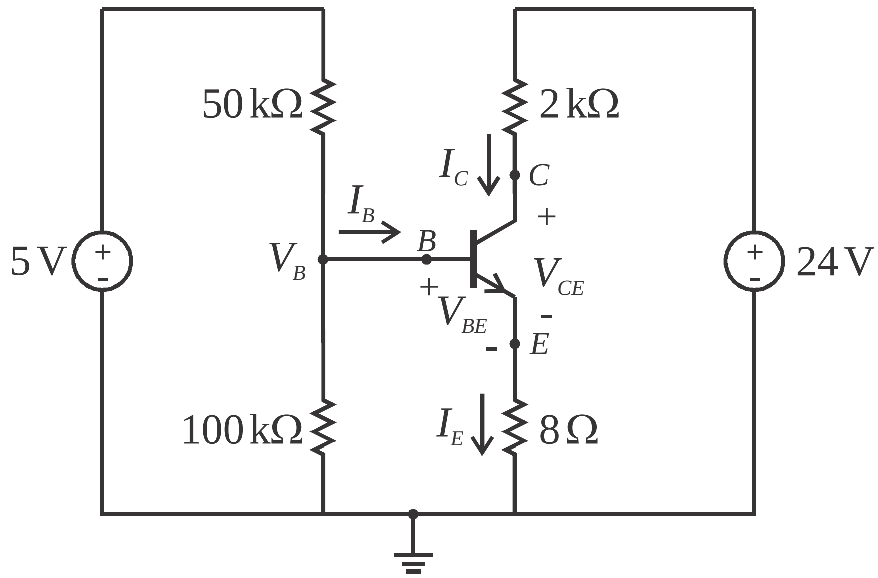
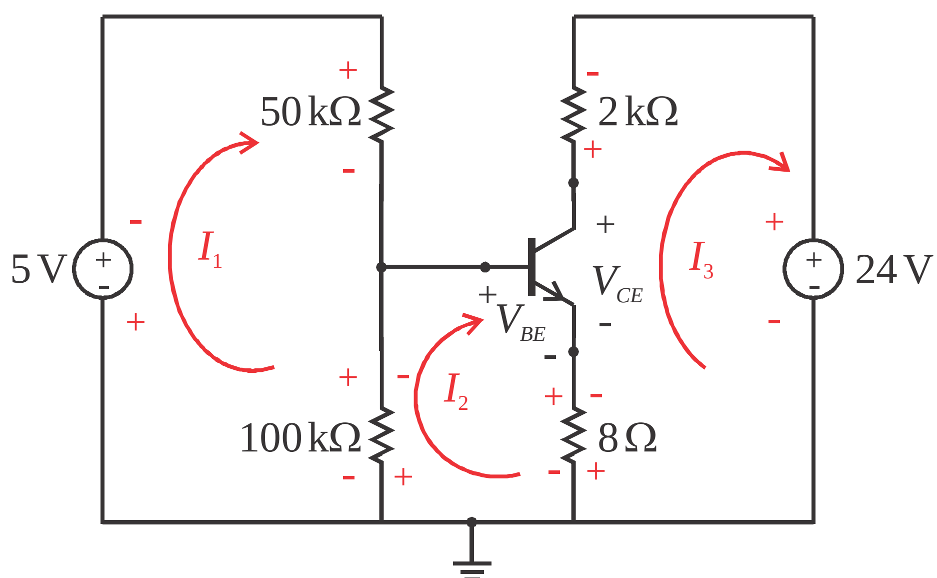
Example-



Given that $\beta = 100$ and $V_{BE} = 0.7$ V, find V_{CE}, V_B, V_E, V_C, I_B, I_C, and I_E.

Mesh Analysis

Redraw circuit and assign mesh currents.



Mesh 1: $-5 + 50\times10^3 I_1 + 100\times10^3 (I_1 - I_2) = 0$

Mesh 2: $100\times10^3 (I_2 - I_1) + \cancelto{0.7}{V_{BE}} + 8(I_2 - I_3) = 0$

Mesh 3: $8(I_3 - I_2) - V_{CE} + 2000 I_3 + 24 = 0$

Simplify equations

$$[50\times10^3+100\times10^3]I_1+(-100\times10^3)I_2\ +(0)I_3=5$$

$$(-100\times10^3)I_1+[100\times10^3+8]I_2+(-8)I_3=-0.7$$

$$(0)I_1+(-8)I_2+[2000+8]I_3+(-1)V_{CE}=-24$$

$\Rightarrow$ 3 equations + 4 unknowns $(I_1, I_2, I_3, + V_{CE})$

How do we simplify?

* Note (from circuit drawing): $I_2 = I_B$ $\leftarrow$ Sub #1

$I_3 = -I_C$

* Now, for BJT transistors, we know that

$I_C = \beta I_B = 100 I_B \overset{\text{use \#1}}{\Rightarrow} I_3 = -100 I_B \Leftarrow$ Sub #2

