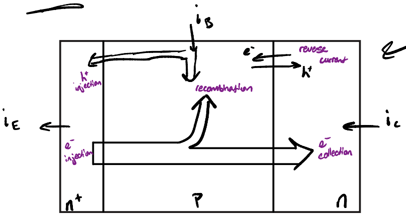
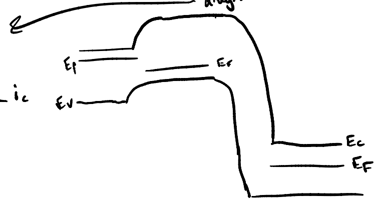
7.6

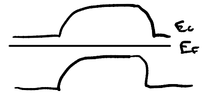
for e^- $i_E = i_B + i_C$



Bias like diagram

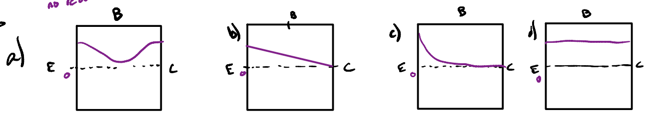


EQ



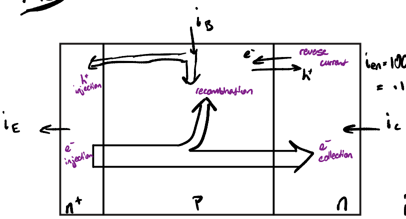
7.9

$I_B = 0$ no recomb symmetrical



best b/c least stored charge = fastest switching

7.12



$i_{En} = 100\,\mu A = .1\,mA$

$B = \frac{i_{CP}}{i_{EP}} = \frac{9.8\,mA}{10\,mA} = .98$

$\gamma = \frac{i_{EP}}{i_{EP} + i_{EN}} = \frac{10\,mA}{10\,mA + .1\,mA} = \frac{10}{10.1} = .99$

$\alpha = B\gamma = .99 \cdot .98 = .97$

$\beta = \frac{\alpha}{1-\alpha} = \frac{.97}{.03} = 32.7$

$\tau_t = \frac{Q_B}{I_{CP}} = \frac{4.9\times10^{-11}}{9.8\times10^{-3}} = 5\ ns$

$\tau_p = \frac{Q_B}{(1-B)\,i_{EP}} = \frac{4.9\times10^{-11}}{(.02)(10\times10^{-3})} = 2.45\times10^{-8}\,s = 24.5\ ns$

i_{CBO} is current from C to B w/open emitter

in pnp, CB is pn, majority carriers are pulled away

$\therefore$ i_{CBO} = minority carriers = i_{Cn} = $1\,\mu A$

7.14

7-32

a)

$i_E = i_{ES}(e^{qV_{EB}/kT} - 1) - \alpha_i\, i_{CS}(e^{qV_{CB}/kT} - 1)$

$i_C = \alpha_N i_{ES}(e^{qV_{EB}/kT} - 1) - i_{CS}(e^{qV_{CB}/kT} - 1)$

$i_C = 0$

$i_{CS}(e^{qV_{CB}/kT} - 1) = \alpha_N i_{ES}(e^{qV_{EB}/kT} - 1)$

$i_E = i_{ES}(e^{qV_{EB}/kT} - 1) - \alpha_i[\alpha_N i_{ES}(e^{qV_{EB}/kT} - 1)]$

$i_E = i_{ES}(1 - \alpha_i\alpha_N)(e^{qV_{EB}/kT} - 1)$

$i_E = i_{EO}(e^{qV_{EB}/kT} - 1)$

$i_E = 0$

$\vdots$ similar as b4

$-i_C = i_{CO}(e^{qV_{CB}/kT} - 1)$ $\quad$ $i_{CO} = i_{CS}(1 - \alpha_i\alpha_N)$

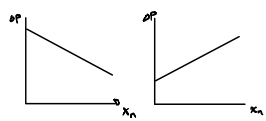
b/c i_C typically flows into transistor and i_{CO} flows out during reverse bias

b)

$i_C = 0 \rightarrow \Delta p_C = \alpha_i \Delta p_E$

$i_E = 0 \rightarrow \Delta p_E = \alpha_N \Delta p_C$

c)



7.20

$W_b = W - W_{EB} - \frac{N_C}{N_B + N_C} W_{CB}$

$V_{biBE} = .0259 \ln\left(\frac{10^{19}\,10^{16}}{(1.5\times10^{10})^2}\right) = .897$

$V_{biBC} = .0259 \ln\left(\frac{10^{16}\,10^{16}}{(1.5\times10^{10})^2}\right) = .696\,V$

