ECE 3030 Spring 2025 HOMEWORK ASSIGNMENT NO. 10
Due: Thursday, April 17th 11:59 pm upload to Carmen 3030 SpeedGrader

1. **(20 pts)** Assume that the base of a Si p^+-n-p transistor is doped with 10^{16} donors/cm^3 and the collector with 10^{15} acceptors/cm^3. (a) Solve for the width x_{n0} of the depletion region on the base side of the collector junction for V_{CB} = -2 V and –10 V. If the base width at equilibrium is 1 μm, is the Early effect for this device significant or not?

2. **(20 pts)** Calculate and plot the excess hole distribution $\delta p(x)$ in the base of a p-n-p transistor from S&B Eq. 7-14 and Fig. 7-7(a) assuming W_b/L_p = 1 and 0.1. The calculations are simplified if the vertical scale is measured in units of $\delta p/\Delta p_E$ and the horizontal scale in units of x_n/W_b.

3. **(20 pts) (a)** <u>Redraw</u> Fig. S&B 7-3 (Lecture 34, Slide 15) for an n^+-p-n BJT with arrows for each electron and hole flow and their directions for normal active mode of operation. and <u>explain</u> the various components of current flow and current directions for the normal active mode of operation. **(b)** Draw the energy band diagram for equilibrium *and* this bias condition.

4. **(20 pts)** A p^+-n-p Si transistor has a uniform area of 2 x 10^{-4} cm^2 and base width W_b of 1 μm. The emitter doping is 10^{18}cm^{-3} and base doping is 10^{16} cm^{-3}. The hole lifetime in the base is 1 μs, the base mobility μ_p^n = 400 cm^2/V-s and the emitter mobility μ_n^p = 250 cm^2/V-s. Assume $\gamma \sim 1$. (a) Calculate I_E and I_C, with V_{EB} = 0.6 V and Δp_C negligible.

(b) Find I_B from the Charge Control Approximation Q_b/τ_p and compare with $I_B = I_E - I_C$ in Slide 18, Lecture 35 or S&B Eq. 7—18(a), 18(b), and 19,

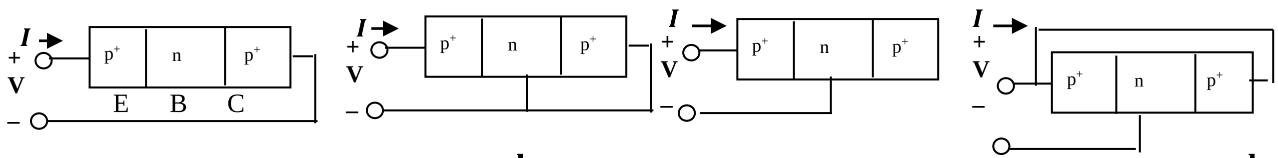
5. **(20 Pts)** A p-n-p transistor Si bipolar transistor has the following properties: A = 10^{-4} cm^2, W_b = 0.2 μm,

<u>Emitter</u>	<u>Base</u>	<u>Collector</u>
$N_a = 5\text{x}10^{18}$ cm^{-3}	$N_d = 10^{16}$ cm^{-3}	$N_a = 10^{15}$ cm^{-3}
τ_n = 100 ps	τ_p = 2500 ps	τ_n = 2 μs
μ_n = 150 cm^2/V-s	μ_n = 1500 cm^2/V-s	μ_n = 1500 cm^2/V-s
μ_p = 100 cm^2/V-s	μ_p = 400 cm^2/V-s	μ_p = 450 cm^2/V-s

Calculate the β of the transistor (a) from B and γ and (b) using the charge control model (Hint: Use Eqs. 7-20 & 7-76). (c) Comment on the comparison.

6. **(<u>Extra Credit: 10 Pts</u>)** For the BJT in Problem 5, calculate the charge stored in the base when $V_{CB} = 0$ and $V_{EB} = 0.7$ V. If the base transit time is the dominant delay component for the BJT, what is the cutoff frequency f_T?

7. **(<u>Extra Credit: 15 pts</u>)** The symmetrical p^+-n-p^+ transistor of the figure below is connected as a diode in the four configurations shown. Assume that V >> kT/q. <u>Sketch</u> $\delta p(x_n)$ in the base region for each case. Which connection seems most appropriate for use as a diode? Why?



a. **b.** **c.** **d.**