Using substitution #2 in the above equations leads to –

$$(150\times10^3)I_1+(-100\times10^3)I_B\ +(0)V_{CE}=5$$

$$(-100\times10^3)I_1+[100\times10^3+8+8(100)]I_B+(0)V_{CE}=-0.7$$

$$(0)I_1+[-8-2008(100)]I_B+(-1)V_{CE}=-24$$

$\Rightarrow$ 3 equations + 3 unknowns

$\Downarrow$ solve using TI-68

$$I_1 = 84.754\,\mu A$$

$$I_B = 77.13\,\mu A$$

$$V_{CE} = 8.5116\ V$$

Using these currents and voltage –

$$I_C = 100\,I_B = 7.713\,mA$$

By KCL, $I_E = I_C + I_B = 7.713 \times 10^{-3} + 77.13 \times 10^{-6}$

$$I_E = 7.79\,mA$$

By Ohm's Law, $V_E = I_E(8) = 7.79 \times 10^{-3}(8)$

$$V_E = 0.06232\,V = 62.32\,mV$$

By Ohm's Law, $V_B = V_{100k\Omega} = (I_1 - \overset{I_B}{I_2})\,100 \times 10^3$

$$= (84.754 \times 10^{-6} - 77.13 \times 10^{-6})\,100 \times 10^3$$

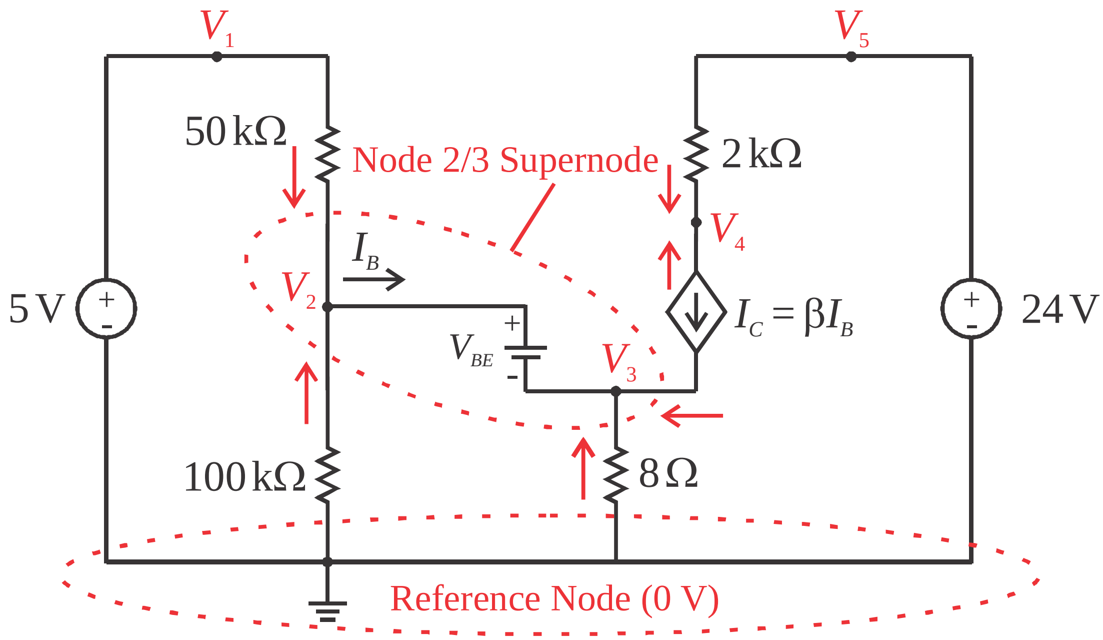
$$V_B = 0.7624\,V$$

By KVL, $V_C = V_E + V_{CE} = 0.06232 + 8.5116$

$$V_C = 8.5739\ V$$

Nodal Analysis

Redraw circuit, using first-order circuit model of BJT transistor, and assign node voltages.



Node 1: $V_1 = 5\,V$

Node 2/3 Aux. Eq'n: $V_2 - V_3 = V_{BE} = 0.7$

Node 2/3 Supernode: $\dfrac{\overset{5}{\cancel{V_1}} - V_2}{50 \times 10^3} + \dfrac{0 - V_2}{100 \times 10^3} + \dfrac{0 - V_3}{8} + \overset{\beta=100}{\beta} I_B = 0$

Node 4: $-\overset{100}{\beta} I_B + \dfrac{\overset{24}{\cancel{V_5}} - V_4}{2000} = 0$

Node 5: $V_5 = 24\,V$

$\Rightarrow$ 4 unknowns $(V_2, V_3, I_B, + V_4)$ + 3 equations

Can we determine I_B in terms of the node voltages?

Using KCL @ node 2,

$$I_B = \frac{0 - V_2}{100 \times 10^3} + \frac{\cancelto{5}{V_1} - V_2}{50 \times 10^3}$$

At this point, we could substitute the above equation for I_B into the node equations to get 3 equations – 3 unknowns <u>OR</u> use the above equation and have 4 equations – 4 unknowns (less likely to make an error) → gather up terms + coefficients

$$(1) V_2 + (-1) V_3 + (0) V_4 + (0) I_B = 0.7$$

$$\left[\frac{-1}{50 \times 10^3} + \frac{-1}{100 \times 10^3}\right] V_2 + \left(\frac{-1}{8}\right) V_3 + (0) V_4 + (100) I_B = \frac{-5}{50 \times 10^3}$$

$$(0) V_2 + (0) V_3 + \left(\frac{-1}{2000}\right) V_4 + (-100) I_B = \frac{-24}{2000}$$

$$\left[\frac{-1}{50 \times 10^3} + \frac{-1}{100 \times 10^3}\right] V_2 + (0) V_3 + (0) V_4 + (-1) I_B = \frac{-5}{50 \times 10^3}$$

$\Downarrow$ solve using TI-68

$$\underline{\underline{V_2 = V_B = 0.76232\,V}}$$

$$\underline{\underline{V_3 = V_E = 0.06232\,V = 62.32\,mV}}$$

$$\underline{\underline{V_4 = V_C = 8.5739\,V}}$$

$$\underline{\underline{I_B = 77.13\,\mu A}}$$

Same answers!

$$V_{CE} = V_C - V_E = \underline{\underline{8.5116\,V}}$$

$$I_E = \frac{V_3 - 0}{8} = \underline{\underline{7.79\,mA}}$$