Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**B**
Test:	**B11**
Type:	**Closed Book, Closed Notes**
Note:	**Available Info/Equation Sheets**

Problem Weighting is noted to the right side of each problem statement.

1. Circle the correct answer: In the depletion region of a forward biased PN junction, the pn product is... [5 pts]

   $> n_i^2$

   $= n_i^2$

   $< n_i^2$

2. Circle the correct answer: In the neutral regions near the depletion region of a forward biased PN junction, the dominant "carrier actions" are... [5 pts]

   drift and diffusion

   generation and recombination

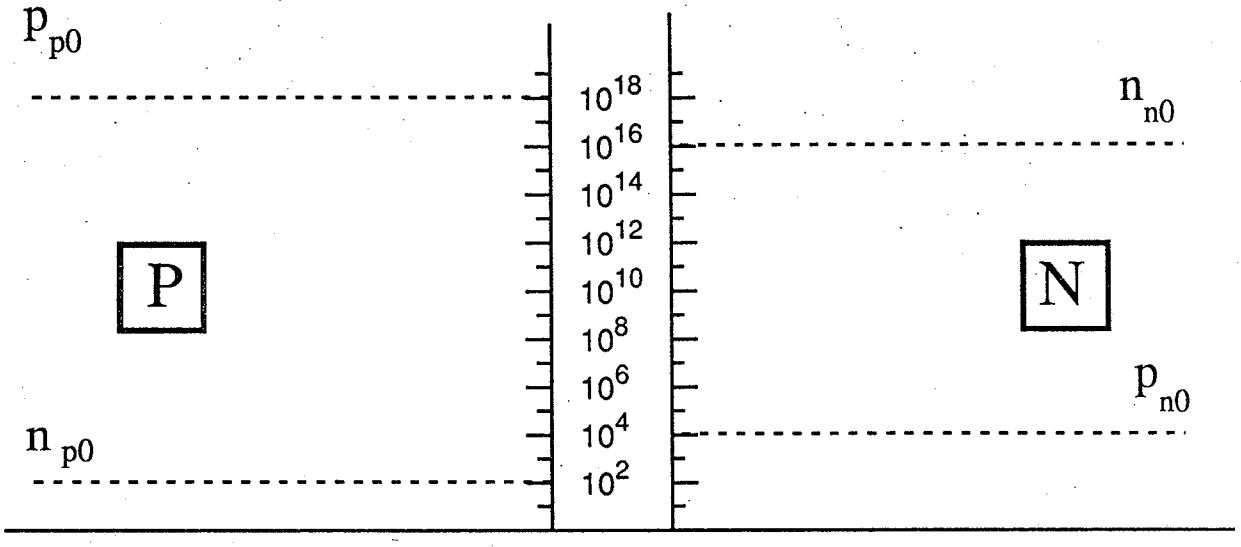
   generation and diffusion

   recombination and diffusion

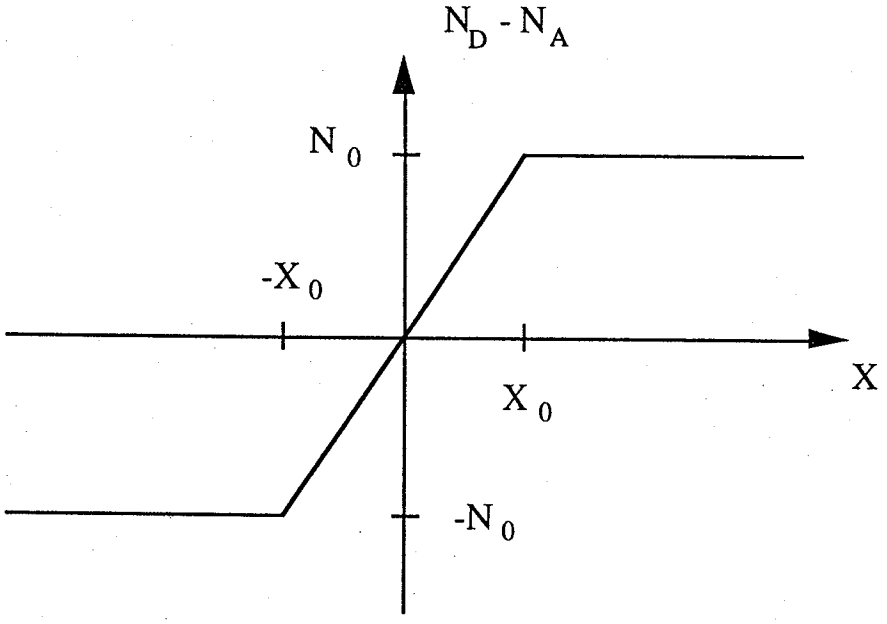
   generation and drift

   recombination and drift

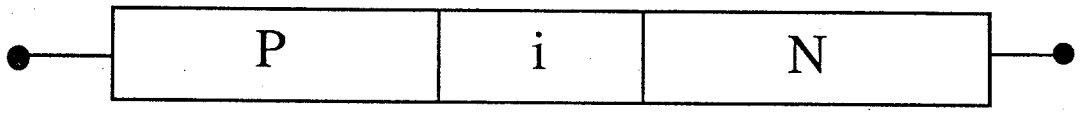
3. Sketch <u>to correct scale on the y-axis</u> the minority and majority carrier densities as a function of position in the neutral regions on both sides of a PN junction if V_A = +29.9337 kT/q. Label each curve clearly. Is high level injection occuring? If so, indicate clearly <u>where</u> high level injection exists. [15 pts]

