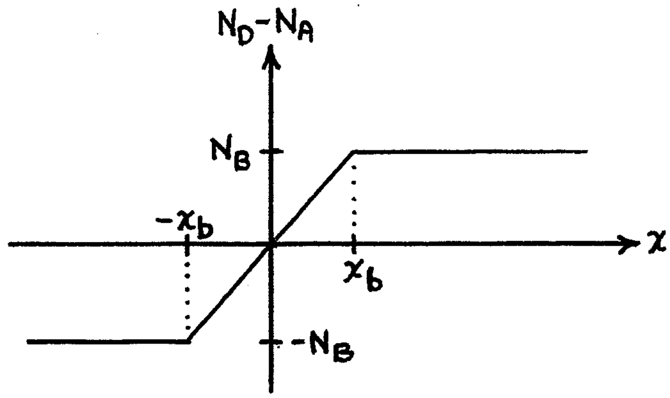
Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B14**
Type:	**Closed Book, Closed Notes**
Note:	**Available Info/Equation Sheets**

Problem Weighting--- **2-1...25 (a,b,c-5, d-10)**
2-2...25 (5 each part)
2-3...25 (5 each part)
2-4...25 (a-10, b-10, c-5)

2 - 1

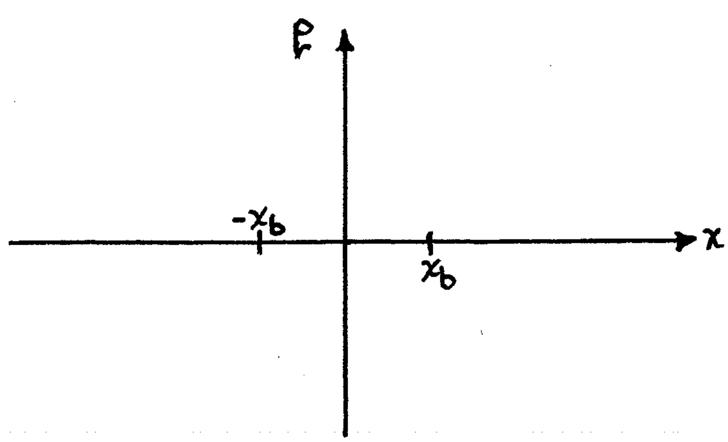
The doping profile inside a Si diode maintained at room temperature is as sketched below.



In answering the following questions assume that the edges of the depletion region lie <u>outside</u> $-x_b \leq x \leq x_b$ for all biases of interest.

(a) Establish an expression for the built-in voltage, V_{bi}.

(b) Invoking the depletion approximation, sketch ρ versus x inside the diode.



(c) Establish an expression for the electric field ($\mathcal{E}$) in the region $-x_p \leq x \leq -x_b$.

(d) **INDICATE** how you would complete the electrostatic development to eventually obtain an expression for the depletion width, W. Be as specific as possible about the equations to be solved and the boundary conditions to be employed. Don't waste time actually performing mathematical manipulations. Organize your answers into steps -- step 1, step 2, etc.

2 - 2

(a) Which of the following assumptions is NOT invoked in deriving the ideal diode equation.

(i) No recombination-generation in the depletion region.

(ii) Low level injection.

(iii) Narrow-base diode (N and P quasi-neutral widths much less than the respective minority carrier diffusion lengths).

(iv) No "other" processes (i.e., no photogeneration, avalanching, tunneling, etc.).

(b) Under reverse biasing and small forward biasing, the dominant current component in a <u>Si</u> PN junction diode maintained at <u>room temperature</u> is:

(i) the diffusion current

(ii) the R-G current

(iii) the ideal-diode current

(iv) the drift current

(c) Which of the following statements is INCORRECT?

(i) PN junction breakdown is a reversible process.

(ii) For tunneling (the Zener process) to occur in a PN junction diode, the depletion width must be very narrow ($\lesssim 10^{-6}$ cm).

(iii) The breakdown voltage is (to first order) inversely proportional to the doping on the lightly doped side of P^+N and N^+P junctions.

(iv) In Si diodes maintained at room temperature, avalanching is the dominant process causing breakdown if $V_{BR} \lesssim 4V$.

(Continued)

(d) In an ideal diode under reverse bias conditions the diffusion admittance vanishes because:

(i) The minority carrier concentrations in the quasi-neutral regions adjacent to the depletion region edges become independent of bias. Consequently, the cited minority carrier concentrations do not fluctuate with the applied a.c. signal.

(ii) Minority carriers cannot follow (respond to) the applied a.c. signal under reverse bias conditions.

(iii) Under reverse bias conditions the current flowing across the depletion region in an ideal diode is associated with minority carriers. Consequently, the diffusion admittance, associated with the majority carriers, becomes vanishingly small.

(iv) The diffusion admittance does not vanish in an ideal diode under reverse bias conditions!

(e) Which of the following statements about the junction capacitance (C_J) is CORRECT?

