roughly the same as, (iii)significantly less than the breakdown voltage of Diode B?
(f) Explain how one determines the correct answer to part (e).

(g) The magnitude of the d.c. current, $|I|$, flowing through Diode A is (i) signficantly larger than, (ii) roughly the same as (iii) signficantly smaller than the magnitude of the d.c.current flowing through Diode B? HINT: For an ideal p+-n diode, $I = AJ_P(x=x_n)$.
(h) Explain how one determines the correct answer to part (g).

T2 – 3
[Outcome–(iii)]

Score_____/15

The measured *I–V* characteristic of a Si diode maintained at room temperature is crudely sketched in the figure below. Note that the current scale is logarithmic for forward bias and linear for reverse bias. Nonidealities exhibited by the characteristic are identified by capital letters. Various possible sources for the deviations from the ideal are listed to the right of the sketch. Identify the cause of each nonideal *I–V* feature; place the proper source number(s) adjacent to the letters on the sketch.



1. Photogeneration
2. Thermal recombination in the depletion region
3. Avalanching and/or Zener process
4. Low-level injection
5. Depletion approximation
6. Thermal generation in the depletion region
7. Band bending
8. Series resistance
9. $V_A > V_{bi}$
10. High-level injection

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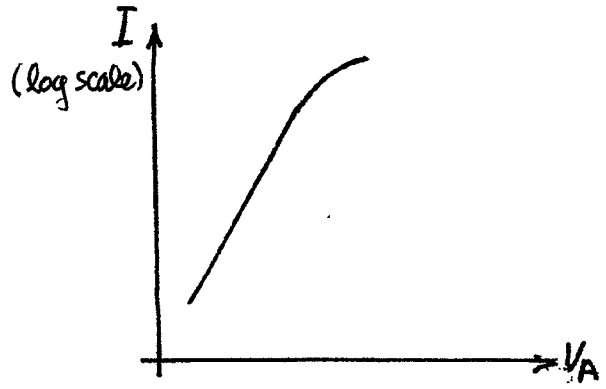
T2 – 4
[Outcome–(iv)]

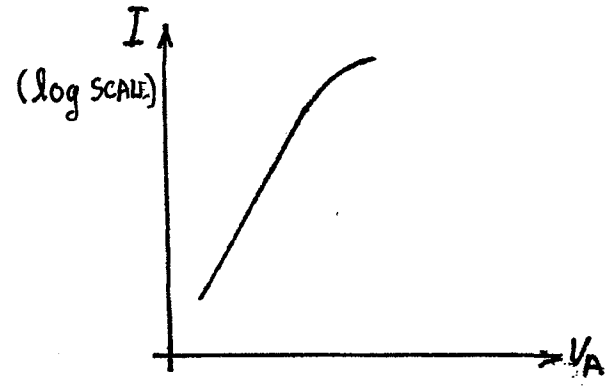
Score_____/12

On the sketches pictured below, roughly indicate using a *dashed line* how the forward bias *I–V* characteristic of a *Schottky* diode would be modified if the noted changes were made. Write "no effect" if your dashed line would be the same as the given characteristic.

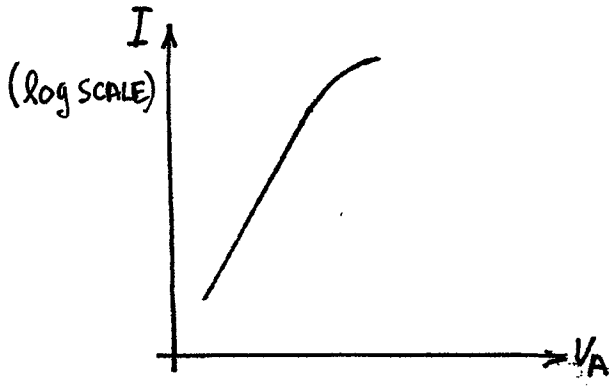
(a) The series resistance (R_S) of the diode is increased.



(b) Φ_B is increased.



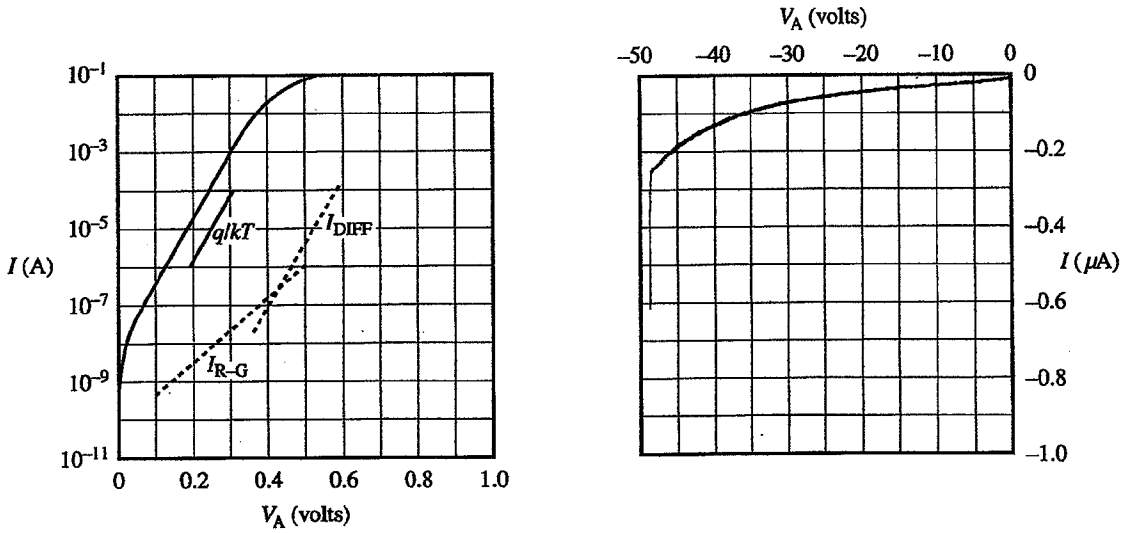
(c) The R–G trap concentration (N_T) is decreased



T2 – 5

[Outcome–(iv)] Score_____/21

The measured *I–V* characteristics† derived from a Schottky diode are reproduced below.



(a) Does the measured *forward-bias I–V* characteristic exhibit any deviations from the ideal device theory? Elaborate (cite all deviations).

(b) Does the measured *reverse-bias I–V* characteristic exhibit any deviations from the ideal device theory? Elaborate (cite all deviations).

(c) Φ_B is sometimes estimated from the measured value of I_s. Given $A = 10^{-4}$ cm^2, $a^* = a =$ 120 amps/cm^2–K^2, and $T = 300$K, estimate Φ_B in the device under analysis.

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