Module 2

Unit 2

TRANSISTOR (BJT)

Review Questions

1 Define current gains α and β. How are they related?
2 In transistor design, the base has most critical features as compared to emitter and collector. Discuss.
3 Why do we bias a transistor? What are the considerations in choosing an appropriate biasing scheme?
4 Draw I - V characteristics (Collector characteristics) for a transistor and discuss the salient features.
5 Explain ‘base width modulation’ and its influence on transistor characteristics.
6 What is collector feedback bias? How does this biasing provide stability to the circuit?
7 Give reasons for the wide use of ‘voltage divider bias’ in BJT amplifiers.
8 Discuss the flow of three currents I_E, I_B and I_C in a forward biased emitter junction and reverse biased collectior junction.

Problems

2.1 A transistor has current gain of 0.99 when used in common base (CB) configuration. How much will be the current gain of this transistor in common emitter (CE) configuration ?

Solution :- The current gain in common base circuit is written as α, and it has been given equal to 0.99.

α and current gain in common emitter configuration β are related as

$$\beta = \frac{\alpha}{1-\alpha}$$

Therefore,

$$\beta = \frac{0.99}{1-0.99} = 99$$

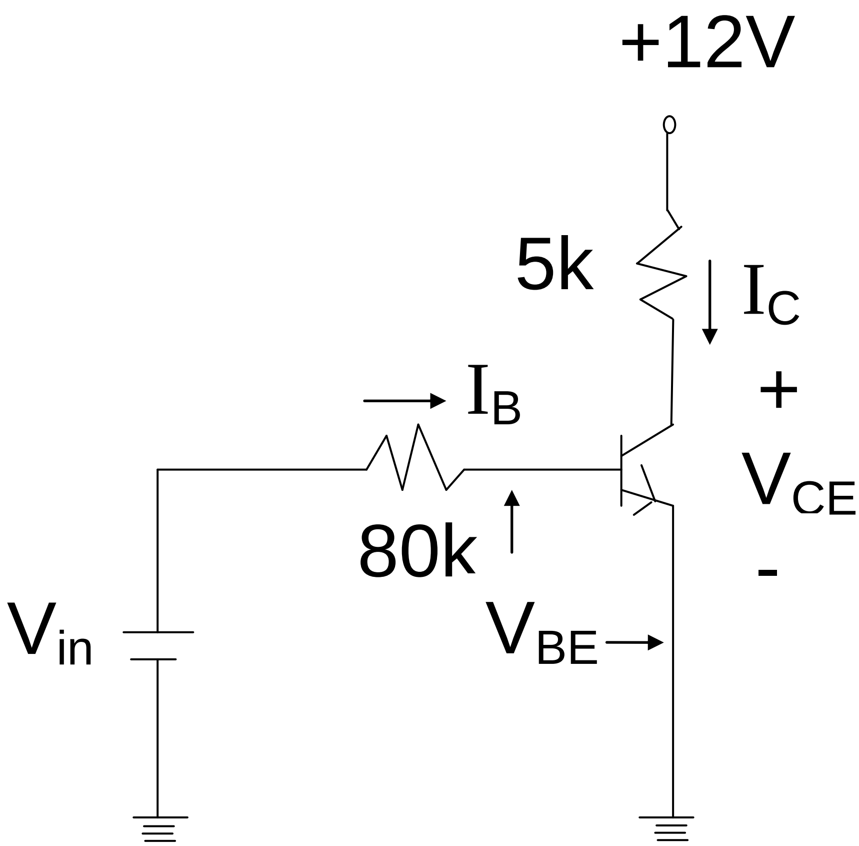
or β = 99

2.2 Determine the minimum value of current gain β required to put the transistor in saturation when

V_{in} = +5V.

Assume, $V_{BE(sat)}$ = 0.8 V,

$V_{CE(sat)}$ = 0.12 V



Solution:- Let I_B and I_C be base current and collector current respectively (see fig. above).

