Homework 5 Due Date Thursday, Feb 28th, in class

Problem 5.9

(a) The pnp transistor shown in Figure P5.8 has a common-base current gain $\alpha = 0.9860$. Determine the emitter current such that $V_C = -1.2$ V. What is the base current? (b) Using the results of part (a) and assuming $I_{EQ} = 2\times10^{-15}$ A, determine V_{EB}.

I.

$i_E = \frac{i_C}{\alpha}$

$I_{EQ} = \frac{I_S}{\alpha}$

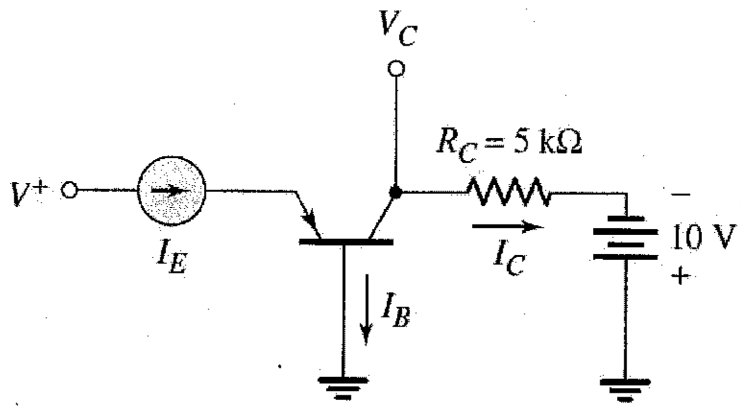


Figure P5.8

$I_C = \frac{(-1.2)-(-10)}{5k} \Rightarrow \boxed{I_C = 1.76mA}$

$i_E = \frac{1.76mA}{0.986} \Rightarrow \boxed{i_E = 1.785\,mA}$

$I_E = I_B + I_C \Rightarrow I_B = I_E - I_C$

$I_B = 1.785mA - 1.76mA = \boxed{24.99\mu A = I_B}$

$I_E = \frac{I_S}{\alpha} e^{(V_{EB}/V_T)} \Rightarrow 1.785mA = 2\times10^{-15} e^{\left(\frac{V_{EB}}{25.9m}\right)}$

$V_{EB} = \ln\left(\frac{1.785mA}{2\times10^{-15}}\right) 25.9m \Rightarrow \boxed{V_{EB} = 712.7mV}$

Problem 5.17

For all the transistors in Figure P5.17, $\beta = 75$. The results of some measurements are indicated on the figures. Find the values of the other labeled currents, voltages, and/or resistor values.

