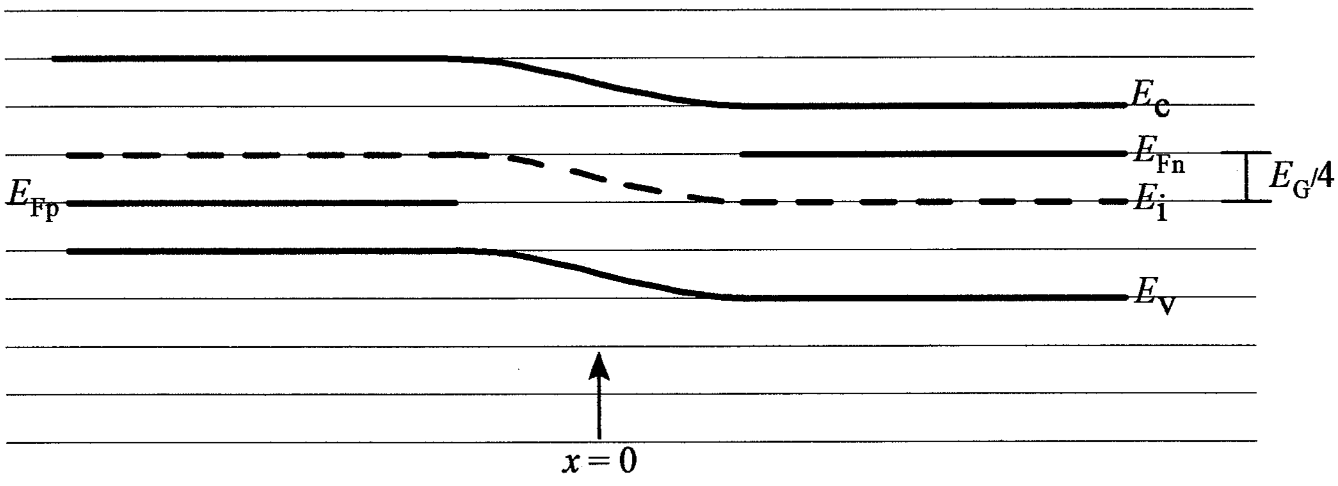
Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B3**
Type:	**Closed Book, Closed Notes**
Note:	**Available Info/Equation Sheets**

Problem Weighting--- **T2-1...40 (a,d–4; b,c,e,f–8)**
T2-2...28 (a,d–8; b,c,e–4)
T2-3...32 (a,b–8; c,d,e,f–4)

T2 – 1

[Outcome–(iv)] Score____/40

Pictured below is the energy band diagram for a Si *pn* junction diode maintained at room temperature.



(a) What is the polarity and magnitude of the applied bias (V_A)? [Record computational equation(s).]

(b) Determine the built-in-voltage (V_{bi}). [Record computational equation(s).]

(c) Assuming a step-junction doping profile, determine W. [Record computational equation(s).]

(d) Adding to the diagram in the problem statement, sketch and label the typically assumed positioning of the electron and hole quasi-Fermi levels (F_N and F_P) through the depletion region.

(e) What is the *np* product at $x = 0$?

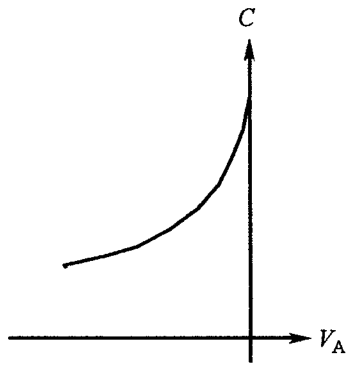
(f) Adding carrier symbols (●, O) to the diagram in the problem statement, identify (i) the major source of the diffusion current (I_{DIFF}) and (ii) the source of the recombination–generation current ($I_{R\text{–}G}$) flowing in the diode.

T2 – 2
[Outcome–(iv or v)] Score____/28

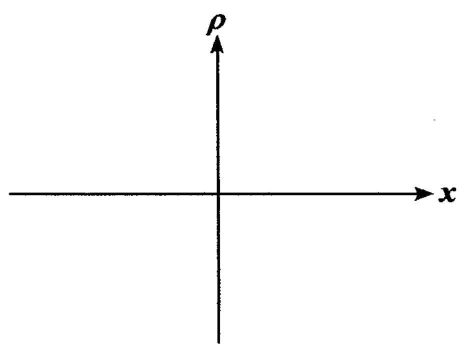
The reverse-bias capacitance (C–V_A) characteristic derived from a diode—it could be a p+-n step-junction diode or an n-type Schottky diode—is sketched below. It is further established that a least squares fit to the $1/C^2$ versus V_A data yields

$$1/C^2 = \alpha_1 - \alpha_2 V_A$$

where α_1 and α_2 are positive constants.



(a) Make a sketch of the **d.c.** charge density inside the diode during the C–V measurement. Specifically note the physical origin of the (+) and (–) charges on your sketch for both a p+-n step-junction diode and an n-type Schottky diode.



(b) Indicate how the term "quasistatically" relates to the capacitance measurement.

(c) For any *pn* junction diode and Schottky diode, the capacitance decreases with increasing reverse bias. Why?

(d) N_D = ? (Establish a relationship that could be used to compute N_D, the *n*-side diode doping concentration.)

(e) V_{bi} = ? (An equation for V_{bi} is desired.)

T2 – 3

[Outcome–(v)] Score____/32

Aluminum (Al) is the metal used in ECE557 to make external contacts to the backside of fabricated Si devices. Except for part (f), answer the following questions assuming the Al-Si contact is ideal and $N_D = 8 \times 10^{16}/\text{cm}^3$ is the backside Si doping. $T = 300\text{K}$, $\Phi_M(\text{Al}) = 4.28\text{eV}$, and $\chi(\text{Si}) = 4.03\text{eV}$.

(a) Determine Φ_S, the Si workfunction.

(b) Roughly to scale, sketch the energy band diagram for the Al-Si contact under equilibrium conditions. Label relevant energy levels.

(c) Is the contact ideally ohmic or rectifying? Explain how you arrived at your answer.

(Continued)

(d) Φ_B = ? [Record computational equation(s).]

(e) V_{bi} = ? [Record computational equation(s).]

(f) The Al-Si contact described in this problem is not really optimum for contacting the backside of fabricated Si devices. Indicate what must be done to achieve a low-resistance Al-Si contact.