Taking +5V as input voltage V_{in}, the summation of voltages (Kirchhoff's voltage law, KVL) in the base-emitter loop gives

$8 \times 10^3 \times I_B + V_{BE} - 5V = 0$

We assume that the transistor is in saturation, so that

$V_{BE} = V_{BE(Sat)} = 0.8\ V$

Therefore ,

$80 \times 10^3 \times I_B + 0.8\ V - 5V = 0$

or , $$I_B = \frac{4.2V}{80 \times 10^3} = 0.0525mA$$

Summation of voltages in the collector loop gives,

$5 \times 10^3 \times I_C + V_{CE} = 12\ V$

or $$I_C = \frac{12 - 0.2}{5 \times 10^3} = 2.36mA$$

And the condition for the transistor in saturation is that the minimum value of gain β ,

$$\beta_{\min} = {I_C}/{I_B} = \frac{2.36mA}{0.525mA} \approx 45,$$

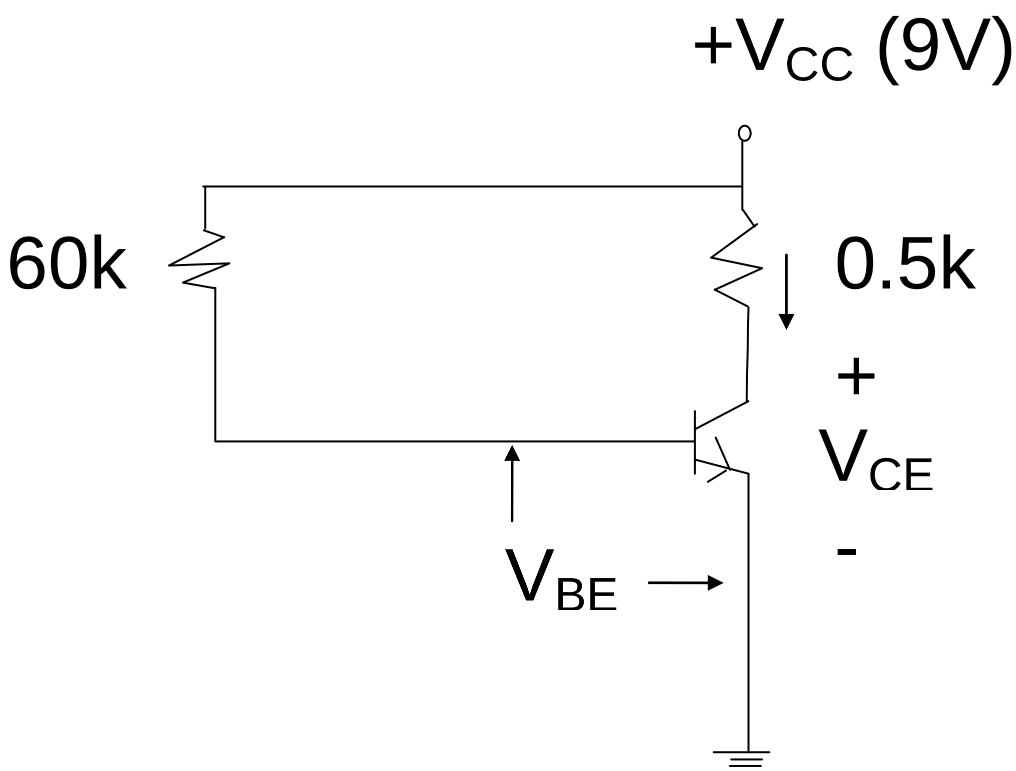
or $\beta_{min} = 45$.

2.3 The fixed bias circuit shown in figure uses a silicon transistor with V_{BE} = 0.7V.

(a) Find the collector current, I_C, and voltage V_{CE}, if β of transistor is 60.

(b) Find I_C and V_{CE} if β changes to 80.

What conclusions may be drawn?