$\alpha = \frac{\beta}{1+\beta}$

$\alpha = 986.84\,m$

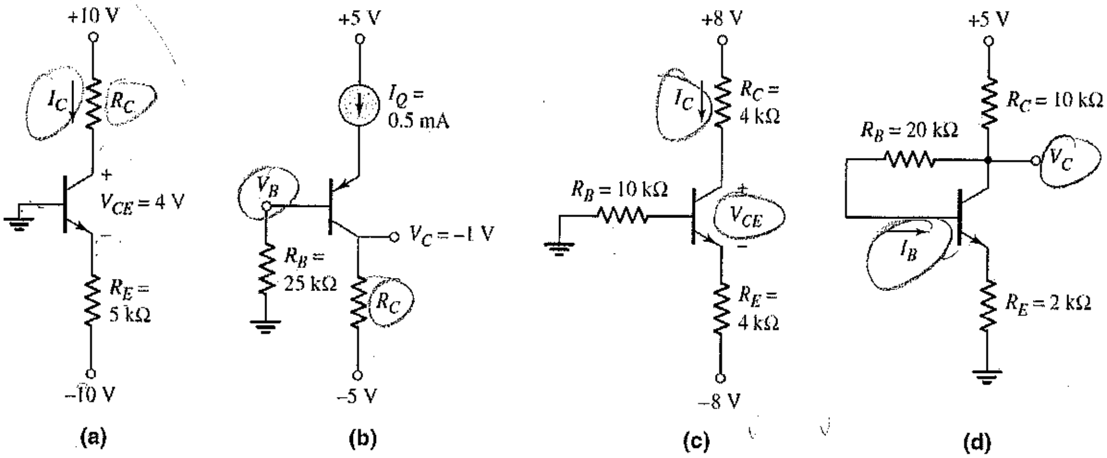


Figure P5.17

a) $-V_{BE} - I_E R_E - (-10) = 0$

$\frac{(-V_{BE} + 10)}{R_E} = I_E = \frac{(-0.7 + 10)}{5K}$

$I_E = 1.86\ mA$

$I_E = \frac{I_C}{\alpha} \Rightarrow I_C = \alpha(I_E)$

$I_C = 0.98684(1.86mA)$

$\boxed{I_C = 1.836mA}$

$V = IR \Rightarrow R = \frac{V}{I}$

$R_C = \frac{10 - 4}{1.836mA} \Rightarrow \boxed{R_C = 3.269K\Omega}$

b) $\beta i_B = \alpha i_E \Rightarrow i_B = \frac{\alpha i_E}{\beta}$

$\Rightarrow I_B = 6.579\mu A$

$V_B = I_B R_B \Rightarrow (6.579\mu A)(25k)$

$\boxed{V_B = 164.5mV}$

$I_C = I_E - I_B \Rightarrow I_C = 0.5mA - 6.579\mu A$

$I_C = 493.42\mu A$

$R_C = \frac{-1 - (-5)}{493.42\mu A} \Rightarrow \boxed{R_C = 8.11K\Omega}$

c) $0 - I_B \overset{10K}{R_B} + \overset{0.7V}{V_{BE}} - I_E \overset{4K}{R_E} - (-8) = 0 \Rightarrow$

$7.3 = I_B R_B + I_E R_E \qquad I_E = (1+\beta)I_B$

$I_B = \frac{7.3}{10K + (1+\beta)4K} \Rightarrow I_B = 23.25\mu A$

$V_B = I_B R_B \Rightarrow V_B = 232.5mV$

$I_E = (1+\beta)(23.25\mu A) \Rightarrow I_E = 1.767mA$

$V_{RE} = I_E R_E \Rightarrow (1.767mA)(4K) = 7.068\,V$

$I_C = \beta I_B \Rightarrow I_C = 75(23.25\mu A) \Rightarrow \boxed{I_C = 1.744mA}$

$V_{RC} = I_C R_C \Rightarrow 1.744mA(4K) \Rightarrow V_{RC} = 6.975V$

$8 - 6.975 - V_{CE} - 7.068 + 8 = 0$

$\boxed{V_{CE} = 1.958V}$

D) $5 - I_C(10K) - I_B(20K) - \overset{0.7V}{V_{BE}} - I_E(2K) = 0$

$4.3 = \beta I_B(10K) + I_B(20K) + (1+\beta)I_B(2K)$

$I_B = \frac{4.3}{\beta(10K) + (20K) + (1+\beta)(2K)} \Rightarrow \boxed{I_B = 4.664\mu A}$

