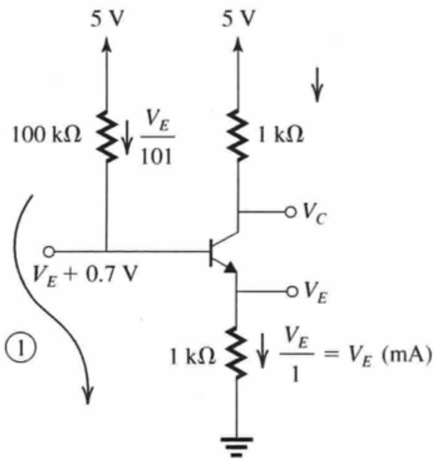
6.61

$\beta = 100$

(a) $R_B = 100\ \text{k}\Omega$ − ∵ R_B is large assume active mode.



$$\frac{100}{101} I_E = \frac{100}{101} V_E\ (\text{mA})$$

Loop (1)

$$5 - \frac{V_E}{101} \times 100 - 0.7 - V_E \times 1 = 0$$

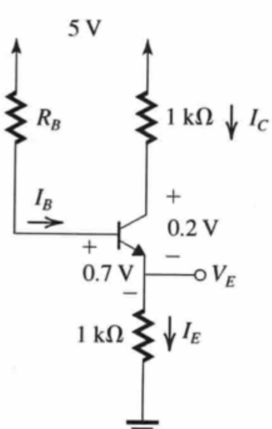
$V_E = 2.16$ V

$V_B = V_E + 0.7 = 2.86$ V

$$V_C = 5 - 1 \times \frac{100}{101} V_E = 2.86\ \text{V}$$

Thus the BJT is in active mode as assumed.

(b) $R_B = 10\ \text{k}\Omega$ - assume saturation



$$I_B = \frac{5 - (V_E + 0.7)}{R_B}$$

$$I_C = \frac{5 - (V_E + 0.2)}{1}$$

$$I_E = \frac{V_E}{1} = I_B + I_C$$

$$\therefore V_E = \frac{4.3 - V_E}{10} + 4.8 - V_E$$

$10V_E + V_E + 10V_E = 4.3 + 48$

$V_E = 2.49$ V

$V_C = 2.49 + 0.2 = 2.69$ V

$V_B = V_E + 0.7 = 3.19$ V

$$\text{Check : } I_C = \frac{5 - 2.69}{1} = 2.31\ \text{mA}$$

$$I_B = \frac{5 - 3.19}{10} = 0.181\ \text{mA}$$

$$\frac{I_C}{I_B} = \frac{2.31}{0.181} = 12.76 < 100$$

Hence, we are in saturation as assumed!

(c) $R_B = 1\ \text{k}\Omega$ - expect saturation, use circuit in (b)

$$I_B = \frac{5 - (V_E + 0.7)}{R_B} = \frac{4.3 - V_E}{1}$$

$$I_C = \frac{5 - (V_E + 0.2)}{1} = \frac{4.8 - V_E}{1}$$

$I_E = I_B + I_C = V_E$

$4.3 - V_E + 4.8 - V_E = V_E$

$V_E = 3$ V

$V_B = 3.7$ V

$V_C = 3.2$ V

Check $I_B = 4.3 - 3 = 1.3$ mA

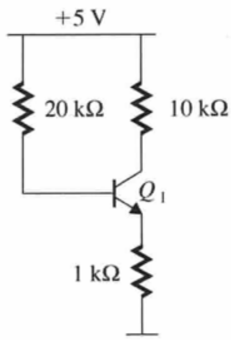
$I_C = 4.8 - 3 = 1.8$ mA

$$\frac{I_C}{I_B} = \frac{1.8}{1.3} = 1.4 < 100$$

∴ Saturation as assumed

6.70

(a)



$$I_E = \frac{5 - 0.7}{1 + 20/(\beta + 1)} = \frac{4.3}{1.2}$$

$= 3.58$ mA

which would make $V_C < V_E$

$\therefore$ Saturated $V_{CE} = 0.2$ V

$$\frac{V_E}{1\text{ k}\Omega} = \frac{5 - 0.7 - V_E}{20\text{ k}\Omega} + \frac{5 - 0.2 - V_E}{10\text{ k}\Omega}$$

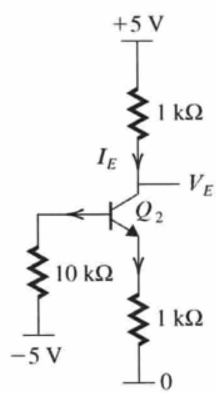
$\Rightarrow 23\, V_E = 13.9$

$\therefore V_E = 0.604$ V

$$\beta_{\text{forced}} = \frac{I_C}{I_B} = \frac{4.8 - V_E}{10} \cdot \frac{20}{4.3 - V_E}$$

$$= \frac{0.42}{0.185} = 2.3$$

(b)