Solution:-

(a) Summation of voltages in base-emitter loop results in

$V_{CC} = R_B I_B + V_{BE}$

or $I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{9 - 0.7}{60 \times 10^3} = 0.138\,mA$

and,

$I_C = \beta I_B$

$= 60 \times 0.138$ mA

$I_C = 8.28$ mA

Summation of voltages in the collector circuit gives,

$R_C I_C + V_{CE} = V_{CC}$

Or $V_{CE} = V_{CC} - I_C R_C$

$= 9 - 8.28 \times 10^{-3} \times 0.5 \times 10^3$

$= 9 - 4.14$

Or $V_{CE} = 4.86$ V

Thus the operating point values are

$I_C = 8.28$ mA , and

$V_{CE} = 4.86$ V

(b) Proceeding in the same way, and if the current gain β equals 80, then

Since $I_B = 0.138$ mA, therefore

$I_C = \beta I_B = 80 \times 0.138$ mA

or $I_C = 12.42$ mA

And $V_{CE} = V_{CC} - I_C R_C$

$= 9 – 12.42 \times 10^{-3} \times 0.5 \times 10^{3}$

$= 9 – 6.21$

$V_{CE} = 2.79$ V

With β = 80, the operating point values are :

I_C = 12,42 mA, and

V_{CE} = 2.79 V

CONCLUSIONS:-

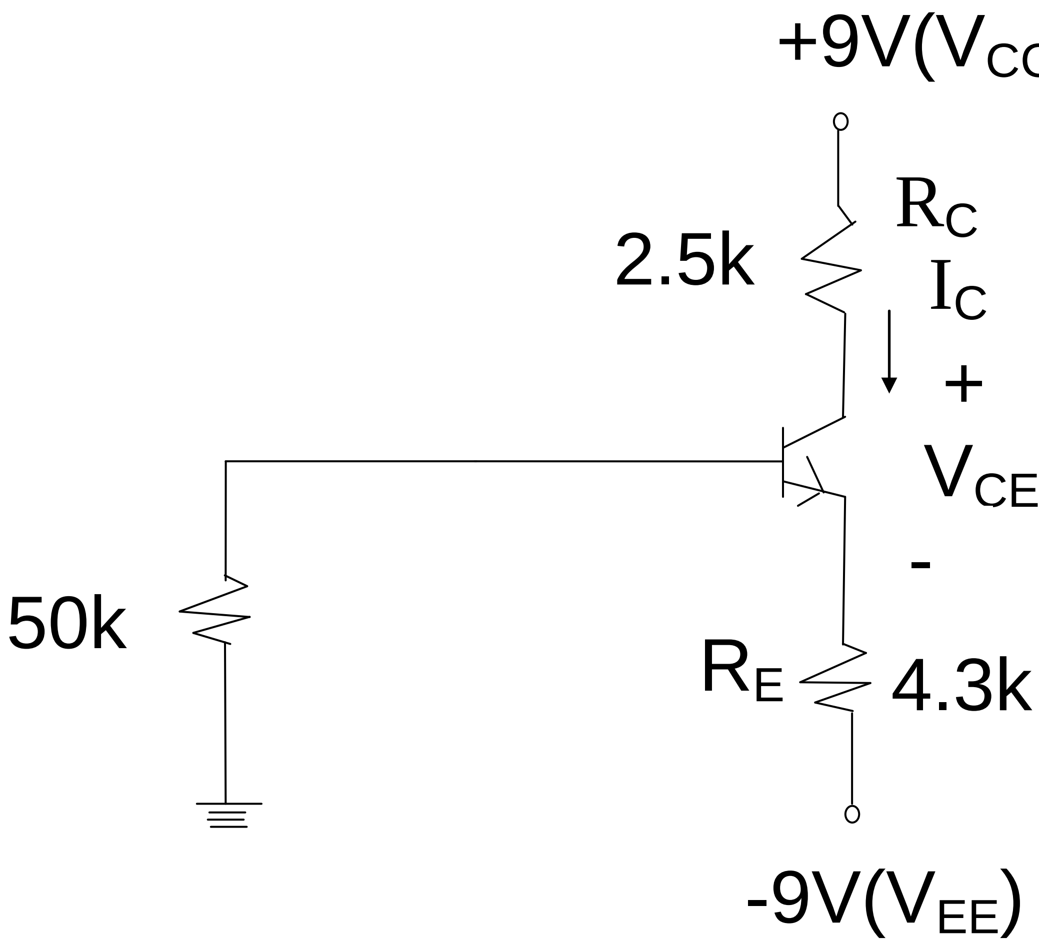
Changes in collector current I_C when β changes from 60 to 80 are from 8.28 mA to 12.42 mA.