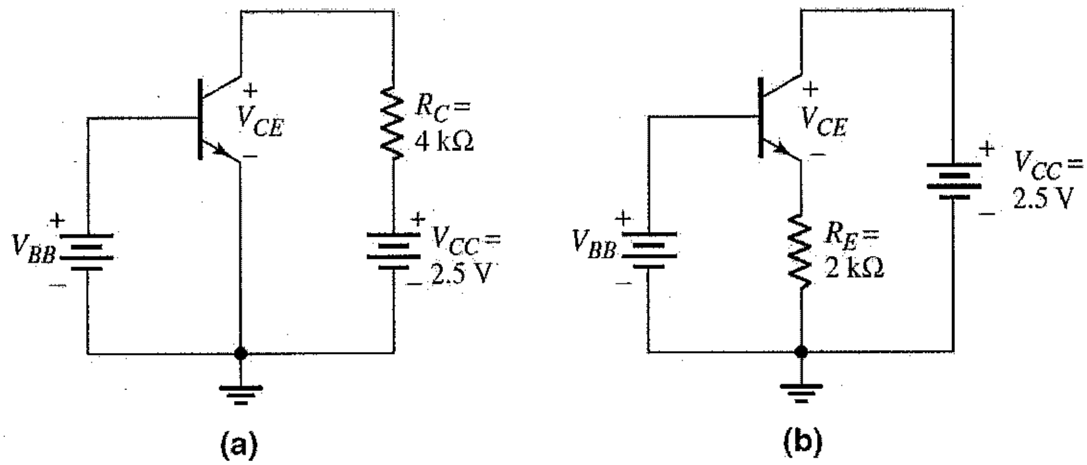
$I_C = \beta(I_B) \Rightarrow I_C = 75(4.664\mu A) \Rightarrow I_C = 349.78\mu A$

$V_{RC} = I_C R_C = 349.78\mu A(10K) \Rightarrow V_{RC} = 3.498V$

$V_C = 5 - V_{RC} \Rightarrow V_C = 5 - 3.498V \Rightarrow \boxed{V_C = 1.502V}$

Problem 5.19

Consider the two circuits in Figure P5.19. The parameters of each transistor are $I_S = 5\times10^{-16}$ A and $\beta = 90$. Determine V_{BB} in each circuit such that $V_{CE} = 1.10$ V.



$V_{BB} = V_{BE}$

Figure P5.19

a) $I_C = \frac{V_{CC} - V_{CE}}{R_C} \Rightarrow \frac{2.5-1.1}{4K}$

$I_C = 350\mu A$

$I_C = I_S e^{\left(\frac{V_{BE}}{V_T}\right)}$

$V_{BE} = \ln\left(\frac{I_C}{I_S}\right)(V_T)$

$V_{BE} = 0.259\left(\ln\left(\frac{350\mu A}{5\times10^{-16}}\right)\right)$

$\boxed{V_{BE} = 0.706\text{ V}}$

b) $V_E = 2.5 - 1.1 = 1.4V = V_E$

$V_{BE} = V_{BB} - V_E \Rightarrow V_{BB} = V_{BE} + V_E$

$V_{BB} = 0.7 + 1.4 = \boxed{V_{BB} = 2.1}$

Problem 5.21

Consider the circuits in Figure P5.21. For each transistor, $\beta = 120$. Determine I_C and V_{EC} for each circuit.