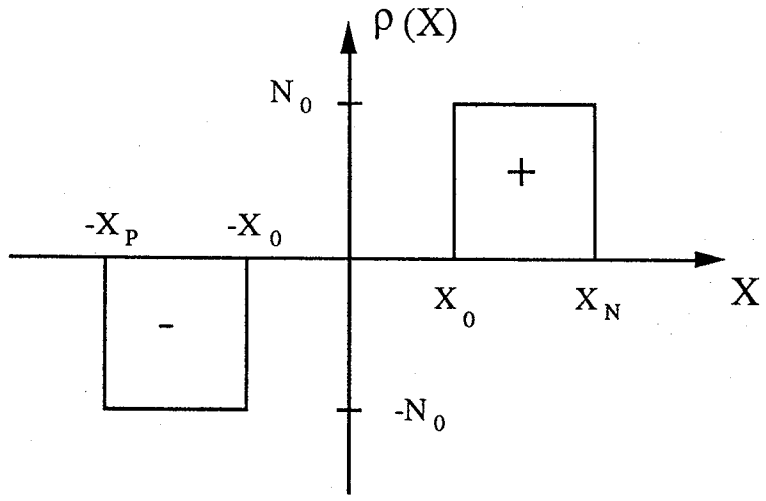


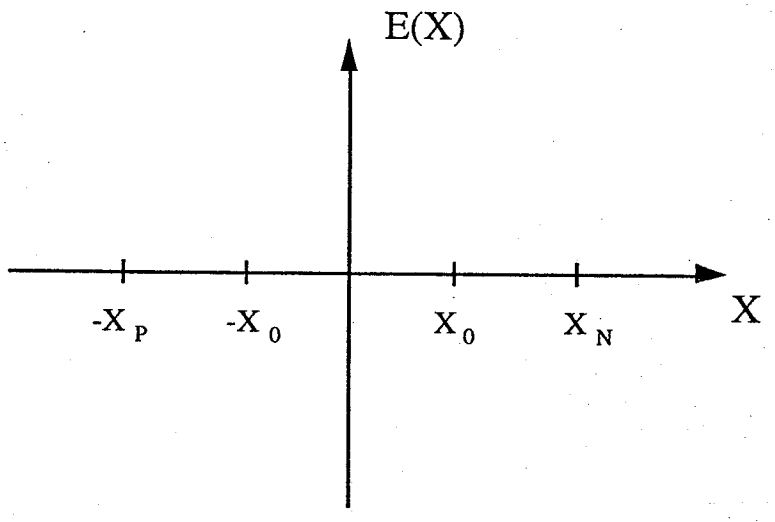
4. A PN junction has a doping profile shown below. Assume the depletion depths X_N and X_P are each greater than X_0 and calculate the built-in potential V_{bi} for this junction. [5 pts]



5. A PiN diode consists of a P-doped region, an N-doped region, and an intermediate region which has no doping (is "intrinsic"). The charge density diagram is shown below. For this junction, sketch the electric field as a function of position. Give an expression for the peak electric field in terms of N_0, X_0, X_N, and X_P. [15 pts]







6. A P+/N/P- bipolar transistor with a narrow base ($W<<<L_B$) has $N_{AE} = 10^{18}$ cm^{-3}, $N_{DB} = 10^{16}$ cm^{-3}, and $N_{AC} = 10^{15}$ cm^{-3}. Assuming this transistor is biased such that $V_{EB} = 0.7184$ V and $V_{CB} = 0.1796$ V, circle the biasing mode of the transistor... [5 pts]

