UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE 130/230A — Prof. Liu
Fall 2013

Homework Assignment #14

Due at the beginning of class on **Thursday, 12/5/13**

Problem 1: BJT Current Components and Output Characteristics

Consider a Si NPN BJT with emitter area $A = 10^{-7}$ cm^2, maintained at room temperature (T = 300K), with parameters for each of the regions as shown in the table below:

Parameter	**Emitter**	**Base**	**Collector**
Dopant concentration (cm^{-3})	10^{18} (n-type)	10^{17} (p-type)	10^{15} (n-type)
Width (μm)	0.5	0.5	2.0
Minority-carrier lifetime (s)	10^{-7}	10^{-6}	10^{-6}

Note that the emitter region and collector region are each short, so that

$$I_{Ep} = qA\frac{D_E}{L_E}p_{E0}\frac{\cosh(W_E'/L_E)}{\sinh(W_E'/L_E)}\left(e^{qV_{BE}/kT}-1\right) \quad \text{and} \quad I_{Cp} = -qA\frac{D_C}{L_C}p_{C0}\frac{\cosh(W_C'/L_C)}{\sinh(W_C'/L_C)}(e^{qV_{BC}/kT}-1)$$

Note that the base region is short, so that

$$I_{En} = qA\frac{D_B}{L_B}n_{B0}\left[\frac{\cosh(W/L_B)}{\sinh(W/L_B)}(e^{qV_{BE}/kT}-1)-\frac{1}{\sinh(W/L_B)}\left(e^{qV_{BC}/kT}-1\right)\right] \quad \text{and}$$

$$I_{Cn} = qA\frac{D_B}{L_B}n_{B0}\left[\frac{1}{\sinh(W/L_B)}(e^{qV_{BE}/kT}-1)-\frac{\cosh(W/L_B)}{\sinh(W/L_B)}\left(e^{qV_{BC}/kT}-1\right)\right]$$

Suppose that the BJT is biased at the edge of saturation: the emitter junction is forward biased such that $exp(qV_{BE}/kT) = 10^{10}$, and the base-collector junction is zero biased (*i.e.* V_{BC} = 0V). Ignore band-gap narrowing in the emitter.

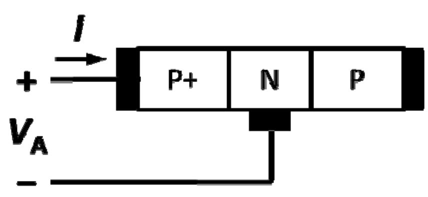
(a) Calculate γ, α_T and β_{dc}
(Note that you'll first need to calculate the quasi-neutral emitter width W'_E, quasi-neutral base width W, and quasi-neutral collector width W'_C, then calculate I_{Ep}, I_{En}, I_{Cp}, and I_{Cn})

(b) Sketch the output characteristic (I_C *vs.* V_{CE}) for $0 < V_{CE} < 3$ V and label it with the value of I_B. Is the effect of base width modulation significant? Explain why or why not.

(c) How would your answers to parts (a) and (b) change if V_{BE} were to be increased to double the value of I_B?

Problem 2: Ebers-Moll Model

When one of the BJT terminals is left floating (unconnected), the BJT behaves like a diode. Consider a PNP BJT configured as shown:



Derive the I *vs.* V_A relationship for this "diode" using the Ebers-Moll equations. (I should be expressed only in terms of V_A and the Ebers-Moll parameters.)