Ex 1 The transistor in the circuit shown in fig.1 has $\beta = 100$ and exhibits a 'V_{BE_1}' of 0.7V at '$i_{c_1} = 1mA$'. Design the circuit so that a current of 2mA flows through the collector and a voltage of +5V appears at the collector.

<u>Given.</u>

$\beta = 100$
$V_{BE_1} = 0.7$
$i_{c_1} = 1mA$

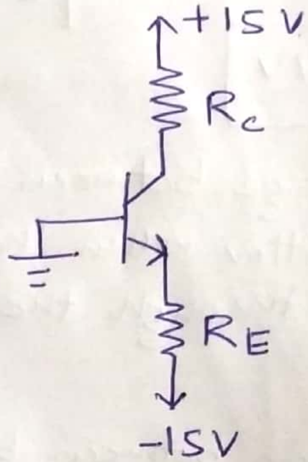


fig. 1

Here design means we have to find the value of 'R_c' & 'R_E'

* V_c = Voltage at collector
  V_E = Voltage at emitter.
  V_B = Voltage at base
  V_{BE} = Voltage between base and emitter.
  V_{CE} = Voltage between collector and emitter.
  I_c = Current through collector.
  I_E = " " emitter.

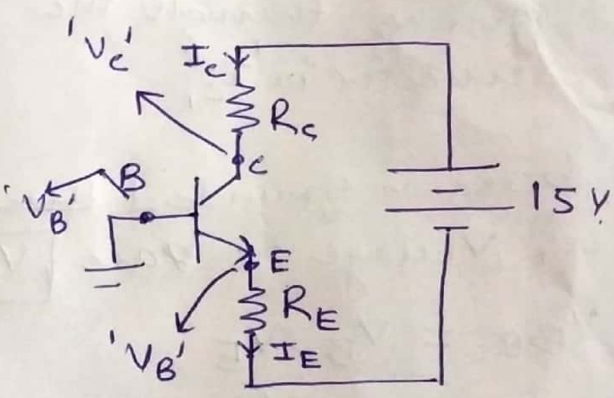


fig 1'

V_{BE} and V_{CE} is given as:

$V_{BE} = V_B - V_E$

$V_{CE} = V_C - V_E$

consider fig 2,

Current through collector, $I_c = \dfrac{15 - V_c}{R_c}$

for $V_c = 5V$, I_c is given as 2mA

$\therefore \quad R_c = \dfrac{15-5}{2mA}$, $\boxed{R_c = 5k\Omega}$

Since $V_{BE_1} = 0.7V$ at $I_{C_1} = 1mA$, the value of V_{BE_2} at $I_{C_2} = 2mA$

$$V_{BE_2} = V_{BE_1} + V_T \ln\left[\frac{I_{C_2}}{I_{C_1}}\right]$$

$$V_{BE_2} = 0.7 + (25\times10^{-3}) \ln\left[\frac{2\,mA}{1\,mA}\right]$$

$$\boxed{V_{BE_2} = 0.717V}$$

Rough work

As we know that

$$I_C = I_S e^{V_{BE}/V_T}$$

So, $I_{C_1} = I_S e^{V_{BE_1}/V_T}$ — (1)

$I_{C_2} = I_S e^{V_{BE_2}/V_T}$ — (2)

on dividing eqn (2) by (1)

$$\frac{I_{C_2}}{I_{C_1}} = e^{(V_{BE_2} - V_{BE_1})/V_T}$$

$$\ln\left[\frac{I_{C_2}}{I_{C_1}}\right] = \left[\frac{V_{BE_2} - V_{BE_1}}{V_T}\right]$$

$$V_T \ln\left[\frac{I_{C_2}}{I_{C_1}}\right] = V_{BE_2} - V_{BE_1}$$

$$\boxed{V_{BE_2} = V_{BE_1} + V_T \ln\left[\frac{I_{C_2}}{I_{C_1}}\right]}$$

* V_{BE_2} = voltage between base and emitter when the current flowing through the collector is 'I_{C_2}'

* V_{BE_1} = voltage between base & emitter when the current flowing through the collector is 'I_{C_1}'

