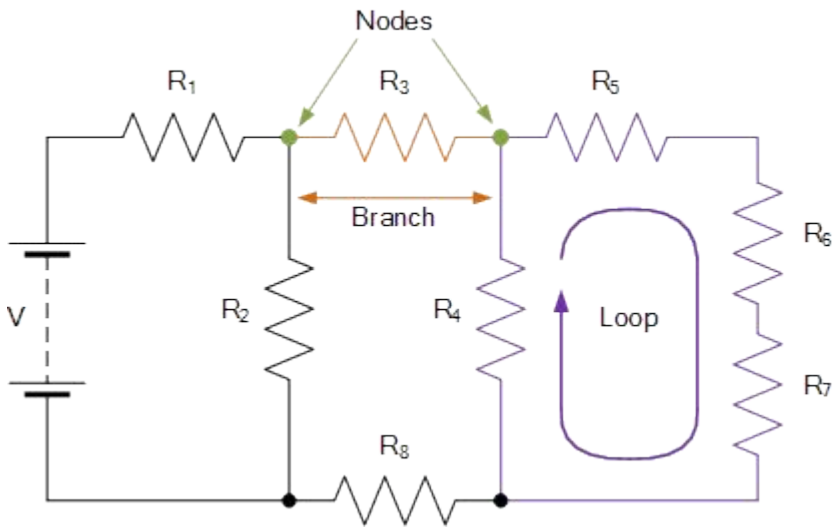
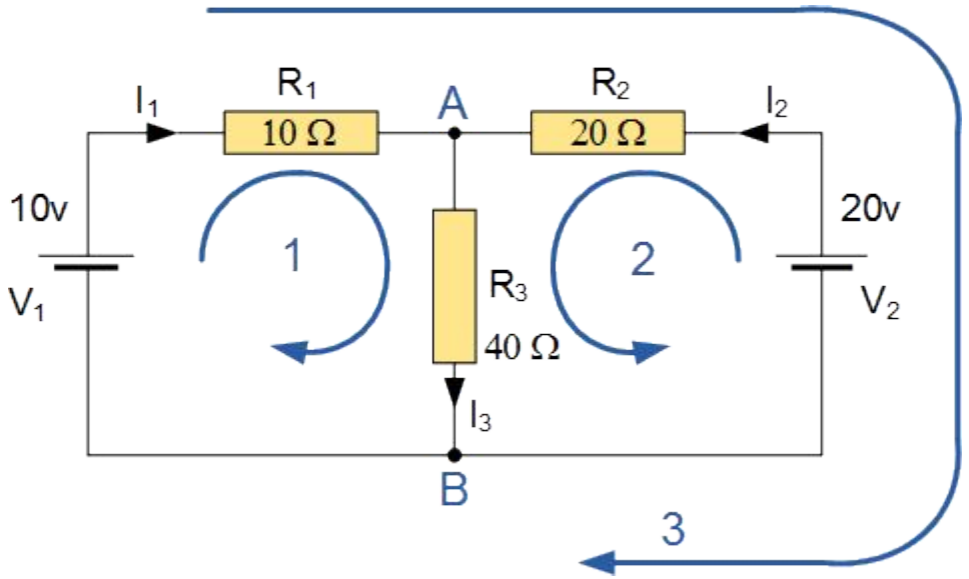




Using **Kirchhoffs Current Law**, **KCL** the equations are given as:

At node A : $I_1 + I_2 = I_3$

At node B : $I_3 = I_1 + I_2$

Using **Kirchhoffs Voltage Law**, **KVL** the equations are given as:

Loop 1 is given as : $10 = R_1 I_1 + R_3 I_3 = 10I_1 + 40I_3$

Loop 2 is given as : $20 = R_2 I_2 + R_3 I_3 = 20I_2 + 40I_3$

NPN

$I_E = I_S\,[\,e^{VBE/VT}\,]$

PNP

$I_E = I_S\,[\,e^{VEB/VT}\,]$

$I_C = \beta I_B$

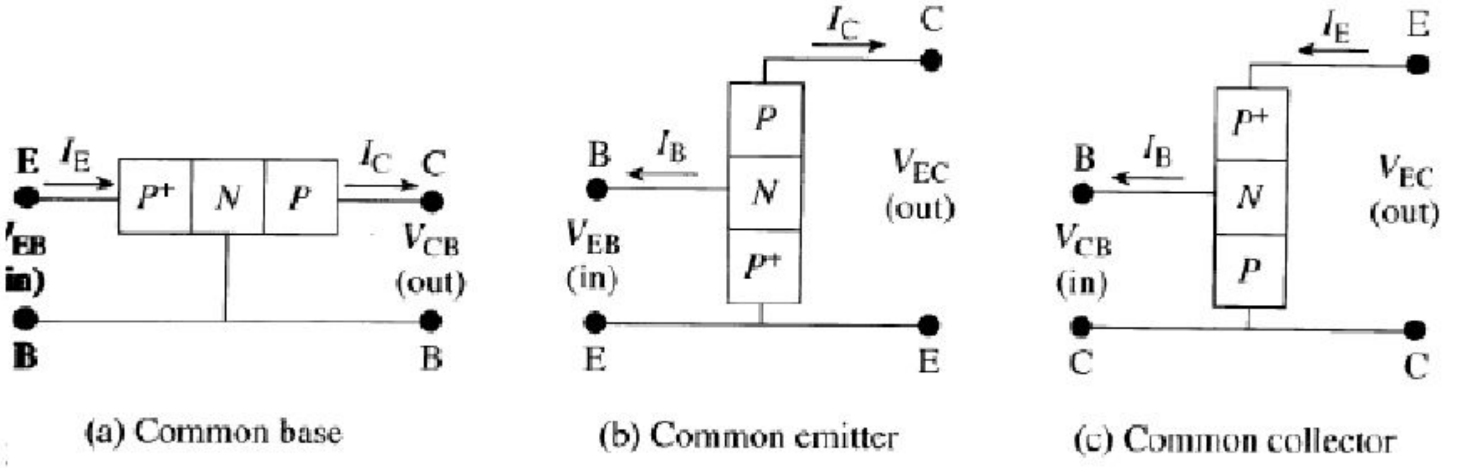
$I_C = \alpha I_E$

$I_E = I_B(\beta + 1)$

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

Based on KCL: $I_E = I_C + I_B$

BJT configurations



Common Base Configuration – has Voltage Gain but no Current Gain.

Common Emitter Configuration – has both Current and Voltage Gain.

Common Collector Configuration – has Current Gain but no Voltage Gain.

Alpha (α):

- It is a large signal current gain in common base configuration.
- It is the ratio of collector current (output current) to the emitter current (input current).

$$\alpha = \frac{I_C}{I_E}$$

- It indicates that the amount of emitter current reaching to collector.
- Its value is unity ideally and practically less than unity.

Beta (β):

- It is a current gain factor in the common emitter configuration. It is the ration of collector current (output current) to base current (output current).

$$\beta = \frac{I_C}{I_B}$$

- Normally Its value is greater than 100.

Gama (γ):

- It is a current gain in common collector configuration and it is the ration of emitter current (output current) to base current (input current).

$$\gamma = \frac{I_E}{I_B}$$

- It is also called emitter efficiency that how much current is injected from the emitter to base after recombination of minority charge carriers in base.
- It's value is high compared to α, β
- Relation between α, β and γ

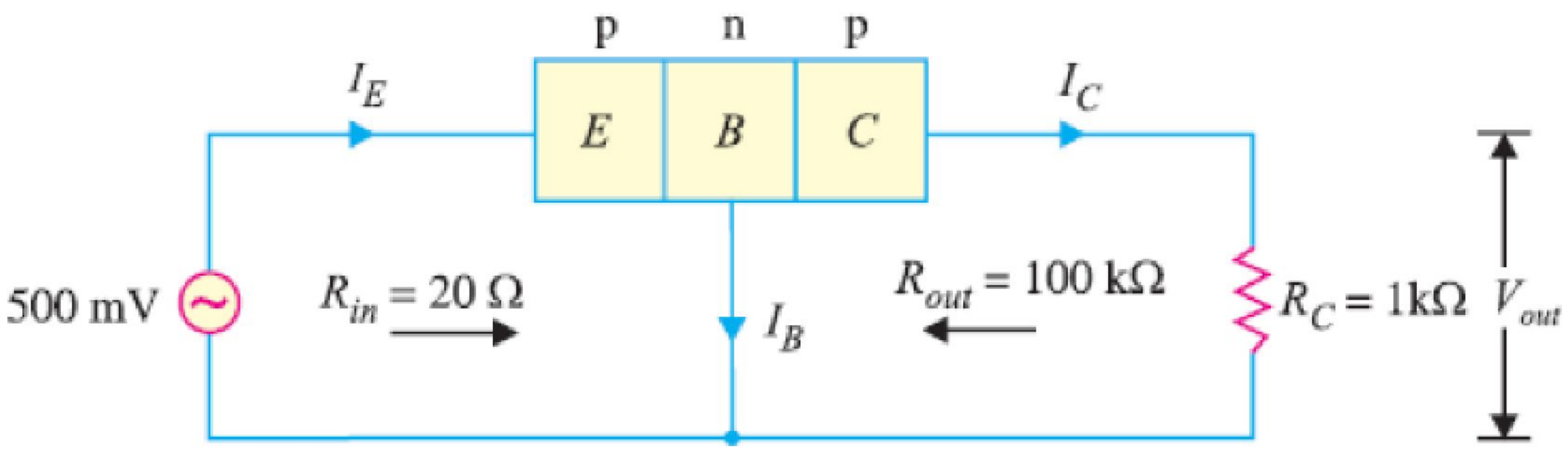
$$\gamma = \beta + 1 = \frac{1}{1-\alpha}$$

