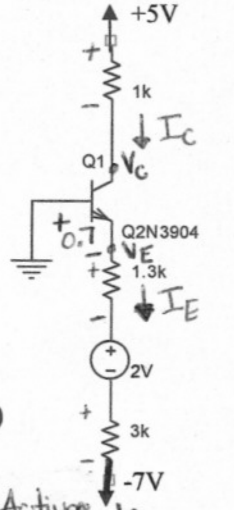
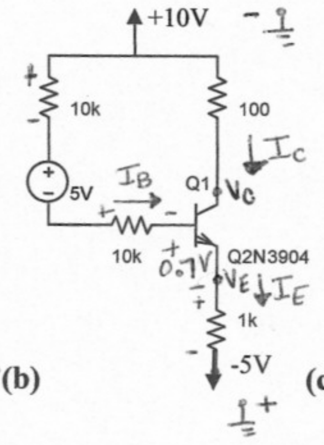
**ECE2280** **Homework #7** **Spring 2007**

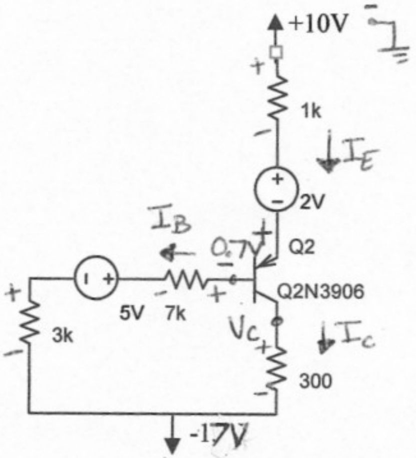
1. Use $|V_{BE}|=0.7$, $\beta=100$. Find voltages at all nodes and currents through all branches. *(worth 4 problems)*



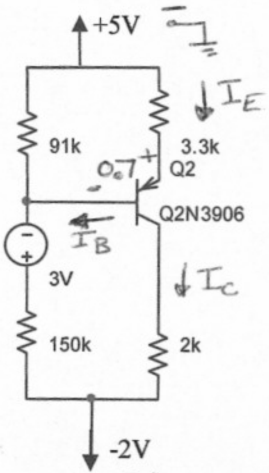
(a)



(b)



(c)



(d)

Assume Active:

a. $+0.7+1.3K(I_E)+2+3K(I_E)-7=0$

$I_E=\frac{(5-0.7)}{4.3K}=\boxed{1mA}$

$-7+I_E(3K)+2+I_E(1.3K)-V_E=0$

$V_E=-5+I_E(4.3K)=\boxed{-0.7V}$

$I_C=\alpha I_E=\frac{100}{101}(1m)=\boxed{0.99m}$

$\boxed{V_B=0}$

$5-I_C(1K)-V_C=0$

$V_C=5-I_C(1k)\cong\boxed{+4V}$

$V_C>V_B>V_E\rightarrow$ Active mode ✓

b. $+10-I_B(10K)-5-I_B(10K)-0.7-I_E(1K)+5=0$

$I_B=\frac{I_E}{(\beta+1)}\Rightarrow I_E=\frac{9.3}{\left[\frac{20K}{(\beta+1)}\right]+1K}=\boxed{7.76mA}$

$I_C=\beta\cdot I_B$
$I_C=\alpha I_E$ $\Rightarrow$ $I_C=\alpha I_E=\boxed{7.69mA}$

$I_B=\boxed{76.9\mu A}$

$V_C=10-100(I_C)=\boxed{9.2V}$

$V_C>V_B>V_E$ Active ✓

$V_B\approx5-I_B(20K)=\boxed{3.5V}$

$V_E\cong-5+1K(I_E)\cong\boxed{2.8V}$

c. $+10-I_E(1K)-2-0.7-I_B(7K)-5-3K(I_B)+17=0$

$I_B=I_E/\beta+1\Rightarrow I_E=\frac{19.3}{\left(\frac{10K}{\beta+1}\right)+1K}=\boxed{17.6mA}$ $I_C=\alpha I_E=\boxed{17.4mA}$

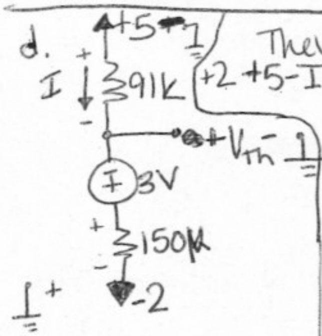
$I_B=I_C/\beta\cong\boxed{174\mu}$

$-17+3K(I_B)+5+7K(I_B)=V_B\Rightarrow V_B=-12+10K(I_B)$

$V_B=\boxed{-10.26V}$ ; $V_E\Rightarrow+10-I_E(1K)-2-V_E=0\Rightarrow V_E=\boxed{-9.6V}$

$-17V+I_C(300)-V_C=0\Rightarrow V_C=\boxed{-11.78V}$ $V_C<V_B<V_E$ ✓

d.



