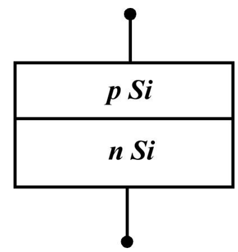
EECS 2077 Test #2, Spring 2014 Name:____

#1 ____/25 pts **Allowed materials: 2 pages of 1-sided equation sheets, writing utensil, calculator.**
#2 ____/30 pts **Remember – we use cgs units! Centimeter/gram/second.**
#3 ____/20 pts kT = 0.026 eV (300K) ε_0=8.854x10^{-14} F/cm ε_r(Si)=11.8
#4 ____/25 pts q= 1.6x10^{-19} C n_i(Si)=1.5x10^{10} / cm^3

<u>Optional Feedback</u>
Rate the length of this test: ***short*** ☐ ***long*** ☐ ***OK*** ☐
Rate the difficulty of this test: ***easy*** ☐ ***hard*** ☐ ***OK*** ☐

1.) 25 pts. An **<u>ideal</u>** Si pn+ junction at 300K has the following parameters (you may or may not need them all).



p-side:	n-side:	General parameters
Na=10^{15}/cm^3	Nd=10^{17}/cm^3	$\varepsilon_{Si}\varepsilon_0$=1x10^{-12} F/cm (11.8 x ε_0 F/cm)
		reverse saturation current = 4.5x10^{-14} A

a) [10 pts.] What are the ideal values for drift (I_{drift}) and diffusion (I_{diff}) currents across the junction at an applied forward bias of +0.7V?

b) [5 pts.] What are the ideal values for drift (I_{drift}) and diffusion (I_{diff}) currents across the junction at an applied reverse bias of -2.0V?

c) [5 pts.] This is a p+n junction. On the n-side of the junction, right near the edge of the depletion region, circle the correct answer for forward bias:

ELECTRON CURRENT DOMINATES HOLE CURRENT DOMINATES THEY ARE EQUAL

d) [5 pts] If you wanted to take this p+n junction, and add one more lightly doped p layer to make it into a p+np BJT, as you designed your device what would be the single most important design feature that you must have to enable BJT operation?

2.) [25 pts, 5 pts each] True or false, for a PNP BJT setup for normal amplification, assume an amplification factor of 100. Circle your answer.

(a) TRUE / FALSE : Collector current changes proportionally (linearly) with change in base current.

(b) TRUE / FALSE : Hole drift across the base-collector increases exponentially with voltage across the emitter-base.

(c) TRUE / FALSE : If 400 holes are collected, then we know that 400 holes are emitted.

(d) TRUE / FALSE : At any given time, there will be 100 extra holes than electrons in the base .

(e) TRUE / FALSE : I_C saturation with increasing V_{CE} occurs because once you have the base-collector reverse biased the collector is all setup to collect holes as drift current.

3.) [25 pts.] Some calculations…. consider a Symmetrical p+-n-p+ BJT, and some starting assumptions. Use the values given to simplify your calculations, don't calculate everything from scratch!

$W_b/L_p = x = 0.01$

$$\textbf{ctnh} = \frac{1}{\tanh} = \frac{e^{2x}+1}{e^{2x}-1} \longrightarrow \sim 100$$

$$\textbf{csch} = \frac{1}{\sinh} = \frac{2}{e^{x}-e^{-x}} \longrightarrow \sim 100$$

$$\textbf{tanh} = \frac{\sinh}{\cosh} = \frac{e^{2x}-1}{e^{2x}+1} \longrightarrow \sim 0.005$$

$$I_{Ep} \approx qA\frac{D_p}{L_p}\Delta p_E \text{ ctnh}\frac{W_b}{L_p}$$

$$I_C \approx qA\frac{D_p}{L_p}\Delta p_E \text{ csch}\frac{W_b}{L_p}$$

$$I_B \approx qA\frac{D_p}{L_p}\Delta p_E \tanh\frac{W_b}{2L_p}$$

$I_C = 2\ \mu A$
$N_A = 5\text{x}10^{18}/cc$
$N_D = 7\text{x}10^{14}/cc$
$W_B = 0.01 \text{ x } L_p$ (in the base)
$V_{EC} = 10$ V

$$qA\frac{D_p}{L_p}p_n = 0.2\,pA$$

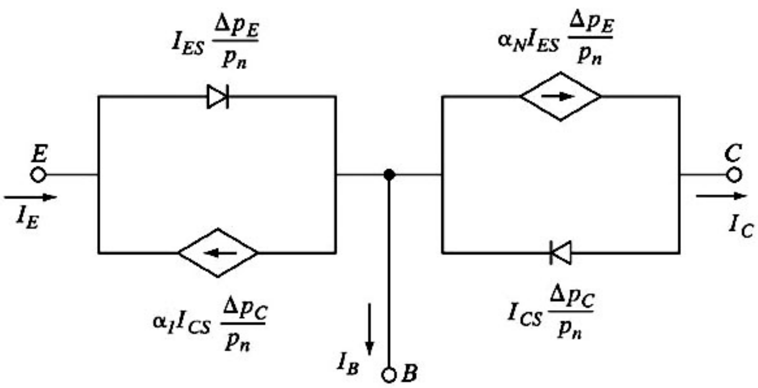
(a) [10 pts] Calculate the excess of holes in the base at the edge of the EB depletion region for a forward bias of 0.3 V across the EB junction.

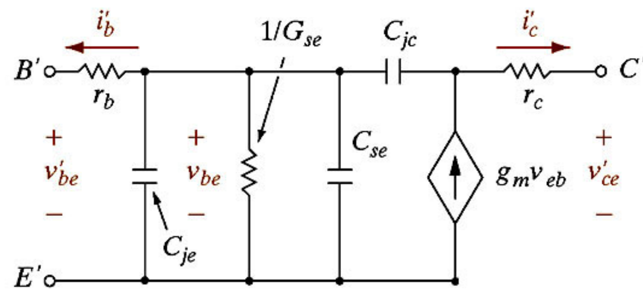
(b) [10 pts] Calculate the base current for a collector current of 2 μA.

(c) [5 pts] Calculate the current transfer ratio. Do this calculation using Beta only (the quickest way).

4) [25 pts] Two models are shown below, one on the left, and one on the right. I will generally refer to them that way. So here are some tougher questions to see really knows their stuff!

$$\Delta p_E = p_n\left(e^{qV_{EB}/kT} - 1\right)$$





(a) [10 pts] Draw a diagram, only one diagram, and mark/annotated it, to explain why for the model at left the current sources are exponential with voltage and why in the model at right the current sources are linear with voltage.

(b) [15 pts] Redraw the model on the right, for a NPN BJT operating in inverse mode (opposite of normal forward active mode). Make sure you list out everything you see in the model, components, voltages, and currents!

EXTRA SPACE