$$\alpha\,\gamma = \beta$$

1) A common base transistor amplifier has an input resistance of 20Ω and output resistance of 100 kΩ.The collector load is 1 kΩ. If a signal of 500 mV is applied between emitter and base, find the voltage amplification. Assume αac to be nearly one

Solution

Here the output resistance is very high as compared to input resistance, since the input junction (base to emitter) of the transistor is forward biased while the output junction (base to collector) is reverse biased.



Input current, $I_E = \dfrac{\text{Signal}}{R_{in}} = \dfrac{500 \text{ mV}}{20\ \Omega} = 25$ mA. Since α_{ac} is nearly 1, output current, $I_C = I_E =$ 25 mA.

$$\text{Output voltage, } V_{out} = I_C R_C = 25 \text{ mA} \times 1 \text{ k}\Omega = 25 \text{ V}$$

$$\therefore \qquad \text{Voltage amplification, } A_v = \frac{V_{out}}{\text{signal}} = \frac{25\,V}{500\,mV} = \mathbf{50}$$

2) In a common base connection , IE = 1mA, IC = 0.95mA. Calculate the value of IB
Solution :

Using the relation,
$$I_E = I_B + I_C$$
$$1 = I_B + 0.95$$
$$I_B = 1 - 0.95 = \mathbf{0.05\ mA}$$

3) In a common base connection, current amplification factor is 0.9. If the emitter current is 1mA, determine the value of base current.

Solution :

Here, $\alpha = 0.9, \quad I_E = 1\text{ mA}$

Now $$\alpha = \frac{I_C}{I_E}$$

or $$I_C = \alpha I_E = 0.9 \times 1 = 0.9\text{ mA}$$

Also $$I_E = I_B + I_C$$

$\therefore$ Base current, $I_B = I_E - I_C = 1 - 0.9 = \mathbf{0.1\ mA}$

4) In a common base connection, IC = 0.95 mA and IB = 0.05 mA. Find the value of α.

Solution :

$$\text{We know } I_E = I_B + I_C = 0.05 + 0.95 = 1 \text{ mA}$$

$$\therefore \quad \text{Current amplification factor, } \alpha = \frac{I_C}{I_E} = \frac{0.95}{1} = 0.95$$

5) In a common base connection, the emitter current is 1mA. If the emitter circuit is open, the collector current is 50 µA. Find the total collector current. Given that α = 0.92.

Solution :

$$\text{Here, } I_E = 1 \text{ mA}, \alpha = 0.92, \quad I_{CBO} = 50 \text{ µA}$$

$$\text{Total collector current, } I_C = \alpha I_E + I_{CBO} = 0.92 \times 1 + 50 \times 10^{-3}$$

$$= 0.92 + 0.05 = 0.97 \text{ mA}$$

Q6. In a common base connection, α = 0.95. The voltage drop across 2 kΩ resistance which is connected in the collector is 2V. Find the base current.

Solution :

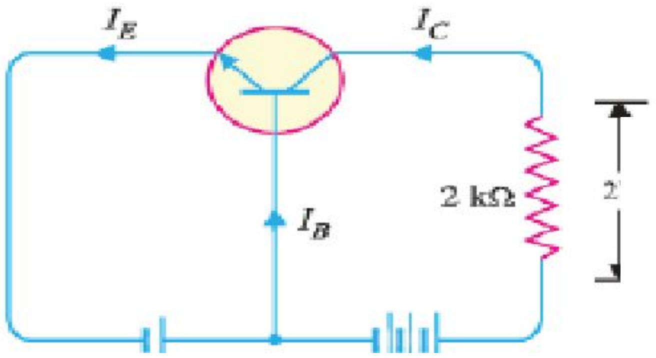


Fig. 2 shows the required common base connectio

The voltage drop across RC (= 2 kΩ) i...

$$I_C = 2\text{ V}/2\text{ k}\Omega = 1\text{ mA}$$

$$\alpha = I_C/I_E$$

$$\therefore \quad I_E = \frac{I_C}{\alpha} = \frac{1}{0.95} = 1.05\text{ mA}$$

Using the relation, $I_E = I_B + I_C$

$$\therefore \quad I_B = I_E - I_C = 1.05 - 1$$

$$= 0.05\text{ mA}$$

Q7. For the common base circuit shown in Fig. 3, determine IC and VCB . Assume the transistor to be of silicon.