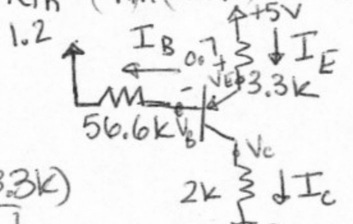
Thevenin $\Rightarrow$

$+2+5-I(91K)+3-I(150K)=0$

$I=\frac{10}{241K}=41.5\mu$

$+5-I(91K)-V_{Th}=0\Rightarrow V_{Th}\cong1.2V$

$R_{Th}=(91\|150K)=56.6K$



$+5-I_E(3.3K)-0.7-I_B(56.6K)-1.2=0$

$I_B=\frac{I_E}{(\beta+1)}\Rightarrow I_E=\frac{3.1}{3.3K+\left(\frac{56.6K}{\beta+1}\right)}=\frac{3.1}{3.3K+560}=\boxed{.8m}$

$I_C=\alpha I_E=\frac{100}{101}(.8m)\cong\boxed{.8m}$

$I_B=\frac{I_E}{101}=\boxed{8\mu A}$

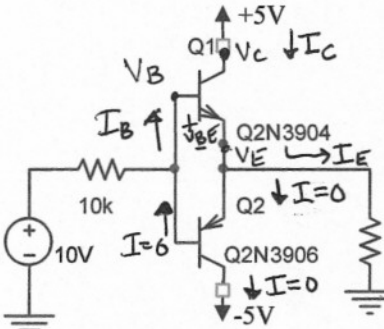
$V_E=5-I_E(3.3K)$
$=\boxed{2.36V}$

$V_B=V_E-V_{EB}=\boxed{1.66V}$

$V_C=-2+I_C(2K)=\boxed{-0.4V}$

$V_C<V_B<V_E$ ✓ Active

2. Use $|V_{BE}|=0.7$, $\beta=100$. Find voltages at all nodes and the currents through all branches. $V_{CE\_SAT}=0.2V$



Q1 on, Q2 off: they can not both be on at the same time. (See Example 5.12 in the book). {Can not have current flow "into" the +10V supply}.

Assume active: $+10 - I_B(10K) - 0.7 - I_E(1K) = 0$  $I_B = \frac{I_E}{\beta+1}$

$\Rightarrow I_E = 8.5m$  $\therefore V_E = 8.5V$, $V_B = 9.2V$

$V_c = +5V$

$\therefore V_c < V_B > V_E$ !! NOT ACTIVE

Assume SAT: $V_{CE}=0.2V$

$+5 - V_{CESAT} - \underbrace{I_E(1K)}_{V_E} = 0$

$\therefore V_E = \boxed{4.8V}$

$V_B = 4.8 + 0.7 = \boxed{5.5V}$

$V_c = \boxed{5V}$

$5 < V_B > V_E$ ✓ SAT

For Q2:

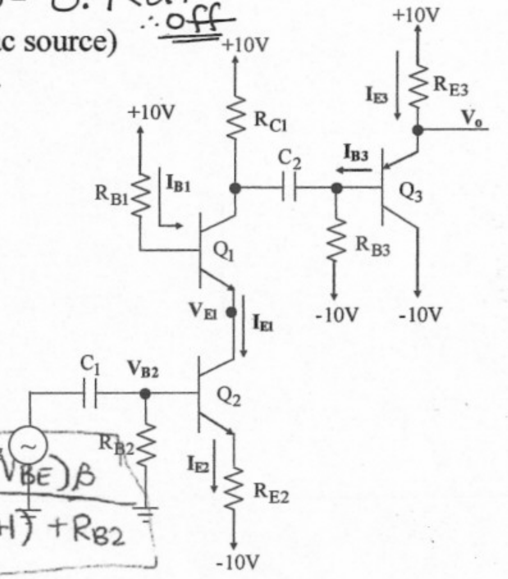
$V_{EB} = 4.8 - 5.5 = -0.7 < 0.7$ $\therefore$ off

$I_E = \frac{V_E}{1K} = \boxed{4.8m}$

$I_B = \frac{(10-5.5)}{10K} = \boxed{0.45m}$

$I_C = I_E - I_B = \boxed{4.35m}$

3. Assume active operation for all transistors. (Vsig is an ac source)
Assume that the capacitors act as an open for DC operation.
(a) Find the symbolic equations for the DC values for $I_{E1}$, $I_{E2}$, $I_{B1}$, $I_{E3}$, $I_{B3}$, $V_o$, $V_{E1}$
(b) Draw the hybrid-π or model-T AC circuit



