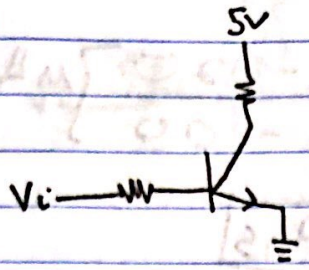
HW2:

1)



Solution: $I_{C(sat)} = \frac{V_{CC} - V_{CE}}{R_C}$

$= \frac{5 - .2}{1000} = 4.8mA$

$I_{BC(EOS)} = \frac{I_{C(sat)}}{\beta} = \frac{4.8mA}{100} = 48\mu A$

$I_{BF} = \frac{V_i - V_{BE(sat)}}{R_B} = \frac{5 - .7}{5K} = 860\mu A$

$I_{BR} = \frac{V_{i(REV)} - V_{BE(sat)}}{5K} = \frac{0 - .7}{5K} = -140\mu A$

$T_S = T_0 \cdot \ln\left[\frac{-140 - 860}{-140 - 48}\right] = \boxed{16.7ns = T_S}$

2)

a) $I_C = 10/1000 = 10mA$

$$\boxed{I_{B(EOS)} = \frac{I_C}{\beta} = 100\mu A}$$

b) $I_{BF} = \frac{10 - .8}{22k\Omega} = \frac{9.2}{22{,}000} = \boxed{420\mu A}$

c) $I_{BR} = \frac{-.8}{22k\Omega} = \boxed{-36\mu A}$

d) $Q_a = T_{BF} I_{B(EOS)} = 20ns \cdot 100\mu A$

$= \boxed{2pC}$

e) $Q_s = T_{BF}(I_{BF} - I_{B(EOS)}) = 20(420 - 100)$

$= \boxed{6.4pC}$

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h)

$$T_s = \tau \cdot \ln\left[\frac{-36 - 420}{-36 - 100}\right] \mu A$$

$$= \boxed{24.19 ns}$$

g)

$$T_s = 20 \ln\left[\frac{-420}{-100}\right] = \boxed{28.70 ns}$$

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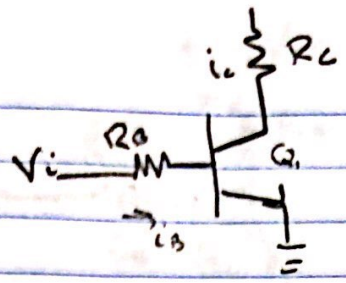
3)



$V_B = -5V$

$V_C = 5V$

$V_E = 0V$

$$C_j(V_{BE}) = C_{jEO}\left[\frac{V_{OBE} - 0}{V_{OBE} - V_{BE}}\right]^{1/2} \qquad V_{BE} = V_E - V_C = -5V$$

$$= [1.5\times10^{-12}]\left[\frac{.9-0}{.9+5}\right]^{1/2} = 5.55\times10^{-13}\,F$$

* $V_{BC} = V_{BE} - V_C = -5-5 = -10V$

$$C_j(V_{BC}) = (0.7\times10^{-12})\left[\frac{.7-0}{.7+10}\right]^{1/2} = 1.7904\times10^{-13}\,F$$

$$Q_{BE} = C_j(V_{BE}) \cdot V_{BE} = 5.55\times10^{-13} \times (-5)$$

$$Q_{BC} = C_j(V_{BC}) \cdot V_{BC} \qquad = \boxed{Q_{BE} = -2.925pC}$$

$$1.7904\times10^{-13} \times (-10)$$

$$= \boxed{-1.7904pC = Q_{BC}}$$

4) $$I_B = \frac{V_i - V_{BE}}{R_B} = \frac{5-.7}{10k} = .43mA$$

$$I_{B(EOS)} = \frac{I_C}{\beta} = \frac{1}{\beta}\cdot\frac{V_{CC}-V_{CE}}{R_C} = \frac{5-.2}{100\cdot1000}$$

$$= .045mA$$

$$C_{jE}(0.7) = 1.5pF\,(.9-0/\,.9-.7)^{1/2} = 3.15pF$$

$$C_j(0.5) = .7pF\,(.7-0/\,.7-.5)^{1/2} = 1.3pF$$

$V_{BC} = V_{BE} - V_{CC} = .7 - .2 = .5$

$$Q_{BE} = 3.15pF \cdot .7V = 2.22pC$$

$$Q_{CE} = 1.3pF \cdot .5 = 0.650pC$$

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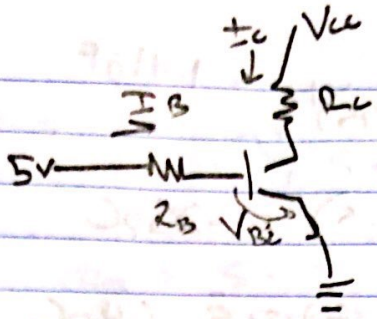
5)



$V_B - I_B R_B - V_{BE(SAT)} = 0$

$5 - I_B R_B - .8 = 0$

$I_B R_B = 4.2$

$V_{CC} - I_C R_C - V_{CE(SAT)} = 0$

$10 - (1000) I_C - .2 = 0$

$I_C = 9.8\text{mA}$

$N_1 = \frac{\beta_{min}}{\beta} \Rightarrow \beta = \frac{30}{10} = 3$

$I_B = \frac{I_C}{\beta} = \frac{9.8 \times 10^{-3}}{3} \rightarrow 3.267\text{mA}$, $4.2 = R_B (I_B)$