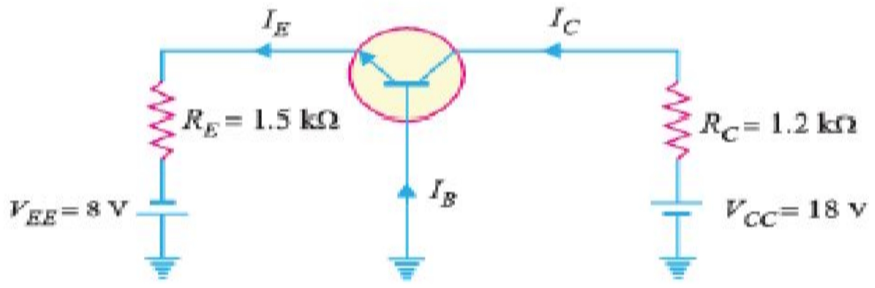


Fig. 3

Solution :

Since the transistor is of silicon, VBE = 0.7V.

Applying Kirchhoff's voltage law to the emitter-side loop,we get,

$$V_{EE} = I_E R_E + V_{BE}$$

$$\text{or} \quad I_E = \frac{V_{EE} - V_{BE}}{R_E}$$

$$= \frac{8V - 0.7V}{1.5\ \text{k}\Omega} = 4.87\ \text{mA}$$

$$\therefore \quad I_C \simeq I_E = 4.87\ \text{mA}$$

Applying Kirchhoff's voltage law to the collector-side loop, we have,

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

$$\therefore \quad V_{CB} = V_{CC} - I_C R_C$$

$$= 18\ \text{V} - 4.87\ \text{mA} \times 1.2\ \text{k}\Omega = 12.16\ \text{V}$$

Q8. Find the value of β if (i) $\alpha = 0.9$ (ii) $\alpha = 0.98$ (iii) $\alpha = 0.99$.

Solution :

(i) $\alpha = 0.9$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9}{1-0.9} = 9$$

(ii) $\alpha = 0.98$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = 49$$

(iii) $\alpha = 0.99$

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

Q9. Calculate IE in a transistor for which β = 50 and IB = 20 μA.

Solution :

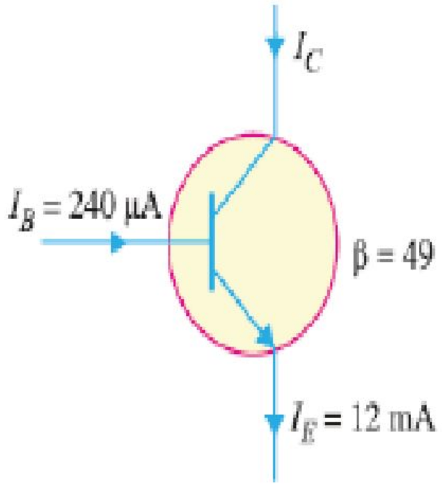
Here $\beta = 50, \quad I_B = 20\mu A = 0.02 \text{ mA}$

Now $\beta = \dfrac{I_C}{I_B}$

$\therefore \quad I_C = \beta I_B = 50 \times 0.02 = 1 \text{ mA}$

Using the relation, $I_E = I_B + I_C = 0.02 + 1 = 1.02 \text{ mA}$

Q10. Find the α rating of the transistor shown in Fig. 4. Hence determine the value of IC using both α and β rating of the transistor.



Solution :

$$\alpha = \frac{\beta}{1+\beta} = \frac{49}{1+49} = 0.98$$

The value of I_C can be found by using either α or β rating as under :

$$I_C = \alpha I_E = 0.98\ (12\ \text{mA}) = 11.76\ \text{mA}$$

Also $$I_C = \beta I_B = 49\ (240\ \mu\text{A}) = 11.76\ \text{mA}$$

Q11. For a transistor, β = 45 and voltage drop across 1kΩ which is connected in the collector circuit is 1 volt. Find the base current for common emitter connection.

Solution :

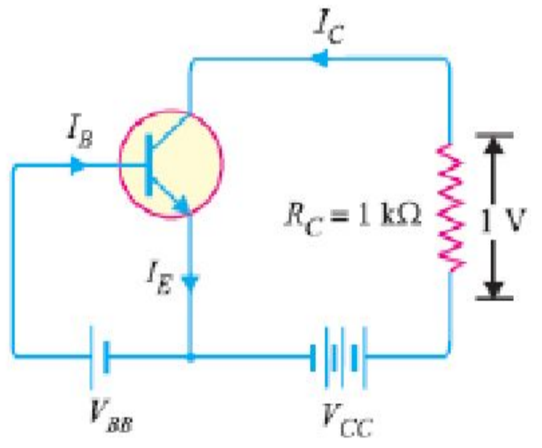


Fig. 5

Fig. 5 shows the required common emitter connection. The voltage drop across RC (= 1 kΩ) is 1 volt.