(a)

$-I_{B2}(R_{B2}) - V_{BE} - R_{E2}(I_{E2}) + 10 = 0$

$I_{B2} = \frac{I_{E2}}{\beta+1} \Rightarrow \boxed{I_{E2} = \frac{10-V_{BE}}{R_{E2} + \frac{R_{B2}}{\beta+1}}}$

$I_{E1} = I_{C2} = \alpha I_{E2} = \boxed{\frac{\alpha(10-V_{BE})}{R_{E2} + \frac{R_{B2}}{\beta+1}} \text{ or } \frac{(10-V_{BE})\beta}{R_{E2}(\beta+1) + R_{B2}}}$

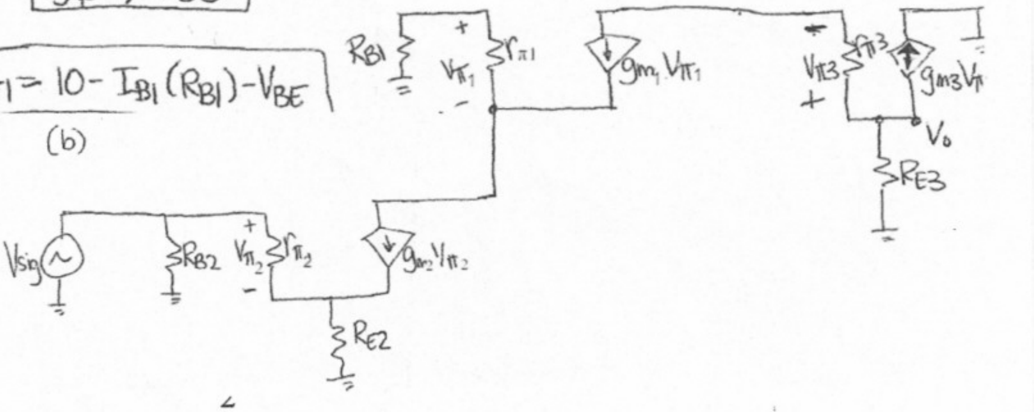
$I_{B1} = \frac{I_{E1}}{\beta+1} = \boxed{\frac{(10-V_{BE})\beta}{R_{E2}(\beta+1)^2 + R_{B2}(\beta+1)}}$

$-10 + I_{B3}(R_{B3}) + V_{BE} + I_{E3}(R_{E3}) - 10 = 0$

$I_{E3} = \boxed{\frac{20-V_{BE}}{R_{E3} + \frac{R_{B3}}{\beta+1}}}$  $I_{B3} = \boxed{\frac{(20-V_{BE})}{R_3(\beta+1)+R_{B3}}}$

$\boxed{V_o = 10 - I_{E3} \cdot R_{E3}}$  $\boxed{V_{E1} = 10 - I_{B1}(R_{B1}) - V_{BE}}$

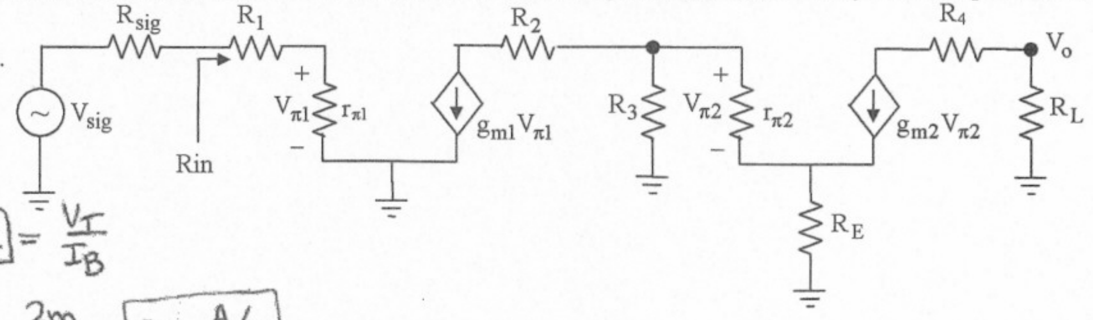
(b)



4. Use $|V_{BE}|=0.7$, $\beta=20$, $V_T=25mV$ (Vsig is an ac source), ignore $r_o$.

This small-signal model circuit is shown below. It was found through a DC analysis that **$I_{C1}=1mA$ and $I_{C2}=2mA$**.