(i) C_J always varies as $1/\sqrt{V_{bi}-V_A}$.

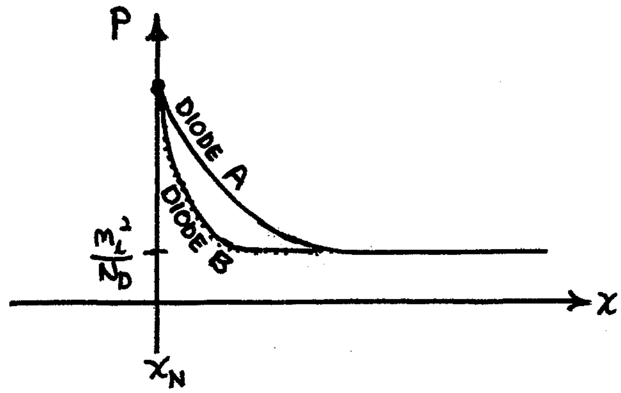
(ii) The minimum observable C_J will occur at V_{BR}.

(iii) C_J vanishes under forward biasing.

(iv) C_J is associated physically with fluctuations in the minority carrier concentrations at the edges of the depletion region.

2 - 3

Minority carrier concentration versus position plots are often used to describe the situation inside semiconductor devices. A plot of the minority carrier concentration on the N-side of two <u>ideal</u> <u>P^+N</u> diodes maintained at <u>room temperature</u> 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.



(a) The diodes are

(i) forward biased. (ii) zero biased. (iii) reverse biased.

(b) The magnitude of the bias applied to Diode B is

(i) large than (ii) the same as (iii) smaller than

the magnitude of the bias applied to Diode A.

(c) The magnitude of the d.c. current, |I|, flowing through Diode B is

(i) significantly larger than (ii) roughly the same as

(iii) significantly smaller than

the magnitude of the d.c. current flowing through Diode A.

(d) The breakdown voltage (V_{BR}) of Diode B is

(i) significantly larger than (ii) roughly the same as

(iii) significantly less than

the breakdown voltage of Diode A.

(e) Diodes A and B are tested in the same switching circuit. (I_F/I_R is the same for both diodes.) Which diode will exhibit the LARGER storage time (larger t_s)?

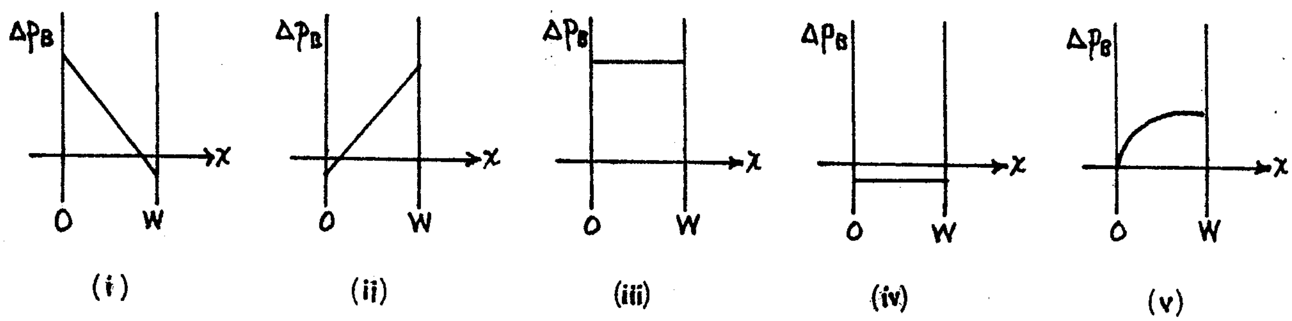
(i) Diode A (ii) Diode B

(iii) t_s will be essentially the same for both diodes

2 - 4

(a) The polarity (F=forward or R=reverse) of the bias being applied to the emitter-base and collector-base junctions of a BJT are specified by citing the biasing "mode". Complete the table below indicating (1) the polarity specified for each of the biasing modes and (2) the minority carrier distribution plot (i-v) associated with the given biasing mode. NOTE: There are really only four BJT biasing modes. Identify the "false" mode with "X" entries in the table.

Biasing Mode	Polarity of Bias emitter-base	Polarity of Bias collector-base	Minority Carrier Distribution in base (i-v)
Active			
Cut-Off			
Saturation			
Inversion			
Inverted Active			



(b) Fill in the spaces in the table below. Independently considering the base transport factor (α_T) and the emitter efficiency (γ), indicate whether the noted change in a BJT device parameter INCREASES, DECREASES, or has NO EFFECT on α_T and γ.

Change	Effect on α_T	Effect on γ
Increase W_B		
Increase τ_B		
Increase N_B		
Increase τ_E		
Increase N_E		

(c) The condition in a BJT where the E-B and C-B depletion regions touch inside the base is referred to as:

(i) Base emptying

(ii) Base-width modulation

(iii) Punch-through

(iv) Base crowding