$\therefore$ $$I_C = \frac{1\,V}{1\,k\Omega} = 1\text{ mA}$$

Now $$\beta = \frac{I_C}{I_B}$$

$\therefore$ $$I_B = \frac{I_C}{\beta} = \frac{1}{45} = 0.022\text{ mA}$$

Q12. A transistor is connected in common emitter (CE) configuration in which collector supply is 8 V and the voltage drop across resistance RC connected in the collector circuit is 0.5 V. The value of RC = 800 Ω. If α= 0.96, determine : (i) collector-emitter voltage (ii) base current.

Solution:

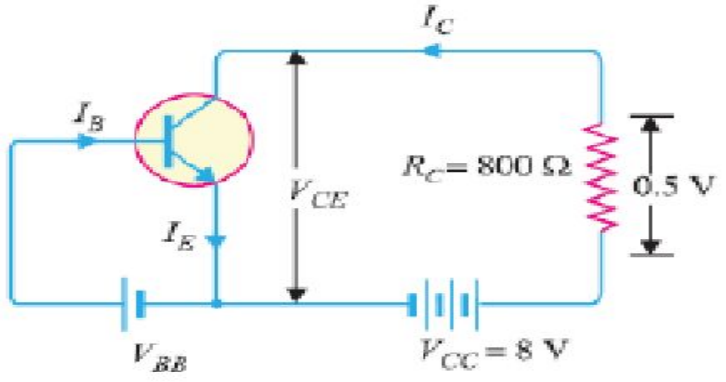


Fig.6

Fig. 6 shows the required common emitter connection with various values.

Collector-emitter voltage, (i)

$$V_{CE} = V_{CC} - 0.5 = 8 - 0.5 = 7.5\ \text{V}$$

(ii)

The voltage drop across R_C (= 800 Ω) is 0.5 V.

$$I_C = \frac{0.5\ \text{V}}{800\ \Omega} = \frac{5}{8}\ \text{mA} = 0.625\ \text{mA}$$

Now $$\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96} = 24$$

$\therefore$ Base current, $$I_B = \frac{I_C}{\beta} = \frac{0.625}{24} = 0.026\ \text{mA}$$

Q13 An n-p-n transistor at room temperature has its emitter disconnected. A voltage of 5 V is applied between collector and base. With collector positive, a current of 0.2 µA flows. When the base is disconnected and the same voltage is applied between collector and emitter, the current is found to be 20 µA. Findα, IE and IB when collector current is1 mA.

Solution :

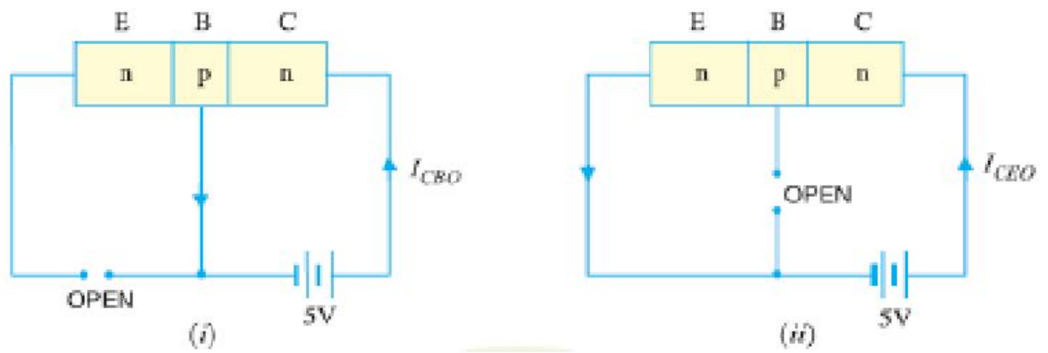


Fig. 7

When the emitter circuit is open as shown in Fig.7 (i) , the collector-base junction is reverse biased. A small leakage current ICBO flows due to minority carriers.

$\therefore \quad I_{CBO} = 0.2\ \mu A$ ...*given*

When base is open [See Fig. 8.23 (*ii*)], a small leakage current I_{CEO} flows due to minority carriers.

