Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B5**
Type:	***Open* Book, *Open* Notes**

Problem Weighting is noted adjacent to problems.

1. Consider a silicon step junction having $N_D = 4x10^{16}$ cm^{-3} and $N_A = 1x10^{16}$ cm^{-3}. If the total depletion width W (= $x_N + x_P$) is 1 μm, sketch (to scale) the space charge distribution in the depletion region. You may employ the depletion approximation in this analysis. Give specific numerical values for x_N and x_P.

[10 pts]

2. The electric field in the depletion region of a pn junction (circle one)…

[~~10~~ 5 pts]

- always causes electrons to drift toward the n-side.
- always causes electrons to drift toward the p-side.
- causes electrons to drift toward the p-side under forward bias and toward the n-side under reverse bias.
- is very small in magnitude, so that drift can be neglected.

3. Explain in a short sentence why the minority carrier diffusion equations cannot be applied within the depletion region of a pn junction.

[5 pts]

4. In the neutral regions near the pn junction, the most important physical processes occurring under reverse bias are (circle one)…

[~~10~~ 5 pts]

- diffusion and generation.
- drift and diffusion.
- drift and recombination.
- diffusion and recombination.
- drift and generation.

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5. If we allow holes and electrons to recombine as they pass through the depletion region of a pn junction, the current in the diode at a given forward bias (compared to the current if carriers cannot recombine in the depletion region) is (circle one)...

[5 pts]

- decreased.
- increased.
- unchanged.

6. A silicon pn junction is maintained under a reverse bias of $V_A = -5$ V in the dark. Calculate the pn product at the center of the depletion region at room temperature.

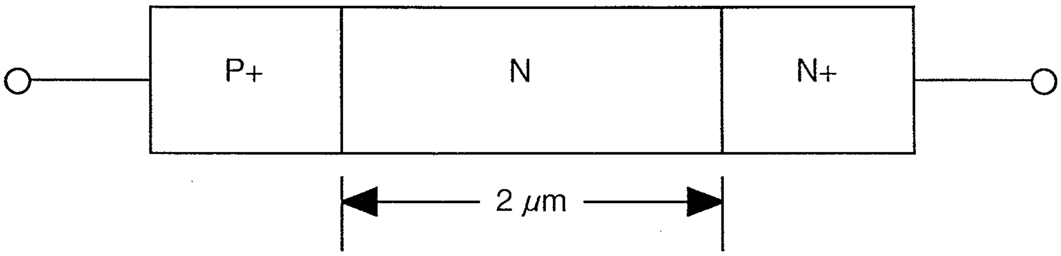
[10 pts]

7. Under reverse bias, the actual current in a pn junction exceeds that predicted by the ideal diode equation due to (circle one)...

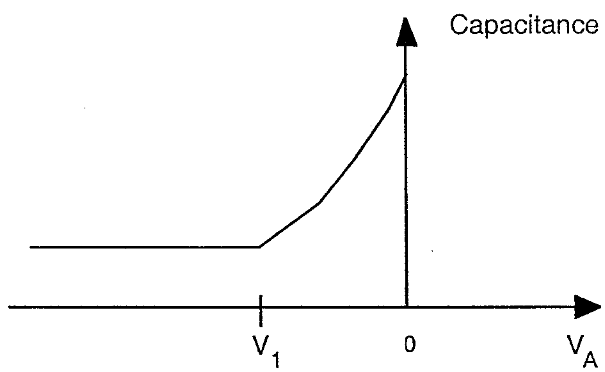
[~~10~~ 5 pts]

- recombination in the depletion region.
- drift due to the electric field in the depletion region.
- generation in the depletion region.
- generation in the neutral regions.

8. Consider the silicon pn diode shown below. The P+ and N+ regions are so heavily doped that they show negligible depletion under normal biases (i.e. the depletion region width in these regions can be regarded as zero). The central N region is doped 3×10^{15} cm^{-3} with phosphorus. The diode is maintained at room temperature in the dark.



The junction capacitance of this diode is also illustrated below as a function of applied voltage.



A. What is the minimum capacitance (i.e. the capacitance in the flat portion of the curve) in F/cm^2?

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[~~5~~ pts]

B. At what value of applied voltage V_A does the capacitance flatten out (i.e. what is the numerical value of V_1)? Hint: For this part, you may assume the built-in potential is 1.1 V.

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[~~5~~ pts]

9. In a metal-semiconductor diode, current flow under forward bias consists primarily of (circle one)...

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[~~10~~ pts]

- majority carriers injected from M -> S.
- minority carriers injected from S -> M.
- majority carriers injected from S -> M.
- minority carriers injected from M -> S.

10. Consider an ideal MS diode formed on n-type silicon. The metal work function Φ_M is 4.33 eV, the electron affinity χ is 4.03 eV, and the donor density N_D is 5×10^{15} cm^{-3}. The diode is maintained in equilibrium conditions at room temperature.

A. What is the MS barrier height Φ_B in units of eV? [5 pts]

B. What is the semiconductor work function Φ_S in units of eV? 10 [~~5~~ pts]

C. What is the width of the depletion region? [~~8~~ 10 pts]

D. What is the sheet charge density on the surface of the metal at x=0 in units of C/cm^2 ?

[5 pts]