And V_{CE} changes from 4.86V to 2.79V.

These changes are drastic and operation may shift to regions to give distorted output.

2.4 Find out the operating point current I_{CQ}, and voltage V_{CEQ} in the circuit shown.

(V_{BE} = 0.7 V, β of transistor is 200).



Solution:-

Considering the potential difference across the resistor R_E, the emitter current I_E ($\approx I_C$) may be written as,

$$I_E \approx I_C = \frac{V_{EE} - V_{BE}}{R_E} = \frac{9 - 0.7}{4.3 \times 10^3}$$

or $I_C = I_{CQ} = 1.93$ mA

Voltage summation in the collector circuit leads to,

$V_{CC} = R_C I_C + V_{CE}$

or $V_{CE} = V_{CC} - R_C I_C$

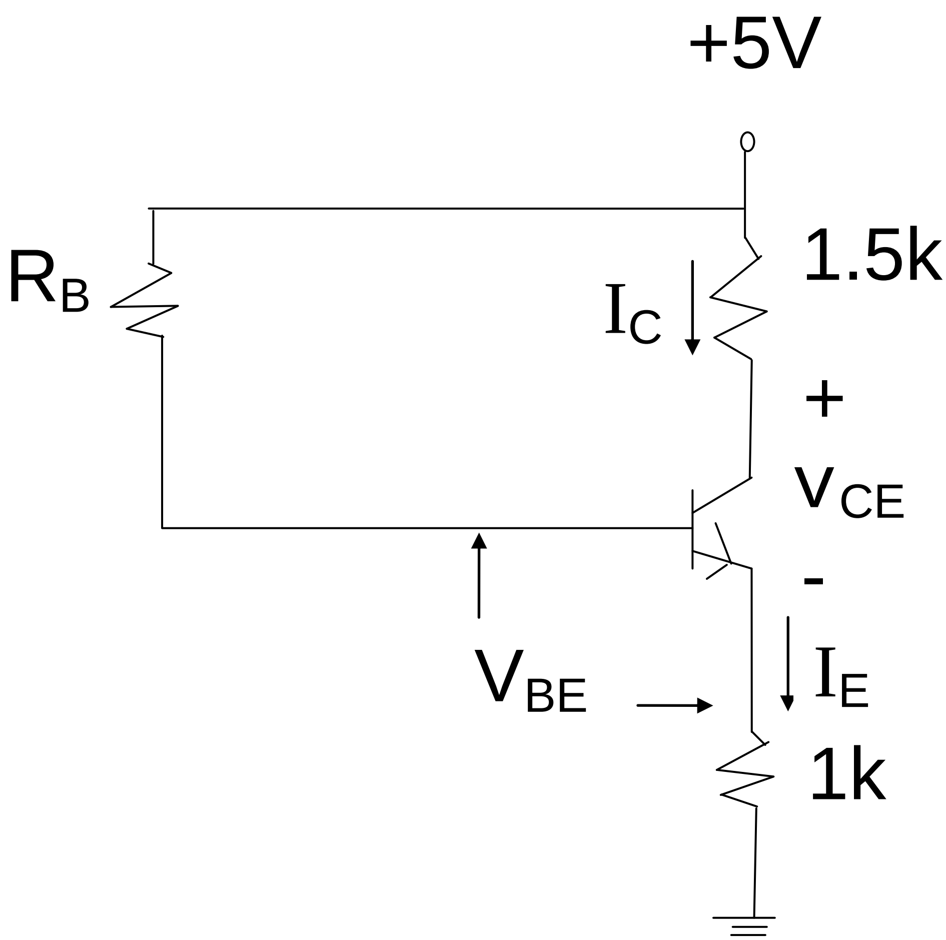
$= 9 - 2.5 \times 10^3 \times 1.93 \times 10^{-3}$

