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

(a) 
\[ I_E = \frac{(5-0.7)}{4.3k} = 1.1mA \]
\[ V_E = -5 + I_E \times (4.3k) = -0.7V \]
\[ V_C = 5 - I_C \times (1k) = 4V \]
\[ V_C > V_B > V_E \rightarrow \text{Active mode} \]

(b) 
\[ I_E = \frac{9}{20} \times 10k \times (\beta+1) = 7.76mA \]
\[ V_C = 10 - 100(I_C) = 9.2V \]
\[ V_E = 5 + 1k(I_E) = 3.8V \]

(c) 
\[ I_B = I_E/(\beta+1) \rightarrow I_E = \frac{19.3}{10k+1} = 17.6mA \]
\[ I_C = \alpha I_E = 17.4mA \]
\[ I_B = I_C/(\beta+1) = 17.4mA \]
\[ V_B = \frac{-10.26V}{10-I_E} \rightarrow V_E = \frac{10-I_B}{10} \]
\[ V_C = \frac{-11.78V}{10} \]

(d) 
\[ V_E = 5 - I_E \times (3.3k) = 2.36V \]
\[ V_B = V_E - V_{EB} = 1.66V \]
\[ V_C = -2 + I_C \times (2k) = -0.4V \]
\[ V_C < V_B < V_E \rightarrow \text{Active} \]
2. Use $|V_{BE}| = 0.7$, $\beta = 100$. Find voltages at all nodes and the currents through all branches. $V_{CE\text{-SAT}} = 0.2V$

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

Assume active: $+10 - I_B(10k) - 0.7 - I_E(1k) = 0$ \[ I_B = \frac{I_E}{\beta+1} \]
\[ \Rightarrow I_E = 8.5mA \quad \Rightarrow V_E = 8.5V, \quad V_B = 9.2V \]
\[ V_C = +5V \quad \Rightarrow V_C < V_B < V_E \quad \text{NOT ACTIVE} \]

$V_B = 4.8 + 0.7 = \frac{5.5V}{1k}$
\[ V_E = \frac{V_E}{1k} = 4.8mA \]
\[ I_B = \frac{10 - 5.5}{10k} = 0.45mA \]
\[ I_C = I_E - I_B = \frac{4.35mA}{1k} \]

3. Assume active operation for all transistors. ($V_{sig}$ 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 $I_{E1}$, $I_{E2}$, $I_{B1}$, $I_{E3}$, $I_{B3}$, $V_0$, $V_{E1}$

(b) Draw the hybrid-π or model-T AC circuit

\[ I_{E2} = \frac{I_{E2}}{\beta+1} \quad \Rightarrow I_{E2} = \frac{10 - V_{BE}}{R_{E2} + R_{B2}/\beta+1} \]
\[ I_{E1} = I_{C2} = \alpha I_{E2} = \frac{\alpha(10 - V_{BE})}{R_{E2} + R_{B2}/\beta+1} \quad \text{or} \quad \frac{(10 - V_{BE})\beta}{R_{E2}(\beta+1) + R_{B2}} \]
\[ I_{B1} = \frac{I_{E1}}{\beta+1} = \frac{(10 - V_{BE})\beta}{R_{E2}(\beta+1) + R_{B2}(\beta+1)} \]
\[-10 + I_{E3}(R_{E3}) + V_{BE} + I_{E3}(R_{E3}) - 10 = 0 \]
\[ I_{E3} = \frac{20 - V_{BE}}{R_{E3} + R_{B3}/\beta+1} \]
\[ I_{B3} = \frac{(20 - V_{BE})}{R_{B3}(\beta+1) + R_{B3}} \]

$V_0 = 10 - I_{E3}R_{E3}$

$V_{E1} = 10 - I_{B1}(R_{B1}) - V_{BE}$
4. Use $|V_{os}| = 0.7$, $\beta = 20$, $V_r = 25 \text{mV}$ ($V_{sig}$ is an ac source), ignore $r_o$.

This small-signal model circuit is shown below. It was found through a DC analysis that $I_{c1} = 1 \text{mA}$ and $I_{c2} = 2 \text{mA}$.

Find the ac parameters, $r_{in}$, and $g_{m2}$, $R_{in}$. (Ignore the AC input source and $R_{sig}$, include $R_1$), Find a symbolic expression for the overall gain, $\frac{V_o}{V_{sig}}$.

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

$$g_{m2} = \frac{I_{c2}}{V_T} = \frac{2m}{25m} = 80 \text{mA/V}$$

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

$$V_o = -g_{m2} V_{in2} \cdot R_L$$

$$V_{in2} = \frac{-g_{m1} V_{in1}}{\left(\frac{R_3}{R_3 + r_{\pi 2} + R_E}\right)}$$

$$V_{in1} = \frac{V_{sig} \left(\frac{r_{\pi 1}}{r_{\pi 1} + R_1 + R_{sig}}\right)}{R_{in} + R_1 + R_{sig}}$$

5. Use $|V_{os}| = 0.7$, $\beta = 100$, $V_r = 25 \text{mV}$ ($V_s$ 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 $I_{c1} = 2.525 \text{mA}$ and $I_{c2} = 1.2625 \text{mA}$. Find $R_{in}$ (ignore $V_s$ and 10Ω), $R_{out}$ (ignore $R_o$), and midband gain, $V_o/V_s$.

$$R_{in} = \frac{1M \left(\frac{R_{\pi 1} + (R_{\pi 2} + g_{m2})(\beta+1)}{g_{m2}}\right)}{2.991 \Omega}$$

$$V_o = \left[\frac{-g_{m1} V_{in1} (2K)}{4K}\right]K$$

$$V_{in1} = \frac{V_s (R_{in})}{R_{in} + 10}$$

$$V_{in2} = \frac{V_s (R_{in})}{R_{in} + 2K} = 0.33V$$

$$V_{in1} = \frac{V_s (R_{in})}{R_{in} + 2K}$$

$$V_o = \frac{V_s (R_{in})}{R_{in} + 2K} = 0.33Vs$$

$$V_o \approx -16.7V/V$$