$\therefore \boxed{R_B = 1.285\text{k}\Omega}$

6) a) $I_{B(EOS)} = \frac{I_{C(sat)}}{\beta} = \frac{V_{CC} - V_{CE(SAT)}}{\beta R_C}$

$= \frac{10 - .2}{100 \cdot (470)} = .208\text{mA}$

$I_{B_f} = \frac{10 - .7}{2\text{k}\Omega} = 4.65\text{mA}$

$I_{B_R} = \frac{-10 - .7}{2\text{k}\Omega} = -5.35\text{mA}$

$T_s = \tau_s \cdot \ln\left[\frac{(-5.35 - 4.65)\text{mA}}{(-5.35 - .208)\text{mA}}\right] = \boxed{17.62\text{ns}}$ storage time part a

b) $I_B^{(EOS)} = .208\text{mA}$

$I_{B_f} = 4.65\text{mA}$

$I_{B_r} = \frac{0 - .7}{2\text{k}} = -0.35\text{mA}$

$T_s = 100 \cdot 300\text{ps} \cdot \ln\left[\frac{(-.35 - 4.65)\text{mA}}{(.35\text{mA} - .208\text{mA})}\right]$

$= \boxed{65.79\text{ns}}$ storage part B time

a) $C_{je} = 2.45\text{pF} \Big/ (1 + 10/.75)^{1/2} = 2.31\text{pF}$

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$C_{jc} = 2\ 3.7pF / (1 + 20/.75)^{1/2} = 1.41pF$

$\Delta Q_{BE} = 7.38pF \cdot (-10 - .5) = -25pC$

$\Delta Q_{BC} = 1.41pF \cdot (4.5 - .5) = 5.64pC$

$I_i = \frac{10+10}{2K} = 10mA$, $I_f = \frac{10 - .5}{2k} = 4.75mA$

$I_{AVG} = \frac{(10 + 4.75)mA}{2} = 7.375mA$

$t_D = \frac{(25 + 5.64)pC}{7.375mA} = \boxed{4.1545nS}$ ← to part A

B)

$C_{je} = 2 \cdot 4.5\,pF / (1 + 16/.75)^{1/2} = 9\ pF$

$C_{jc} = 2 \cdot 3.7pF / (1 + 20/.75)^{1/2} = 4.95\ pF$

$\Delta Q_{BE} = 9 \cdot (-.5) = -4.5pC$

$\Delta Q_{BC} = 1.95pF \cdot (4.5 - .5) = 7.8pC$

$I_i = \frac{10}{2k} = 5mA$, $I_f = \frac{10 - .5}{2K} = 4.75mA$

$I_{AVG} = \frac{(5 + 4.75)mA}{2} = 4.875mA$

$t_D = (4.5 + 7.8)pC / 4.875mA = 2.523nS$

ANSWERS

a) $\boxed{t_S = 17.62nS}$ $\boxed{t_D = 4.1545nS}$

b) $\boxed{65.79nS = t_S}$ $\boxed{2.523nS = t_D}$

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7)

a) $\Delta Q = C \Delta V$

$10^{-12}(5+5) =$ **10pC**

b) $I_B = \frac{5-.7}{5000} = .86mA$

$T = 1/f \cdot 1/5\cdot10^6$

$I_{Bavg} = \frac{1}{T}\int_0^6 I_s\,dt \rightarrow 5\cdot10^6 \int_0^{1/5\cdot10^6} (.86mA)\,dt$

$5\cdot10^6 (.86mA)\frac{1}{5\cdot10^6} =$ **.86mA**

c) $I_{C(sat)} = \frac{V_{CC}-.1}{470}$

$I_{B(cos)} = V_{CC}-.1 \Big/ 470\cdot100$

$I_{BS} = \frac{5-.7}{5000} = .86mA$

$I_{BF} = \frac{I_S}{BR}\left[e^{V_{BC}/V_T - 1}\right] =$ **$1.45\times10^{-12}\left[\frac{I_S}{B_R}\right]$**

d) $T_S = T_{OFF} - T_{FALL}$

$\frac{T}{2} - T_S = \frac{1}{10\cdot10^5} - \frac{10}{10^4} =$ **90ns**

e) $V_C(10\%) = .5$

$V_C(90\%) = 4.5$

$FRC = 1/2\left[\frac{4.5}{470} + \frac{4.5}{470}\right]$

$I = 86 - 5.3 = 80.7mA$

$t_f = \frac{C\Delta V}{I} = (10)(47)\Big/80.7 =$ **.495ns = t_f**

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f) $T_f = 2.2\tau = 2.2RC(0)$

$= 2.2(51k)(10pF)$

$= \boxed{110ns}$

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8)

a) $V_{OL} = V_{CE(sat)} = 0.2V$

$V_{iL} = V_{BE} = 0.7V$

$\boxed{V_{OH} = V_{CC} = 5V}$

b) $V_{iH} = V_{BE} + R_B I_B$

$I_B = B(V_{CC} - V_{iL}) / R_C$

$I_B = 43\,\mu A$

$\boxed{V_{iH} = 1.56V}$

c) $I_B = V_i - V_{BE} / R_B$

$I_B = 215\,\mu A$

forced $\beta = I_C(sat) / I_B = 1.8 / .215 = \boxed{7.37}$

d) $V_{OH} = V_{iH} \cdot \beta = 5 \cdot \beta = \boxed{40V}$

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