$= 9 - 4.83$

or $V_{CE} = V_{CEQ} = 4.17$V

2.5 Calculate the approximate value for the base resistor R_B which will forward bias the emitter junction of silicon transistor (β = 100) in the circuit. Collectior – emitter voltage V_{CE} of 2.5 V reverse biases the collector.

(V_{BE} = 0.7V)



Solution:-

We assume that the emitter junction is in forward bias and V_{BE} = 0.7V.

Summation of voltages in the base-emitter circuit results in,

$R_B I_B + V_{BE} + R_E I_E = V_{CC}$

Since $I_C = I_E$,

and $\beta I_B \ or \ I_B = \frac{I_C}{\beta} = \frac{I_E}{\beta}$

Then above equation yields,

$$R_B . \frac{I_E}{\beta} + V_{BE} + R_E I_E = V_{CC}$$

$$or\ I_E \left(\frac{R_B}{\beta} + R_E \right) = V_{CC} - V_{BE} = 5.0 - 0.7$$

$$or\ I_E \left(\frac{R_B}{\beta} + R_E \right) = 4.3 \qquad ------------- (A)$$

Now, summation of voltages in the collector – emitter circuit gives,

$R_C I_C + V_{CE} + R_E I_E = V_{CC}$

Because $I_C = I_E$

And substituting for other parameters

$I_E(R_C + R_E) = V_{CC} - V_{CE}$ = 5.0 – 2.5 = 2.5

$$or\ I_E = \frac{2.5}{(R_C + R_E)} = \frac{2.5}{(1.5 + 1) \times 10^3} = 1mA$$

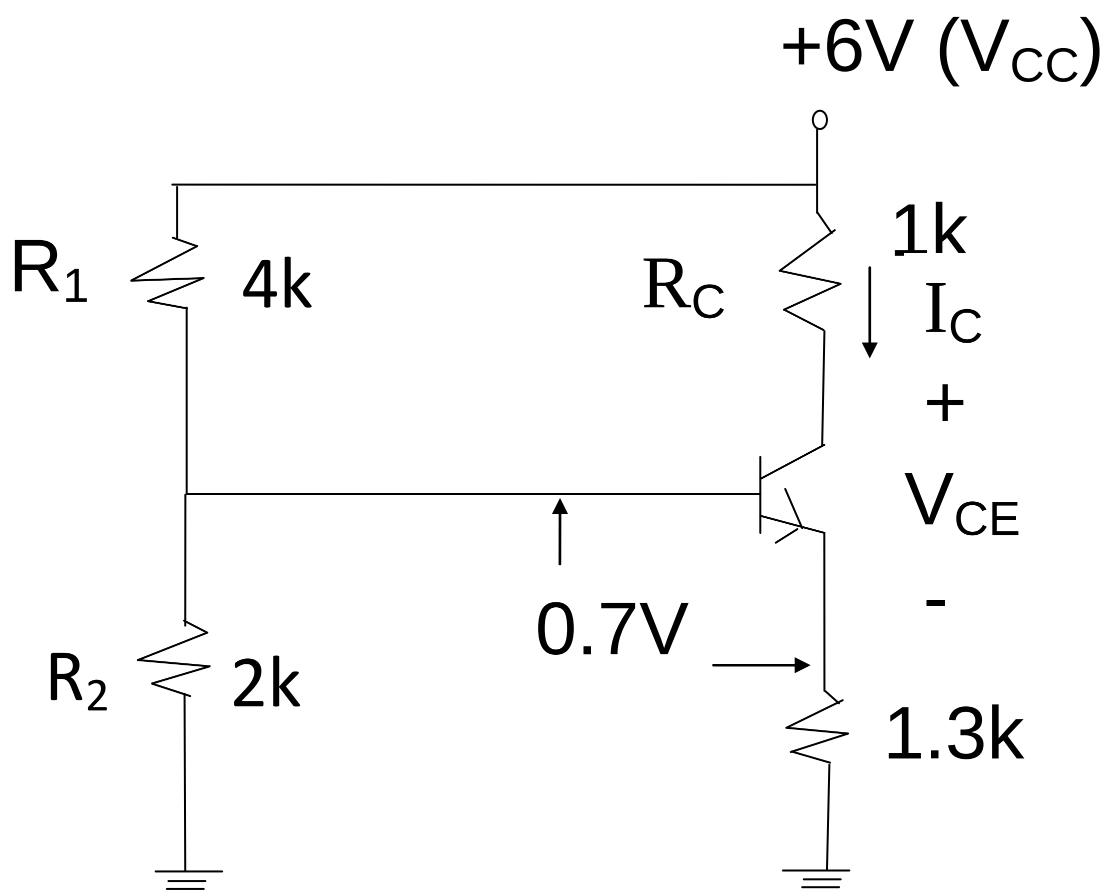
Substituting I_E = 1mA in eq^n (A)