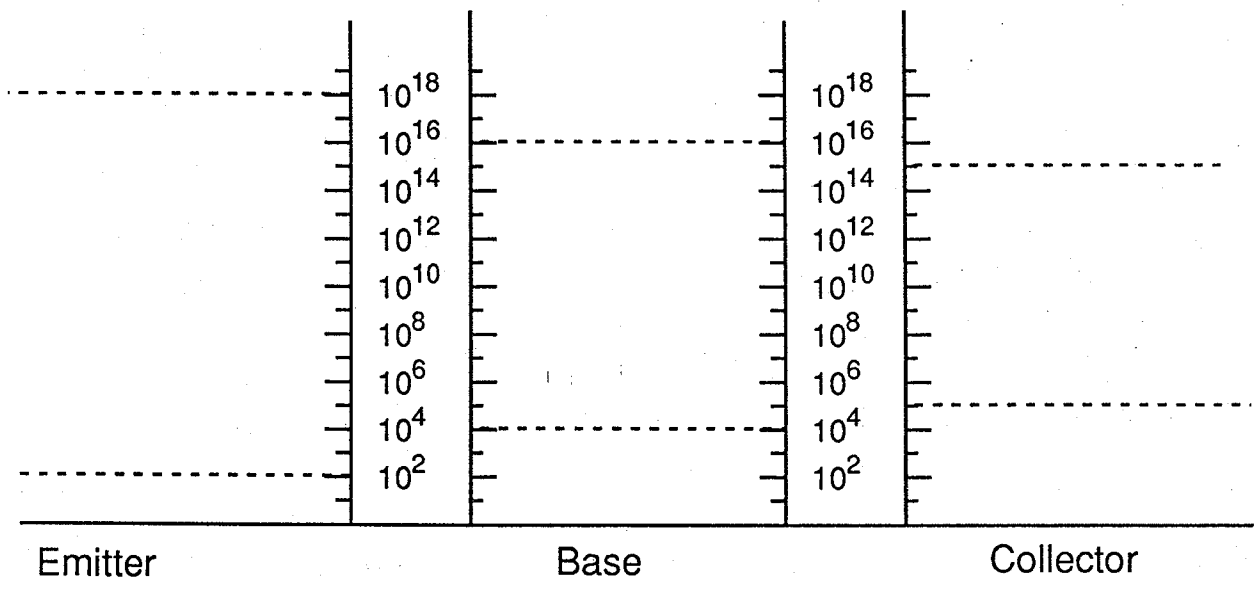
Forward Active

Inverse Active

Saturation

Cutoff

7. On the diagram below, sketch <u>to correct scale on the y-axis</u> the minority carrier densities in the neutral emitter, base, and collector for the device of question 6. [15 pts]



8. Consider a P+/N/P- bipolar transistor in the (forward) active mode and assume negligible recombination in the base. For each situation below, circle the most appropriate answer: [20 pts]

A. If the base width W is reduced by a factor of 2 (and all other parameters remain unchanged), the collector current will be...

reduced by a factor of two

unchanged

increased by a factor of two

B. If the base doping N_B is reduced by a factor of 2 (and all other parameters remain unchanged), the collector current will be...

reduced by a factor of two

unchanged

increased by a factor of two

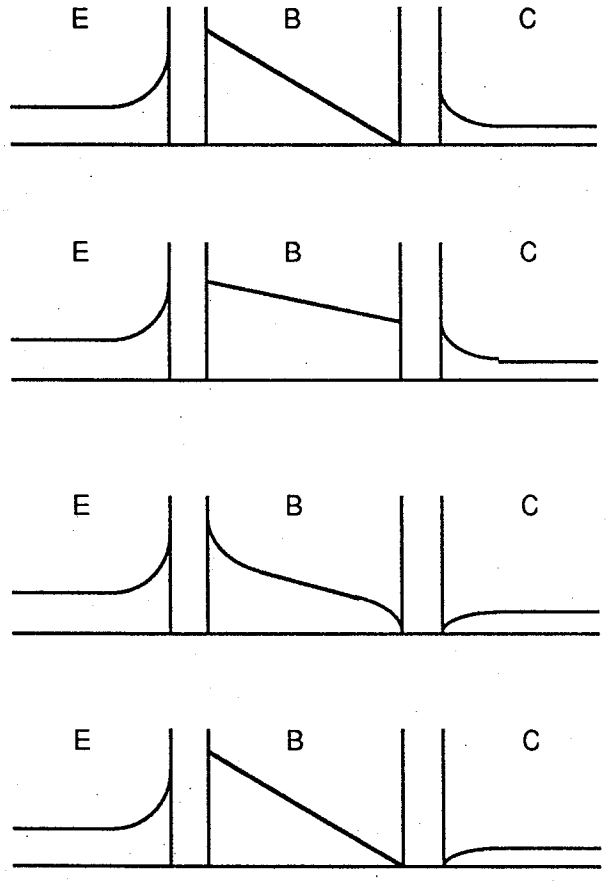
C. If the emitter-base voltage V_{EB} is reduced by kT/q (i.e. $V_{EB} \rightarrow V_{EB}$-kT/q), the collector current will be...

reduced by a factor of 2.0000

reduced by a factor of 2.7183

reduced by a factor of 3.1416

D. The minority carrier density in the neutral regions is best represented by...



9. Assume the base current of a PNP BJT is held constant at I_B and use the Ebers-Moll model to obtain an expression for the emitter-to-collector voltage V_{EC} *at the boundary between the (forward) active region and the saturation region*, as illustrated below. Leave your answer in terms of I_B and the Ebers-Moll parameters I_{FO}, I_{RO}, α_F, and α_R (not all parameters may be necessary). [15 pts]