$\therefore \quad I_{CEO} = 20\ \mu A$ . . . *given*

We know $\quad I_{CEO} = \dfrac{I_{CBO}}{1-\alpha}$

or $\quad 20 = \dfrac{0.2}{1-\alpha}$

$\therefore \quad \alpha = 0.99$

Now $\quad I_C = \alpha I_E + I_{CBO}$

Here $\quad I_C = 1\text{mA} = 1000\ \mu A\ ;\ \alpha = 0.99\ ;\ I_{CBO} = 0.2\ \mu A$

$\therefore \quad 1000 = 0.99 \times I_E + 0.2$

or $\quad I_E = \dfrac{1000 - 0.2}{0.99} = 1010\ \mu A$

and $\quad I_B = I_E - I_C = 1010 - 1000 = 10\ \mu A$

Q14) The collector leakage current in a transistor is 300 μA in CE arrangement. If now the transistor is connected in CB arrangement, what will be the leakage current? Given that β = 120.

Solution

$$I_{CEO} = 300\ \mu A$$

$$\beta = 120 \ ; \ \alpha = \frac{\beta}{\beta+1} = \frac{120}{120+1} = 0.992$$

Now, $$I_{CEO} = \frac{I_{CBO}}{1-\alpha}$$

$\therefore$ $$I_{CBO} = (1-\alpha)\, I_{CEO} = (1-0.992) \times 300 = 2.4\ \mu A$$

Note that leakage current in *CE* arrangement (*i.e.* I_{CEO}) is much more than in *CB* arrangement (*i.e.* I_{CBO}).

Q15. For a certain transistor, IB = 20 μA; IC = 2 mA and β = 80. Calculate ICBO.

Solution :

$$I_C = \beta I_B + I_{CEO}$$

or $$2 = 80 \times 0.02 + I_{CEO}$$

$\therefore$ $$I_{CEO} = 2 - 80 \times 0.02 = 0.4 \text{ mA}$$

Now $$\alpha = \frac{\beta}{\beta+1} = \frac{80}{80+1} = 0.988$$

$\therefore$ $$I_{CBO} = (1-\alpha)\, I_{CEO} = (1-0.988) \times 0.4 = 0.0048 \text{ mA}$$

ICBO is the collector current with collector junction reverse biased and base open-circuited. ICEO is the collector current with collector junction reverse biased and emitter open-circuited. ICBO is reverse leakage current going from the Collector to the Base. This current is then amplified by β to produce additional Collector current, thus the "1+β" term.

Q16. Using diagrams, explain the correctness of the relation ICEO = (β + 1)ICBO.

Solution :

The leakage current ICBO is the current that flows through the base-collector junction when emitter is open as shown is Fig. 8.

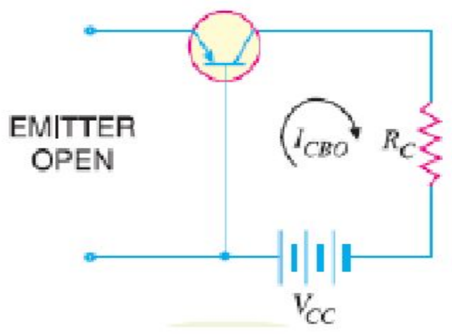


Fig. 8

When the transistor is in CE arrangement, the base current (i.e. ICBO) is multiplied by β in the collector as shown in Fig. 9.

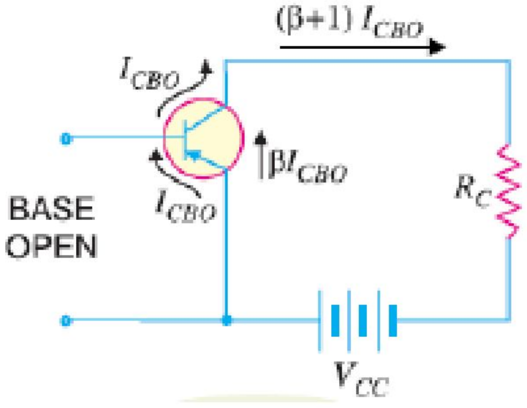


Fig.9

$$\therefore \quad I_{CEO} = I_{CBO} + \beta I_{CBO} = (\beta + 1)\ I_{CBO}$$

Q17. Determine VCB in the transistor circuit shown in Fig. 10 (i). The transistor is of silicon and has β = 150.