Now, base is grounded ~~then~~ here so, voltage at base $\boxed{V_B = 0}$

$$V_{BE} = V_B - V_E$$

$$V_{BE} = 0 - V_E$$

$\boxed{V_{BE} = -V_E}$ (for both the cases, either I_{C_1} or I_{C_2})

$$V_{BE_2} = -V_{E_2}$$

$$\boxed{V_{E_2} = -0.717V}$$

* [illegible]

$$\boxed{\alpha = \frac{\beta}{\beta+1}} = \frac{100}{101} = \boxed{\alpha = 0.99}$$

The ~~…~~, collector ~~…~~ current is given as

$$I_c = \alpha I_E$$

$$I_{c_2} = 0.99 I_{E_2}$$

$$I_{E_2} = \frac{2\ mA}{0.99} \qquad \boxed{I_{E_2} = 2.02\ mA}$$

The current through the emitter can be determined as

$$I_{E_2} = \frac{V_{E_2} - (-15)}{R_E}$$

$$R_E = \frac{V_{E_2} - (-15)}{I_{E_2}}$$

$$R_E = \frac{-0.717 + 15}{2.02}$$

$$\boxed{R_E = 7.07\ k\Omega}$$

Ex. 2 In the circuit shown in fig. 2, the voltage at the emitter was measured and found to be −0.7 V. If $\beta = 50$, find I_E, I_B, I_c and V_c.

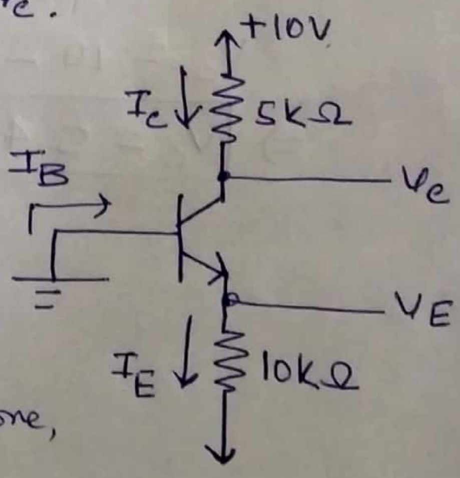


fig.2

Given $\beta = 50$

$V_E = -0.7V$

as base is grounded, $V_B = 0$

To find I_E, I_B, I_c & V_c.

Solution:– As Base is grounded, therefore,

$V_B = 0$,

and we can find the … 3,

current I_c, …

$$\boxed{I_c = \alpha I_E}$$

$$\alpha = \frac{\beta}{\beta+1}, \quad \frac{50}{51} = \boxed{0.98 = \alpha}$$

→ ~~To find~~ Emitter current I_E can be determind as

$$I_E = \frac{V_E - (-10)}{R_E} = \frac{-0.7+10}{10} = 0.93mA$$

$$\boxed{I_E = 0.93mA}$$

$$\therefore \quad I_c = \alpha I_E = 0.98 \times 0.93 = 0.9114 mA$$

$$\boxed{I_c = 0.9114mA}$$

As we know that,

$$I_E = I_c + I_B$$

$$I_B = I_E - I_c \Rightarrow 0.93 - 0.9114 = 0.0186 mA$$

$$\boxed{I_B = 18.6 \mu A}$$

Similarily,

$$I_c = \frac{10 - V_c}{R_c}, \quad I_c R_c = 10 - V_c$$

$$\Rightarrow V_c = 10 - I_c R_c \Rightarrow 10 - (0.9114^{mA} \times 5k\Omega)$$

$$V_c = 10 - 4.557$$

$$\Rightarrow \boxed{V_c = 5.44V}$$

Ex 3 Analyze the circuit shown in fig. 3. Determine all the node voltages and branch current. Assume $\beta = 100$.