$\alpha = \frac{120}{1+120} = .99174$

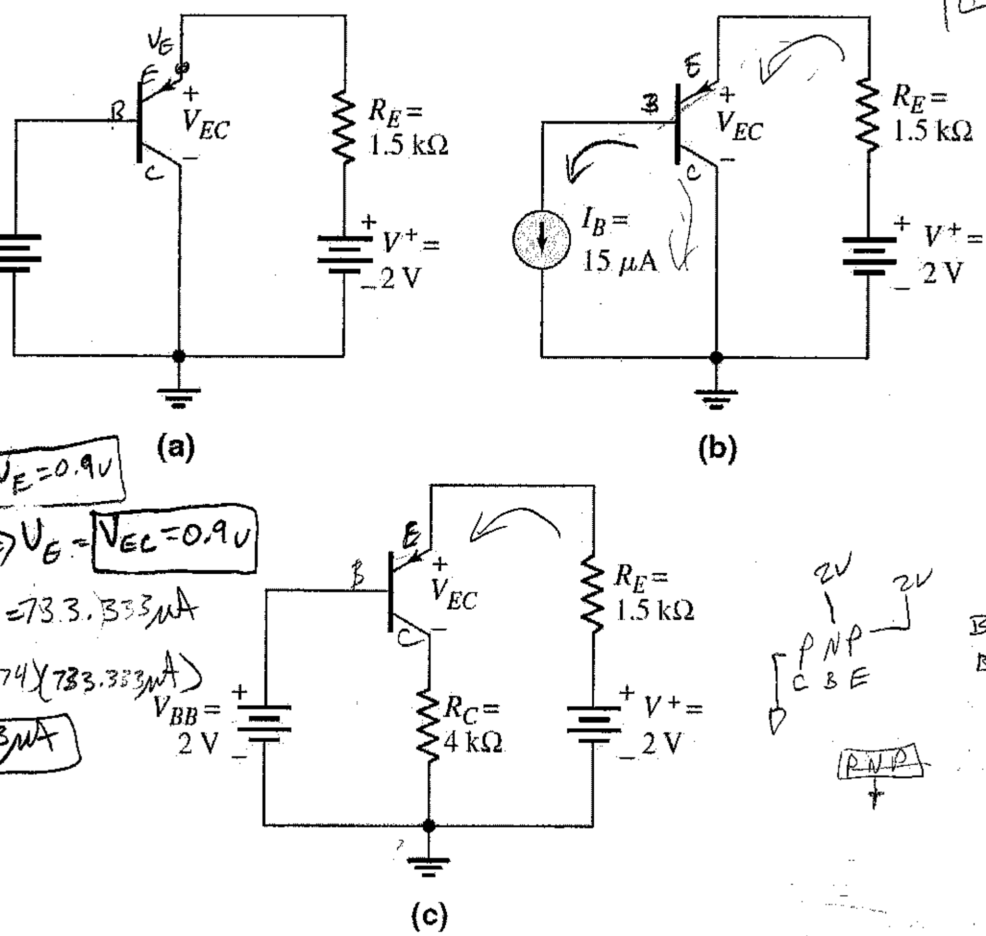


Figure P5.21

$V_{BE} =$ Foward

$V_{BC} =$

2V 2V

PNP

C B E

BC = Reversed

BE = Cutoff

a)