Assume saturated

$$I_E = \frac{5 - V_E}{1\text{ k}\Omega}$$

$$I_B = \frac{V_E - 0.7 + 5}{10\text{ k}\Omega}$$

$$I_C = \frac{V_E - 0.2}{1\text{ k}\Omega}$$

$$\frac{5 - V_E}{1} = \frac{(V_E - 0.7) + 5}{10} + \frac{V_E - 0.2}{1}$$

$\Rightarrow 21 V_E = 4.77$ or $V_E = 2.27$ V

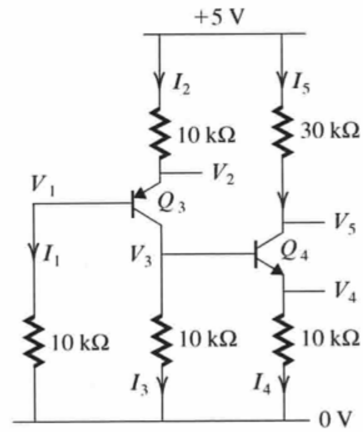
$V_B = V_E - 0.7 = 1.57$ V

$V_C = V_E - 0.2 = 2.07$ V

[Check $V_E = 5 - 1$ V](0.657 + 2.07) = 2.27 V]

$$\beta_{\text{forced}} = \frac{1.87}{0.343} = 5.45$$

(c)



Assume Q_3 & Q_4 Saturated

$V_1 = V_2 - 0.7$ V

$V_3 = V_2 - 0.2$ V

$V_4 = V_2 - 0.9$ V

$V_5 = V_2 - 0.7$ V

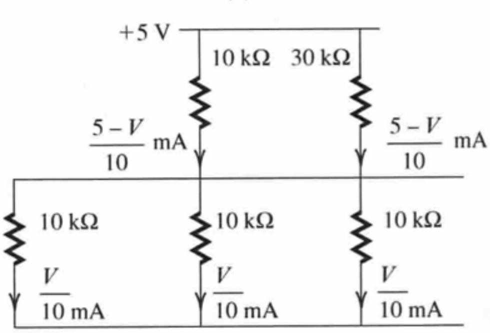
$I_2 = I_1 + I_3 + I_4 - I_5$

$$I_2 = \frac{5 - V_2}{10}$$

$$\Rightarrow \frac{5 - V_2}{10} = \frac{V_2 - 0.7}{10} + \frac{V_2 - 0.2}{10} + \frac{V_2 - 0.9}{10} - \left[\frac{5 - (V_2 - 0.7)}{30}\right]$$

$\Rightarrow 13V_2 = 26.1$ mA

(d)



$V_2 \approx 2.0$ V

$$\beta_3 \text{ forced} = \frac{I_3 + I_4 - I_5}{I_1} = \frac{0.17}{0.13} = 1.3$$

$$\beta_4 \text{ forced} = \frac{I_5}{I_4 - I_5} = \frac{0.123}{0.11 - 0.123} = ??$$

$$I_{C4} > I_{E4}$$

(c) Using " Giant Node Approximation"

$$\frac{5-V}{10} + \frac{5-V}{30} = \frac{V}{10} + \frac{V}{10} + \frac{V}{10}$$

$20 - 3V + 5 - V = 9V$

$13\,V = 20$

$V = 1.54$ V

Hence $I_{C3} = 0.115$ mA

$I_{E3} = 0.154$ mA

However, for Q_4 - without approximation

$$I_{C4} = \frac{5 - (V_2 - 0.7)}{30}$$

$$I_{E4} = \frac{V_2 - 0.9}{10}$$

Hence for $I_{C4} < I_{E4}$

we need $V_2 > 2.1$ V

and as by" Propagrating V_{GS}" shown below, Q_4 cannot operate properly

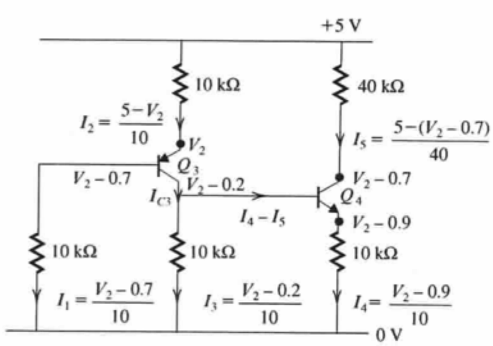
The "Giant Node Approximation" does simply " Scale up" with $V \alpha V_{CC}$ but unfortunately it does not "Scale down" when $V_{BE} > V_{CC}/10$ (say)

To fix problem : either

(a) raise V_{cc}

(b) raise R_{c3}

(c) Using " Propagate V_2 method"



$$\frac{5 - V_2}{10} + \frac{5.7 - V_2}{40} = \frac{V_2 - 0.7}{10} + \frac{V_2 - 0.2}{10} + \frac{V_2 - 0.9}{10}$$

$20 - 4V_2 + 5.7 - V_2 = 12V_2 - 7.2$

$\Rightarrow 7V_2 = 32.9$

$\Rightarrow V_2 = 1.94$ V

I_{B3}	= 0.124 mA	I_{E4}	= 0.104 mA
I_{E3}	= 0.306 mA	I_{C4}	= 0.094 mA
I_{C3}	= 0.182 mA	I_{B4}	= 0.01 mA

β_3 -forced $= \frac{0.182}{0.124} = 1.47$ $\qquad$ β_4 -forced $= \frac{0.094}{0.01} = 9.4$

Note: using "Giant Node" method

$$\frac{5-V}{10} + \frac{5-V}{40} = \frac{3\,V}{10}$$

$17\,V = 25$

$\Rightarrow V_2 = 1.47$ (30% difference)