Find the ac parameters, $r_{\pi 1}$ and $gm_2$, $R_{in}$. (Ignore the AC input source and Rsig, include R1), Find a symbolic expression for the overall gain, $\frac{Vo}{Vsig}$.



$r_{\pi 1} = \boxed{500\,\Omega} = \frac{V_T}{I_B}$

$g_{m2} = \frac{I_{C2}}{V_T} = \frac{2m}{25m} = \boxed{80m\ A/V}$

$\boxed{R_{in} = R_1 + r_{\pi 1}}$

$V_o = -g_{m2} V_{\pi 2} \cdot R_L$

$V_{\pi 2} = -\frac{g_{m1} V_{\pi 1} (R_3)}{[R_3 + r_{\pi 2} + R_E(\beta+1)]} \cdot r_{\pi 2}$

$V_{\pi 1} = \frac{V_{sig}(r_{\pi 1})}{(r_{\pi 1} + R_1 + R_{sig})}$

$$\boxed{\frac{V_o}{V_{sig}} = \frac{-g_{m2} R_L (r_{\pi 1})(-g_{m1})(R_3)(r_{\pi 2})}{(r_{\pi 1} + R_1 + R_{sig})[R_3 + r_{\pi 2} + R_E(\beta+1)]}}$$

5. Use $|V_{BE}|=0.7$, $\beta=100$, $V_T=25mV$ (Vs is an ac source), ignore $r_o$. This small-signal model comes from a circuit that has 2 transistors Q1 and Q2 denoted below as subscripts 1 and 2. It was found that $I_{E1}=2.525m$ and $I_{E2}=1.2625m$. Find $R_{in}$(ignore Vs and 10Ω), $R_{out}$(ignore $R_L$), and midband gain, Vo/Vs.

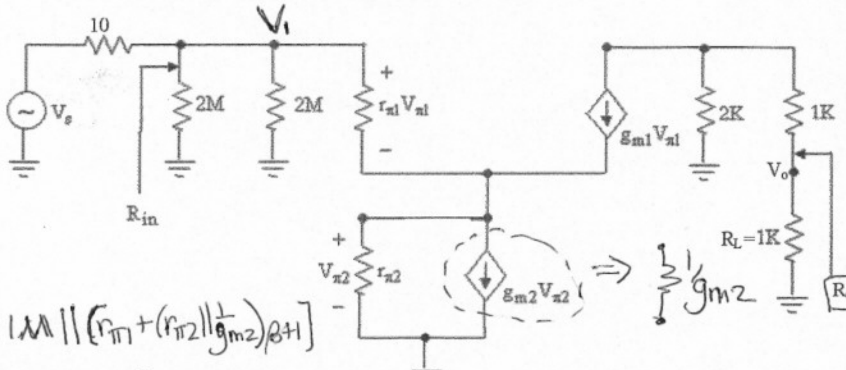
AC parameters ⇒

$r_{\pi 1} = \frac{V_T}{I_B} = \frac{25m}{\left(\frac{2.525m}{101}\right)} = 1,000\,\Omega$

$g_{m1} = \frac{I_{C1}}{V_T} \cong 100m\ A/V$

$r_{\pi 2} = \frac{25m}{\left(\frac{1.2625m}{101}\right)} \approx 2K\,\Omega$

$g_{m2} = \frac{I_{C2}}{V_T} \approx 50m\ A/V$

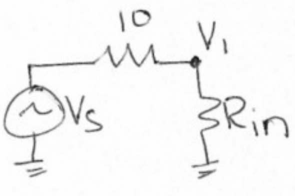


$\boxed{R_{out} = 1K + 2K}$

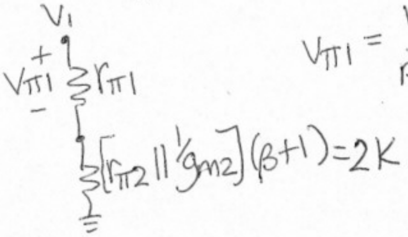
$R_{in} = 1M \| [r_{\pi 1} + (r_{\pi 2} \| \frac{1}{g_{m2}})(\beta+1)]$

$R_{in} \cong \boxed{2,991\,\Omega}$

$V_o = \left[-\frac{g_{m1} V_{\pi 1}(2K)}{4K}\right] 1K$



$V_1 = \frac{V_s(R_{in})}{R_{in}+10} \approx V_s$



$V_{\pi 1} = \frac{V_1 (r_{\pi 1})}{r_{\pi 1} + 2K} = 0.33 V_1$

$\therefore V_o = -g_{m1}(500)(.33 V_s)$

$\frac{V_o}{V_s} \approx \boxed{-16.7\ V/V}$