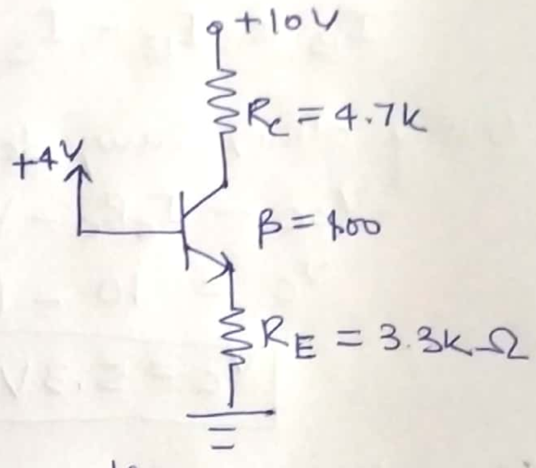
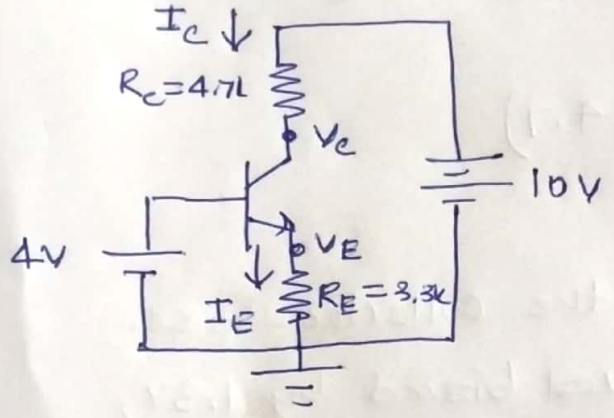


fig.3.

Solution fig. 3 can be redrawn as



Let us assume that the transistor is in active mode

$\therefore\ V_{BE} = 0.7V$

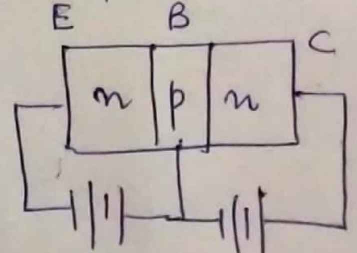
$V_{BE} = V_B - V_E$

$0.7 = 4 - V_E$, $\boxed{V_E = 3.3V}$

We know the voltages at the two end of the resistor R_E, therefore it is easy to find current I_E

$$I_E = \frac{V_E - 0}{R_E} \Rightarrow \frac{3.3}{3.3k} = \boxed{1mA = I_E}$$

Since the collector is ~~colle~~ connected through R_C to the +10V supply, it appears ~~that~~ possible that the collector voltage will be higher than the base voltage, which essential for active mode operation. Assuming this is the case, we can evaluate the collector current,



$$I_C = \alpha I_E$$

The value of α can be obtained as

$$\alpha = \frac{\beta}{1+\beta} = \frac{100}{101} \simeq \boxed{0.99 = \alpha}$$

$I_c = 0.99 \times 1 = \boxed{0.99mA = I_c}$

as $I_E = I_c + I_B$

$I_B = I_E - I_c = 1 - 0.99 \Rightarrow \boxed{0.01mA = I_B}$

Using ohm's law, determine the voltage V_c

$V_{cc} - I_c R_c - V_c = 0$

$V_c = 10 - (0.99 \times 4.7)$

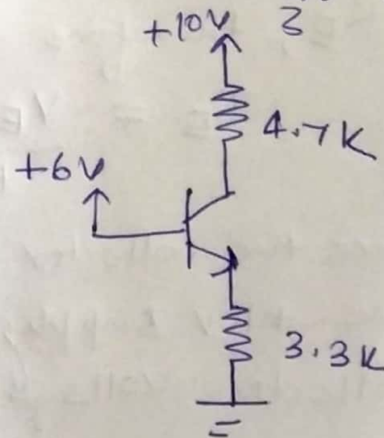
$\boxed{V_c = 5.3V}$

Since the base is at +4V, the collector-base junction is Reversed - ~~bised~~ biased by 1.34, and the transistor is indeed in the active mode as assumed.

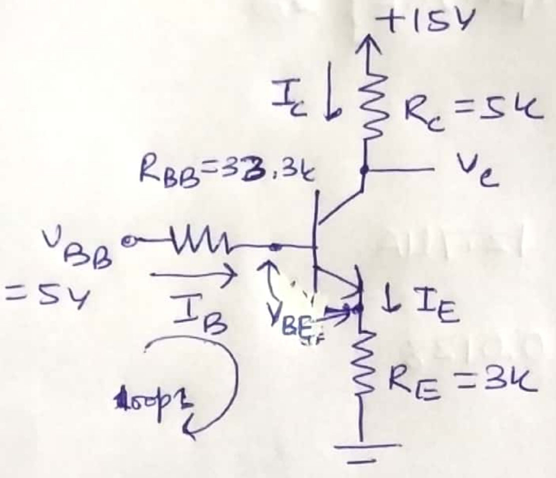
$V_B - V_c \Rightarrow 4 - 5.3$

$\Rightarrow -1.3V$

Ex 4 For the fig. shown ~~is~~ below, determine the voltages at all node and current the current through all branches.