$W_{EB} = \sqrt{\frac{2\epsilon}{q N_B}(V_{biBE} - V_{EB})}$

$W_{CB} = \sqrt{\frac{2\epsilon}{q}\frac{N_C + N_B}{N_C N_B}(V_{biBC} - V_{CB})}$

for $V = .2$ $= 3.02\times10^{-5}\,cm = .302\,\mu m$

$= .426\times10^{-4}\,cm = .426\,\mu m$

for $V = .6$ $= 1.97\times10^{-5}\,cm = .197\,\mu m$

$\frac{N_C}{N_B + N_C} = \frac{1}{2}$ $\quad$ $\frac{1}{2} \cdot .426 = .213$

$W_B = 1.5 - .302 - .213 = .985\,\mu m$ $\quad$ $V_{EB} = .2V$

$W_B = 1.5 - .197 - .213 = 1.09\,\mu m$ $\quad$ $V_{EB} = .6V$

7.21

$B = \frac{1}{\cosh\left(\frac{W_b}{L_p}\right)} \approx 1 - \frac{1}{2}\left(\frac{W_b}{L_p}\right)^2$

$= 1 - \frac{1}{2}(.0985)^2$

$= .995$ for $V_{EB} = .2$

$L_p = \sqrt{D_p \tau_p} = 10\,\mu m$

$L_n = \sqrt{D_n \tau_n} = 10\,\mu m$

$D_n = D_p$ so $\frac{D_n}{D_p} = 1$

$\gamma = \frac{1}{1 + \frac{N_B D_n W_b}{N_E D_p W_E}}$

$= \frac{1}{1 + \frac{10^{16}(.985)}{10^{18} \times 3}} = .99967$ for $V_{EB} = .2$

for $V_{EB} = .6$ $\quad B = 1 - \frac{1}{2}(.109)^2 = .994$

$\gamma = \frac{1}{1 + \frac{10^{16} \times 1.09}{10^{18} \times 3}} = 3.63 \times 10^{-4}$

7.22

$V_{EB} = .2$

$\alpha = B\gamma = .9947$

$\beta = \frac{\alpha}{1-\alpha} = 187.7$

$I_E = I_{Ep} + I_{EN} = 8.254\,pA$

$I_C = \alpha I_E = 8.21\,pA$

$I_B = I_E - I_C = .044\,pA$

$G_B = \frac{N_B W_B}{D_p} = 9.85 \times 10^{10}\ s/cm^4$

$V_{EB} = .6$

$\alpha = B\gamma = .9936$

$\beta = \frac{\alpha}{1-\alpha} = 155.3$

$I_E = I_{Ep} + I_{EN} = 38\,\mu A$

$I_C = \alpha I_E = 37.8\,\mu A$

$I_B = I_E - I_C = .2\,\mu A$

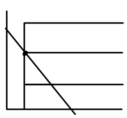
$G_B = \frac{N_B W_B}{D_p} = 1.09 \times 10^{11}\ s/cm^4$

Self Quiz 1

$I_B = \frac{V_1 - V_{BE}}{R_B} = \frac{11-1}{100k} = .1\,mA$

a) $\beta = \frac{I_C}{I_B} = \frac{5}{.1} = 50$

b)



c) $V_{CE} = 11 - 1K \cdot 5mA = 11 - 5 = 6V$

d) Edge of sat ~ $V_{CE} = 1V$ $\quad I_C = \frac{11-1}{1K} = 10mA$

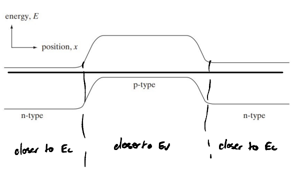
$I_C = 10mA \rightarrow I_B = .2mA$

$V_{1new} = 1 + .2 \times 100K = 1 + 20 = 21V$

e) $V_{CE} = 1 - 1K \cdot 5mA = 6V$

f) When $V_{CE} = 1V$ for $I_C = 10mA \rightarrow I_B = .2mA$ or greater

Self Quiz 2



flat cuz Equilibrium

Self Quiz 3

a) increase, $\gamma = \frac{I_{EP}}{I_{EP} + I_{EN}}$ when W_B decreases I_{EN} (e^- injected current from the base) also decreases. smaller I_{EN} = larger γ

b) increase, $B = \frac{I_C}{I_{EP}} \approx 1 - \left(\frac{W_B}{2L_p}\right)^2$ smaller W_B 1 - smaller = larger B

c) increase, $\beta = \frac{\alpha}{1-\alpha}$ $\quad \alpha = B\gamma$ both B and γ increase so

d) decrease, $V_A \propto \frac{1}{W_B}$