Solution :

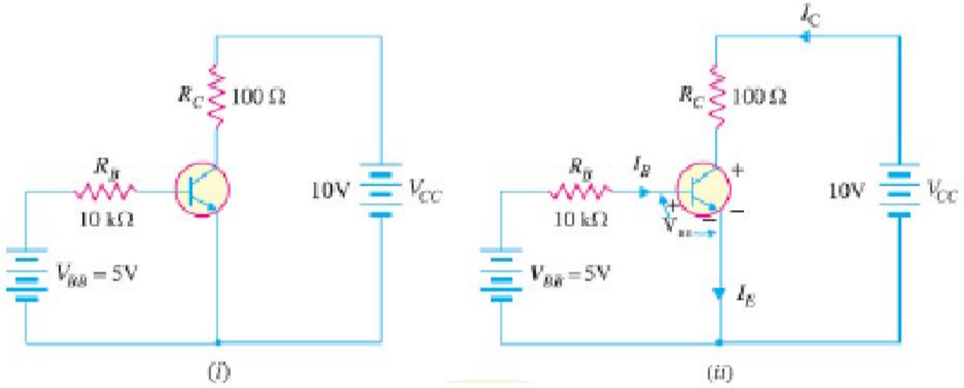


Fig.10

Solution :

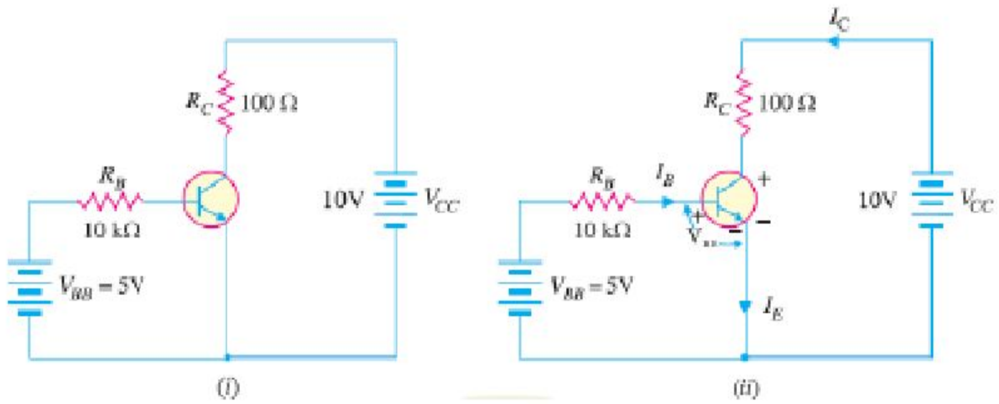


Fig.10

Fig. 10 (i) shows the transistor circuit while Fig. 10 (ii) shows the various currents and voltages along with polarities.

Applying Kirchhoff's voltage law to base-emitter loop, we have,

$$V_{BB} - I_B R_B - V_{BE} = 0$$

or $$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5V - 0.7V}{10\ k\Omega} = 430\ \mu A$$

∴ $$I_C = \beta I_B = (150)(430\ \mu A) = 64.5\ mA$$

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

$$= 10V - (64.5\ mA)\ (100\Omega) = 10V - 6.45V = 3.55V$$

We know that : $$V_{CE} = V_{CB} + V_{BE}$$

∴ $$V_{CB} = V_{CE} - V_{BE} = 3.55 - 0.7 = 2.85V$$

Q18. In a transistor, IB = 68 μA, IE = 30 mA and β = 440. Determine the α rating of the transistor. Then determine the value of IC using both the α rating and β rating of the transistor.

Solution :

$$\alpha = \frac{\beta}{\beta+1} = \frac{440}{440+1} = 0.9977$$

$$I_C = \alpha I_E = (0.9977)(30 \text{ mA}) = 29.93 \text{ mA}$$

Also $I_C = \beta I_B = (440)(68\ \mu\text{A}) = 29.93 \text{ mA}$

Q19. A transistor has the following ratings : IC (max) = 500 mA and βmax = 300. Determine the maximum allowable value of IB for the device.

Solution :

$$I_{B\,(max)} = \frac{I_{C\,(max)}}{\beta_{max}} = \frac{500 \text{ mA}}{300} = \mathbf{1.67 \text{ mA}}$$

For this transistor, if the base current is allowed to exceed 1.67 mA, the collector current will exceed its maximum rating of 500 mA and the transistor will probably be destroyed.

Q20. Fig. 11 shows the open circuit failures in a transistor. What will be the circuit behaviour in each case ?