$$1 \times 10^{-3} \left(\frac{R_B}{100} + 1 \times 10^3 \right) = 4.3$$

R_B = 330 X 103Ω

or R_B = 330 kΩ

2.6 The operating point values of current $I_C(=I_{CQ})$ and voltage $V_{CE}(=V_{CEQ})$ in the circuit have magnitudes of 0.9 mA and 3.72 V respectively when the current gain β for the transistor is 100. The transistor in the circuit is replaced by another one with β = 200. Calculate the new values of I_{CQ} and V_{CEQ}. What do you infer?



Solution:-

Thevenized voltage V_{th} across R_2 is

$$V_{TH} = \frac{2\times10^3}{2\times10^3+4\times10^3}\times V_{CC}$$
$$= \frac{2}{6}\times 6$$
$$= 2V$$

That is V_{TH} = 2V

And, as we have derived the relation earlier,

$$I_E = I_{CQ} = \frac{V_{TH} - V_{BE}}{R_E + R_{TH}/\beta}$$

Where Thevenized resistance R_{TH} is

$R_{TH} = R_1 || R_2$ = 4k || 2k = 1.33 kΩ,

Then with β= 200,

$$I_E = I_C = I_{cQ} = \frac{2-0.7}{1.3\times10^3+0.006\times10^3}$$
$$or\ I_{CQ} = 0.995\,mA$$

Further, summation of voltage in the collector circuit under the condition

$I_C = I_E$ leads to,

$V_{CC} = I_C (R_C + R_E) + V_{CE}$

Or, $V_{CE} = V_{CEQ} = V_{CC} - I_C (R_C + R_E)$

= 6V – 0.995 mA (1k + 1.3k)

