EECS 2077 Test #2, Fall 2016 Name:____

#1 ____/25 pts **Allowed materials: 1 page of a 1-sided equations sheet, writing utensil, calculator.**
#2 ____/25 pts **Remember – we use cgs units! Centimeter/gram/second.**
#3 ____/25 pts kT = 0.026 eV (300K) ε_o=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

1) [25 pts.] Some calculations…. consider a Symmetrical p+-n-p+ BJT made of Silicon, and some starting assumptions. Use the values given to simplify your calculations, don't calculate everything from scratch!

$$W_b/L_p = x = 0.01$$

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

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

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

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

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

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

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

$I_C = 2\,\mu A$
N_A= 5x10^{18}/cc
N_D= 7x10^{14}/cc
W_B= 0.01 x L_p (in the base)
V_{EC}= 10 V

(a) [8 pts] What is the concentration 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) [6 pts] What is the concentration of holes in the base at the edge of the BC depletion region for a forward bias of 0.3 V across the EB junction?

(c) [5 pts] Calculate the base current.

(d) [6 pts] Calculate the emitter current.

2.) [25 pts] Mish-mash of problems that are *variations* of problems that many of you missed on the last test…

(a) An ideal p+n junction at 300K, made out of an unknown material (is not Si) has the following parameters (you might not need them all).

p-side:	n-side:	General parameters
$Na=10^{17}/cm^3$	$Nd=10^{15}/cm^3$	$\varepsilon_r=10$
$Dn=20\ cm^2/sec$	$Dp=40\ cm^2/sec$	$n_i=10^{10}\ /\ cm^3$
$Ln=10^{-3}\ cm$	$Lp=10^{-2}\ cm$	$A = 50\ \mu m^2$

a) What are the DRIFT and DIFFUSION current densities (A/cm^2) across the junction at an applied forward bias of 0.8 V.

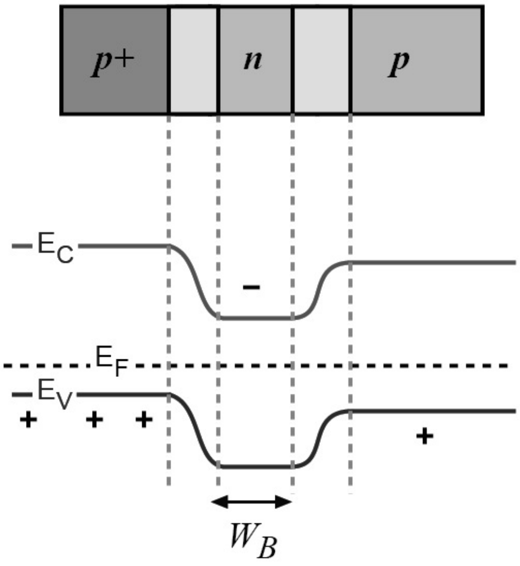
Calculations:

[7 pts] Answer for DRIFT: __________

[8 pts] Answer for DIFFUSION: _________

b) [10 points] An electron starts with no energy and is accelerated through 1V applied across a slab of undoped Si, and does not give up any energy as it accelerates (does not lose any of its gained energy). Diagram a representative band-diagram and note the starting position and final position for the electron. Remember, Si has a bandgap that is approximately 1 eV, so the electron position diagrammed should be roughly correct in energy relative to the band-diagram.

3.) [25 pts, 5 pts each] Consider a PNP BJT.



Circle all the correct answers below (there may be more than one).

(a) In normal forward active mode, current flow of holes from the emitter to the base occurs mainly by:

Diffusion Drift Recombination Could be any of these.

(b) In normal forward active mode, current flow of holes across the base occurs mainly by:

Diffusion Drift Recombination Could be any of these.

(c) In normal forward active mode, current flow of holes across the collector occurs mainly by:

Diffusion Drift Recombination Could be any of these.

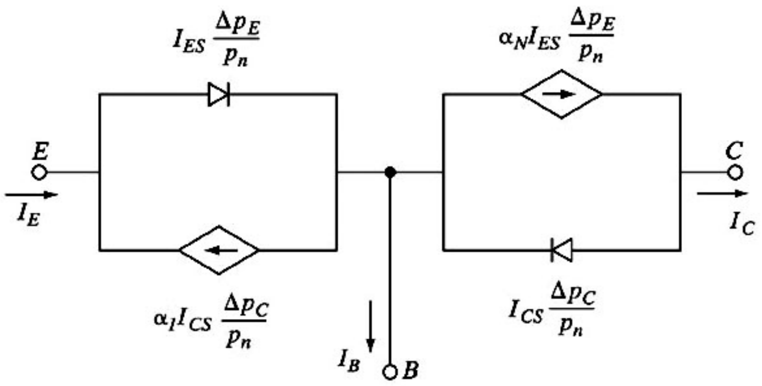
(d) The BJT is placed in a circuit and biased such that it is flowing a lot of current, and the BJT is getting hot. Where will most of the heat be generated in the BJT?

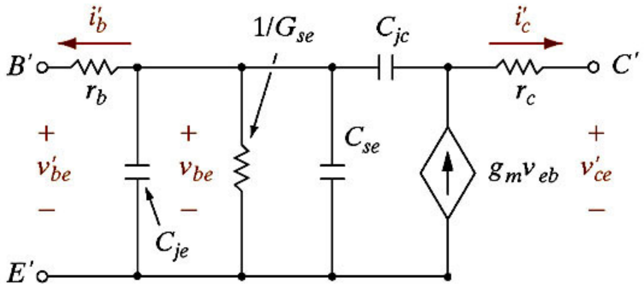
Mainly near the emitter. Right in the middle at the base. Near the collector. All of these equally.

(e) Lastly, a quick/easy calculation problem (<u>you may or may not need all the information below</u>). In normal forward active mode, let's say I started with an additional 10^8/cc electrons in the base (due to base current) and I increase the added electrons to 10^9/cc (by increasing the base current). Assume the doped concentration of electrons in the base is 10^{15}/cc and the doped holes in the emitter is 10^{18}/cc. By how much will the collector current increase?

(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.

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





(a) [10 pts] Draw a diagram, only one diagram, and mark/annotate 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) [8 pts] Redraw the model on the left for what components are needed for normal forward active mode only.

(c) [7 pts] What does the $1/G_{se}$ term in the model on the right represent? Answer with a single term <u>only</u>.

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Extra Space