



8 - BJT Currents

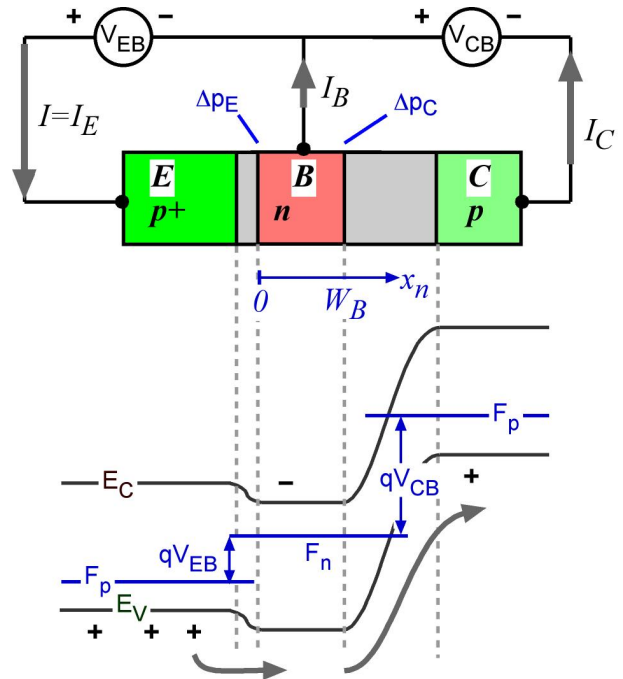
Name: _____

Agenda: (1) review the quiz / (2) 5 minutes minimum for lecture questions and review / (3) start the problems!

In-Class Problems

(1) See the equations below for the terminal currents of a PNP BJT.

(a) because all three current equations are similar you only have to choose one, for the one you choose, substitute in all the terms for Δp_E and write the resulting equation with **blue marker** for all terms that are part of I_0 , **green** for all terms that are the rest of the standard diode equation (voltage dependence), and **red** for the terms that make this different than just a diode by accounting for current amplification.



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

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

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

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

(b) rewrite the equation you chose above again, but for the case of an NPN BJT. Don't overthink this, I just want you to see that it is simple and that we don't have to re-derive everything for NPN. Note, the current direction will change for NPN BJT but that is taken care of by 'q' (electrons vs. holes).

(c) All the semiconductor terms (D, L, p, etc), for which region of the BJT are they from, E, B, or C?

(2) Some calculations, we will take it one step at a time.... consider a Symmetrical p+-n-p+ BJT:

$$N_D = 5 \times 10^{14} / \text{cc}$$

$$W_B = 0.01 \times L_p \text{ (in the base)}$$

$$V_{EC} = 10 \text{ V}$$

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

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

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

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

Keep your calculations simple using only the equations above and the diode equations! This will test if you really understand the above equations (more than just 'plug and chug' with equations).

The lecture slides have a lot of the information that you need (for example, we are using here the same W_b/L_p ratio as used in slides).

However, note that the lecture video slides have an error. Use $\tanh(W_b/2L_p) = 0.005$ (not 0.01, I forgot to divide by 2).

(a) 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. *Hint, this is a simple equation, found on slide 4 and slide 19.*

(b) Calculate the emitter current for a forward bias of 0.3 V across the EB junction. You can do this without the answer from (a) if you are smart about it! *Hint, I already calculated a lot of what you need in the information presented.*

(c) This should be real easy too (not require a ton of calculations): calculate the base current for a forward bias of 0.3 V across the EB junction. *Hint for one way to do this (there are two ways): calculate Beta using ratios of uncommon terms between I_c and I_b , and then if I_e and I_c are really close, just use amplification factor and I_e to calculate I_b . You will find a very large amplification factor, which means I_e and I_c are almost identical (I_b is really small).*

(d) This should be super easy: calculate the collector current for a forward bias of 0.3 V across the EB junction.

(e) For the case described in (b) if we added one additional electron to the base, on average how many more holes would be in the base at any given time.

