EE130, Spring 1993
Midterm #2
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Problem #1 (18 points)

The small-signal model of a pn diode is shown below together with the corresponding device structure parameters.

Diagram of pn diode here where g_d = small-signal conductance
C_d = small-signal diffusion capacitance
C_j = small-signal junction capacitance

Indicate in the table below how the small-signal parameters will change when the (i) quasi-neutral widths x_p and x_n, (ii) minority carrier lifetimes T_n and T_p and (iii) doping concentration N_a and N_d increases. Use up-arrow, down-arrow, or 0 to denote an increase, decrease, or no change respectively.
[In case you want to elaborate some answers, comment briefly at the bottom of this page.]

Diagram of Table here

Problem #2 (20 points total)

The cross-section of a n-channel JFET with the gate connected to terminal 2 is shown below. V_2 is negative.

Diagram of N-channel JFET here

(a) (6 points) When V_2 is more negative than a certain value V_{2sat}, the current I becomes constant with V_2. Sketch the depletion region boundary around the p+ gate when V_2 is equal to V_{2sat}.

(b) (8 points) With gate connected to terminal 2 and $V_2$2sat in terms of the built in voltage of the p+/n junction **greek letter needed here**, the channel doping concentration (N_d), and the channel thickness (t).

(c) (6 points) Sketch qualitatively I versus V_2 from 0 to V_{2sat} [note that V_2 is

Problem #3 (32 points total)

A symmetrical, uniformly doped npn bipolar transistor has the following structure:

Diagram of npn bipolar transistor

(a) (10 points) In the forward active mode, calculate the forward gain **beta sub F needed here**

(b) The transistor is biased by a constant current source with I_B = 2mA. Assume that the space-charge regions have negligible changes in width when I_B is applied and the space-charge region recombination/ generation currents are zero.

Different diagram of npn bipolar transistor

(i) (7 points) Sketch the **excess** minority carrier concentrations of the E, B, and C regions in the above figure.

(ii) (5 points) Identify the operation mode of the transistor (forward active, reverse active, saturation, cut-off ?). Briefly explain your answer.

(iii) (10 points) Calculate the **excess** minority carrier concentrations at x_2 and x_4.

Problem #4 SHORT QUESTIONS (30 points total)

(a) (10 points) You are given an intergrated-circuit bipolar transistor (npn or pnp) enclosed in a black box with three extended leads connected to the emitter, base, and collector. The three leads are labeled X,Y and Z. You only have the following measurement equipment: (1) an ammeter, and (2) a variable voltage source.

Diagram of black box here

(i) Describe how you can find out which lead is connected to the **base** using I-V measurements. Whenever possible, use figures or sketches to explain your method.

(ii) After you have identified the base terminal, describe how you can find out whether the transistor is npn or pnp.

(b) (10 points) A p+/n junction has a constant built-in electric field E_0 (along +x direction) in the n-side quasi-neutral region. The juncion is forward biased.

Diagram of p±n junction here

(i) Write down an expression for the hole current in the n-side in terms of the hole concentration p(x).

(ii) In the figure above, sketch p(x).

(c) (10 points) A p+/n long-base junction is forward biased with a current source I_F. At t=0, the current source is switched to zero.

Diagram of Current vs. Time

(i) Derive the time-dependence of the stored excess minority carrier Q_p for t>0.

(ii) Sketch qualitatively the time developments of $P_n'(x)$.
