ECE-606 Practice Problems for Midterm #2 on 11/20/12

1. Consider a silicon step junction in which $N_A = 10^{16}$ cm^{-3} and $N_D = 5\text{x}10^{16}$ cm^{-3}. We derived the ideal diode equation under the assumption of low level injection in the neutral regions on both sides of the junction (this was necessary to allow us to use the MCDE to solve for the diffusion currents). At what applied voltage V_A will this low-level injection assumption fail? On which side of the junction will high-level injection occur first?

2. Sketch the total minority carrier concentrations in the emitter, base, and collector of a narrow base P+/N/P- bipolar transistor under the following conditions:

a. $V_{EB} > 0 > V_{CB}$

b. $V_{EB} > V_{CB} > 0$

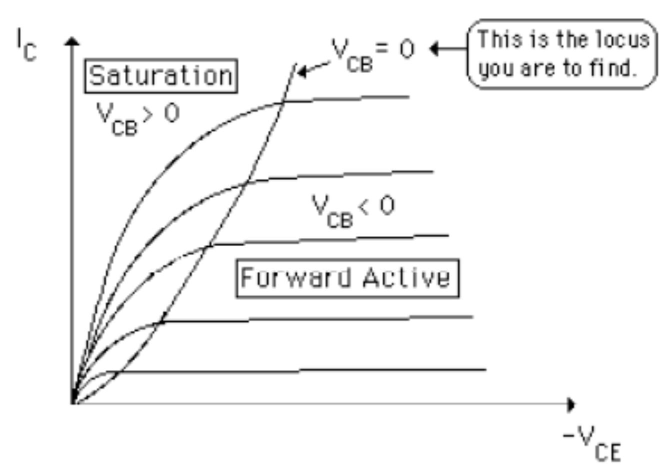
c. $V_{CB} > V_{EB} > 0$

d. $V_{CB} > 0 > V_{EB}$

e. $V_{EB} = V_{CB} << 0$

3. A typical set of I_C - V_{CE} curves for a p-n-p BJT in the common emitter mode are shown below. The boundary between the forward active region and the saturation region is the curve corresponding to $V_{CB} = 0$, as indicated below. Using the Ebers-Moll model, obtain an equation for this curve in the form of $I_C = f(V_{CE})$.

   Note: Your equation should be expressed in terms of the Ebers-Moll parameters I_{FO}, I_{RO}, α_F, and α_R. You do not need to substitute actual device parameters into the equation



4. Consider a p+/n/m bipolar transistor, where the p- collector region is replaced by a metal. Assume that $\Phi_M - \chi = E_G/2$. Answer the questions that follow.

a. Draw the band diagram in equilibrium.

b. Draw the band diagram if the transistor is operated in the forward active region. In your sketch, illustrate the flow of electrons and holes in the various regions of the device, and indicate where generation/recombination is taking place. You should specifically include carrier actions at the ohmic contact to the emitter and the metal contact forming the collector-base junction.

c. With the transistor operated in saturation, sketch the minority carrier densities in the neutral emitter and neutral base if both base and emitter are *short* compared to the minority carrier diffusion lengths in these regions. Give expressions for the carrier densities at the edges of the depletion regions in terms of the applied voltages V_{EB} and V_{CB}.

5. Answer the "thought questions" below with a few sentences each.

a. How is the minority carrier hole current on the n side of a pn junction influenced by hole mobility and hole lifetime? If we double the mobility, what happens to the current? If we increase the density of RG centers (so that the lifetime goes down), what happens to the current? Is this what you would expect?

b. If we force the current in a pn junction to change abruptly (by using an ideal current source in the external circuit), the slopes of the minority carrier densities at the edge of the neutral regions change abruptly. Explain whether this statement is true or false. Support your answer with a short argument.

Please review the following topics carefully for the second midterm test.

a. Breakdown Mechanisms in p-n junctions

b. p-n junction diode electrostatics. Please pay attention to the electric field distribution in the diode.

c. Ebers-Moll model for various BJT configurations such as common-emitter etc.

d. Current components in an **n-p-n** and **p-n-p** bipolar junction transistor

e. Drift diffusion equations.