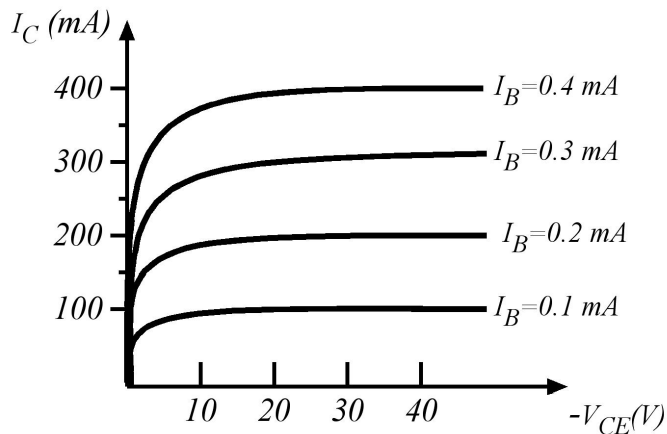
(f) For the case described in (b) and (c) if we added one additional electron to the base, and that electron had a lifetime of 10 μs , on average how many holes would be collected by the collector within 10 μs after the electron was added to the base. *This is also simple... (sort of, if you can see how to solve it).*

(g) Tougher question, for (f) how many holes need to be emitted? *I know it is close to the answer for (f), but give me the exact number so it shows me you understand how the BJT works.*

(h) In the lab, you measure that the maximum current you can obtain for this BJT is 1 mA. What is the output resistance of this BJT?

(i) In the lab, you cut the wire going to the base terminal. What will the voltage drop be across the base-collector region?

(3) Consider the BJT with the following stand-alone I_C vs. V_{CE} characteristic. Using load-line, graphically determine the collector current for a base current (I_B) of 0.4 mA. Assume the BJT externally is powered with 40 V power supply, and that the collector (which is the output of the device) has a resistance of 100 ohms.



(4) True or false, for a PNP BJT setup for normal amplification, assume an amplification factor of 100.

(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.

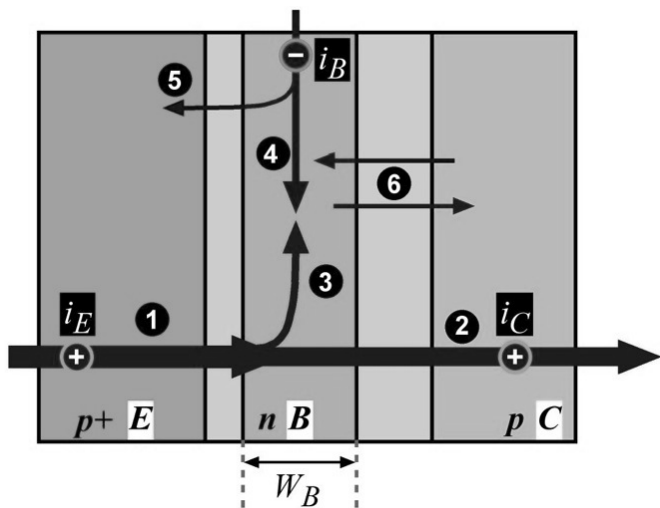
(c) TRUE / FALSE : If 400 holes are collected, then we know that 400 holes are emitted.

(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.

(5) For the diagram below, label the currents in order from LARGEST in magnitude to SMALLEST in magnitude. Just list them as numbers, such as 1,6,4,5,3,2. You may assume forward bias electron diffusion 5 is greater than reverse saturation electron and hole drift 6. If two currents are equal, you may note that by circling both of them in your answer. Note, only two of the currents are equal (the rest have a clear ordering).

Answer: _____, _____, _____, _____, _____, _____,



Please provide your anonymous feedback. On a paper (such as this) without your name please respond:

(1) What are the top few *worst* things about this course or the professor?

(2) What are the top few *best* things about this course or the professor?

(3) Any comments you would like to share in general?