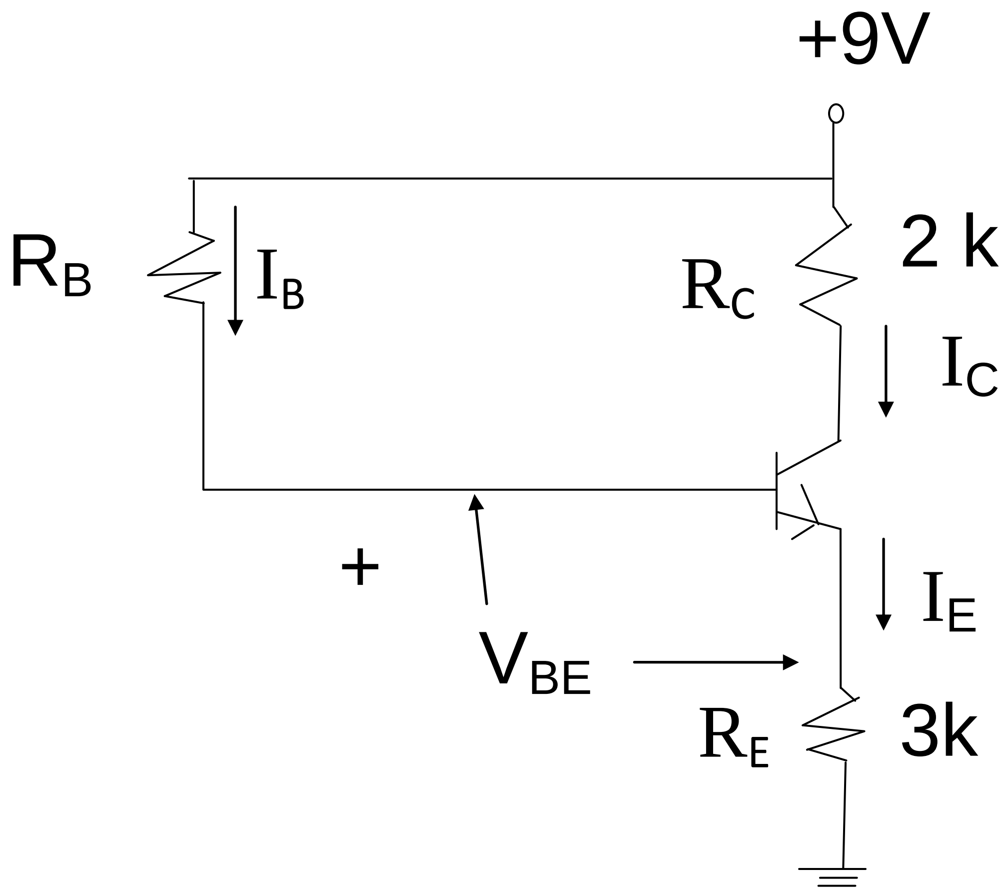
Or V_{CEQ} = 3.71V

Inference:

The circuit is highly stable as the change in collector current is 0.995 – 0.99 = 0.005 mA only (change is ≈0.5%) which is negligible. Similarly V_{CE} changes only 0.3% which is also negligible when β changes by 100% i.e from 100 to 200.

(2.7) Calculate the value of resistor R_B in the circuit shown to put V_{CE} at 3.0V

(V_{BE} = 0.7V and β = 80)



Solution:-

Summation of voltages in the base-emitter circuit gives,

$R_B I_B + V_{BE} + R_E I_E = V_{CC}$

Now, $V_{BE} = 0.7$ V, and $I_C = I_E$.

Also, $I_B = \frac{I_C}{\beta} = \frac{I_C}{80}$

Substituting these in above equation, and taking resistances in kΩ,

$$R_B \cdot \frac{I_C}{80} + 3k \times I_C = V_{CC} - V_{BE}$$
$$= 9 - 0.7 = 8.3$$
$$or\ \ R_B \cdot \frac{I_C}{80} + 3k \,.\, I_C = 8.3 \ \ ------------(A)$$

Summation of voltages in the collector circuit results in,

$I_C R_C + V_{CE} + I_E$ X 3k = 9V

or I_C X 2k + 3.0V + I_C X 3k = 9V

or I_C (2k +3k) = 9 - 3 = 6V

$$or\ \ I_C = \frac{6V}{5k} = 1.2mA$$

Substituting the value of I_C in eqn (A)

$$R_B \cdot \frac{1.2}{80} + 3k \times 1.2\,mA = 8.3V$$
$$or\ \ R_B = \frac{4.7}{0.015\,mA} = 313.3k$$
$$R_B \approx 313k$$