$V_E = V_{BE} + V_{BB}$

$V_E = 0.7 + 0.2$ $\boxed{V_E = 0.9V}$

$V_{EC} = V_E - 0 \Rightarrow V_E = \boxed{V_{EC} = 0.9V}$

$I_E = \frac{2 - 0.90}{1.5K} = I_E = 733.333\mu A$

$I_C = \alpha I_E = (0.99174)(733.333\mu A)$

$\boxed{I_C = 727.3\mu A}$

b) $V_{CE}(sat) = 0.2V$

$I_E = \frac{2 - 0.2V}{1.5k} \Rightarrow I_C < 1.2mA$

$I_E = I_C + I_B$

$I_C = I_E - I_B \Rightarrow 1.2mA - 15\mu A$

$I_C = 1.185mA$

$V_{EC} = 2 - 1.188mA(1.5K)$

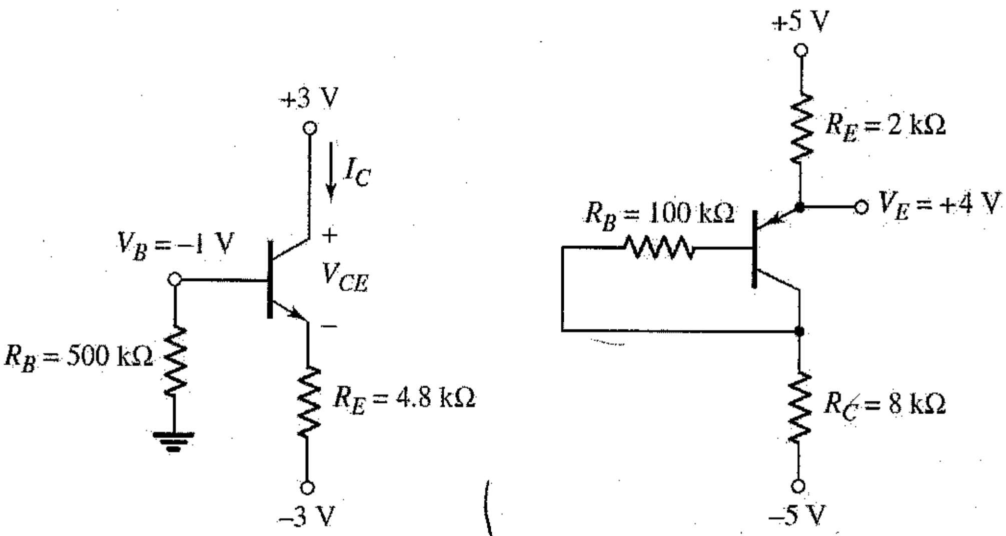
$\boxed{V_{EC} = 222.5\ mV}$

c) Because neither PN Junction is foward Biased, $I_E = \boxed{I_C = \emptyset}$

$\therefore$ $\boxed{V_{EC} = 2V}$

Problem 5.23

In the circuits shown in Figure P5.23, the values of measured parameters are shown. Determine β, α, and the other labeled currents and voltages. Sketch the dc load line and plot the Q-point.



(a) (b)

Figure P5.23

a)

$-1-0.7-I_E R_E-(-3)=0$

$I_E = \frac{3-1-0.7}{4.8k} \Rightarrow \boxed{I_E = 270.833\mu A}$

$I_B = \frac{-1}{500k} \Rightarrow \boxed{I_B = -2\mu A}$

$I_C = I_E - I_B \Rightarrow \boxed{I_C = 268.833\mu A}$

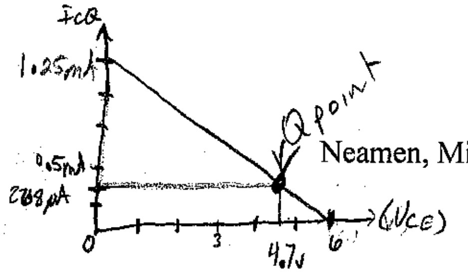
$\frac{I_C}{I_B} = \beta = \frac{272.833\mu A}{2\mu A} \Rightarrow \boxed{\beta = 134.416}$

$\alpha = \frac{\beta}{1+\beta} \Rightarrow \boxed{\alpha = 0.9926}$

$6 = V_{CE} + I_E R_E \Rightarrow 6-(270.833\mu A)(4.8k)$

$\boxed{V_{CE} = 4.7V}$

$I_C = 0$ then $V_{CE} = 6V$, $V_{CE} = 0$ then $I_{C,E} = \frac{6}{4.8k} =$ $I_{C,E} = 1.25mA$



b) $I_E = \frac{5-4}{2k} = 500\mu A = I_E$

$V_E - V_{BE}(on) - I_B R_B - I_C R_C - (-5V) = 0$

$V_E = I_B R_B + (I_E - I_B) R_C - 5 + 0.7$

$V_E = I_B (R_B - R_C) + I_E R_C - 5 + 0.7$

$I_B = \frac{V_E - I_E R_C + 5}{R_B - R_C} \Rightarrow \frac{(4-(500\mu A)(8k)+5)-0.7}{100K-8K}$

$\boxed{I_B = 46.74\mu A}$

$I_C = I_E - I_B \Rightarrow 500\mu A - 46.74\mu A =$

$\boxed{I_C = 453.26\mu A}$

$\beta = \frac{I_C}{I_B} = \frac{453.26\mu A}{46.74\mu A} \Rightarrow \boxed{\beta = 9.698}$

$\alpha = \frac{\beta}{1+\beta} = \boxed{0.9065 = \alpha}$

$V_{CE} = 0$ then $I_{CE} = \frac{10}{10K} = 1mA$

$I_C = 0$ then $V_{CE} = 0$

$V_{CE} = (I_C R_C - 5) - 4$

$V_{CE} = -5.37V$

$\boxed{V_{EC} = 5.37V}$