Ex.5 For the circuit shown in fig 5. Determine the voltages at all nodes and the current through all branches. Assume $\beta = 100$.



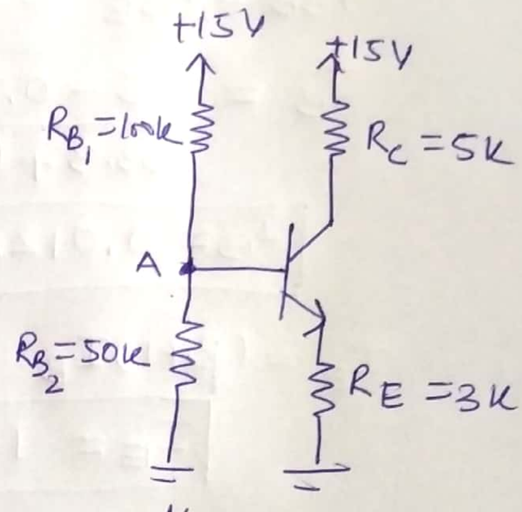


fig '5'

→ using voltage divider/ Thevenin's theorem we can find the voltage at node 1. and redraw circuit shown in fig 5'

$$V_{BB} = 15 \times \frac{R_{B_2}}{R_{B_1} + R_{B_2}} = \frac{15 \times 50}{50 + 100}$$

$$\boxed{V_{BB} = +5V}$$

$$R_{BB} = (R_{B_1} // R_{B_2}) = \left[\frac{100 \times 50}{100 + 50}\right] = \boxed{33.33k\Omega}$$

Apply KVL in loop 1

$$V_{BB} - I_B R_{BB} - V_{BE} - I_E R_E = 0 \quad -(1)$$

as we know that $I_E = I_c + I_B$

$$I_E = \beta I_B + I_B$$

$$I_E = (\beta + 1) I_B \quad -(2)$$

from eqn (2) put the value of I_E in eqn (1)

$$V_{BB} - I_B R_{BB} - V_{BE} - (\beta+1) I_B R_E = 0$$

$\cancel{I_B} (R_B +$

$$V_{BB} - V_{BE} = I_B [R_{BB} + (\beta+1) R_E]$$

$$I_B = \frac{5 - 0.7}{33.3 + (101 \times 3)}$$

$$\boxed{I_B = 0.0128 mA} = 12.7 \mu A$$

$$\therefore \quad I_E = (\beta+1) I_B = 101 \times 0.0128$$

$$\boxed{I_E = 1.29 mA}$$

as $\quad I_E = I_C + I_B$

$$I_E = I_E - I_B \Rightarrow 1.29 - 0.0128$$

$$\boxed{I_C = 1.28 mA}$$

To find the V_B,

$$I_B = \frac{V_{BB} - V_B}{R_{BB}}, \quad V_B = V_{BB} - I_B R_{BB}$$

$$V_B = 5 - [0.128 \times 33.3]$$

$$V_B = 5 - 0.426$$

$$\boxed{V_B = 4.57 V}$$

similarly, we can find V_C and V_E

$$I_E = \frac{V_E - 0}{R_E}, \quad V_E = I_E R_E = 1.29 \times 3$$

$$\boxed{V_E = 3.87 V}$$

$$I_C = \frac{V_{CC} - V_C}{R_E}, \quad V_C = V_{CC} - I_C R_E$$

$$V_C = 15 - (1.28 \times 5)$$

$$\boxed{V_C = 8.6 V}$$

$V_B - V_C$
$\Rightarrow 4.57 - 8.6$
$\Rightarrow -4.03 V$

Thus, the collector is at higher potential by base by 4.03 V which means transistor is in active mode. as assumed.