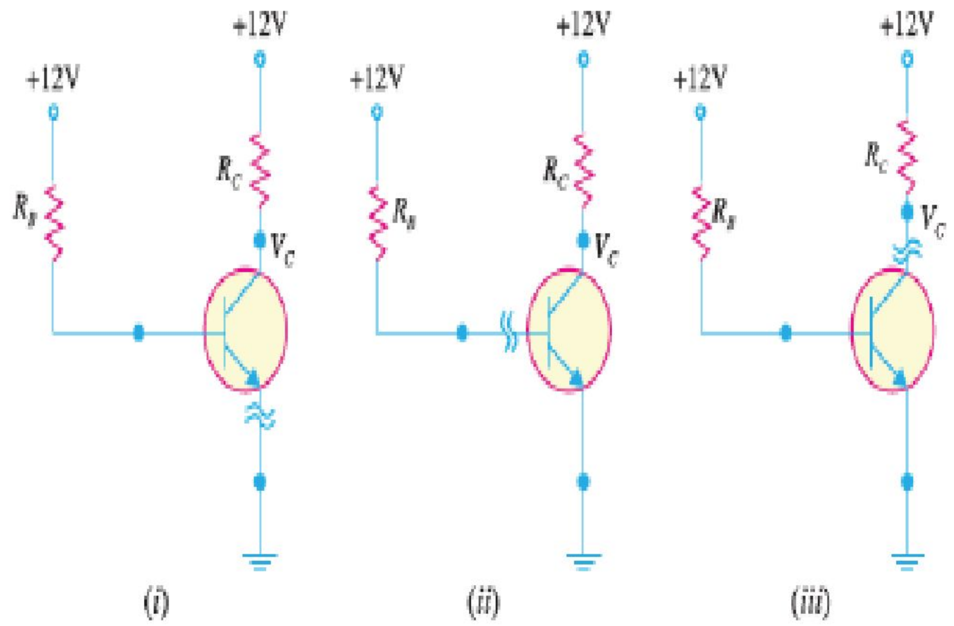


Fig. 11

(i) Open emitter :

Fig. 11 (i) shows an open emitter failure in a transistor. Since the collector diode is not forward biased, it is OFF and there can be neither collector current nor base current.
Therefore, there will be no voltage drops across either resistor and the voltage at the base and at the
collector leads of the transistor will be 12V.

(ii) Open-base :

Fig. 11 (ii) shows an open base failure in a transistor. Since the base is open, there can be no base current so that the transistor is in cut-off. Therefore, all the transistor currents are 0A. In this case, the base and collector voltages will both be at 12V.

(iii) Open collector :

Fig. 11 (iii) shows an open collector failure in a transistor. In this case, the emitter diode is still ON, so we expect to see 0.7V at the base. However, we will see 12V at the collector because there is no collector current.

Emitter-Bias Configuration (Solved Problem)

For the emitter-bias circuit, determine:

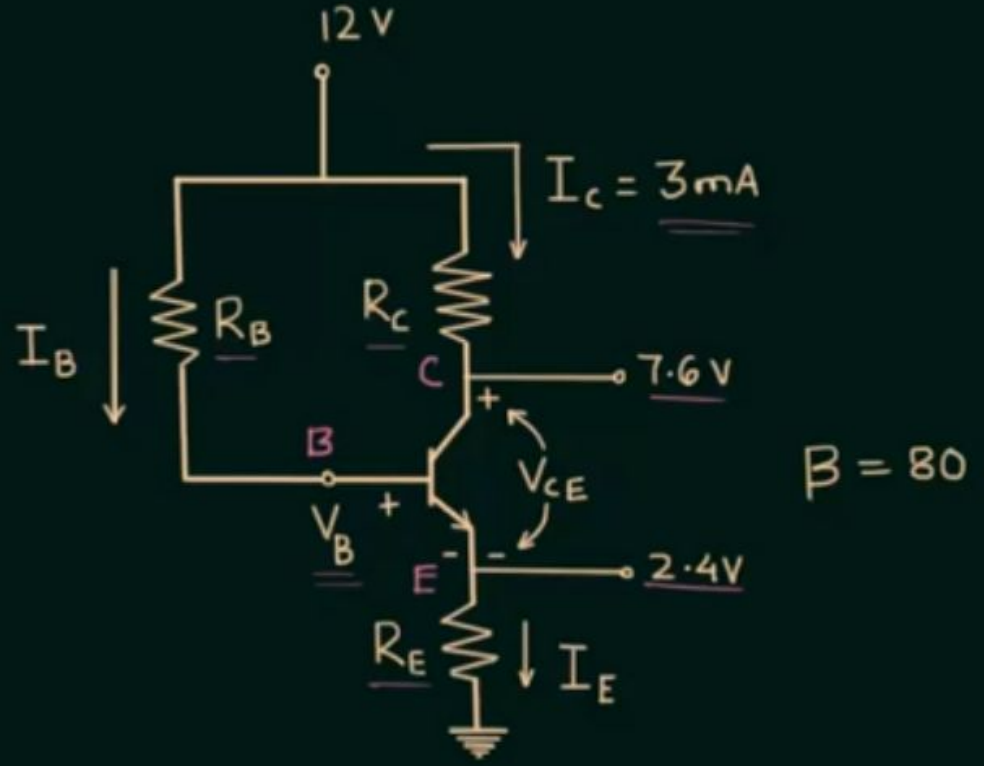
(a) R_C

(b) R_E

(c) R_B

(d) V_{CE} (o/p)

(e) V_B



$I_C = 3mA$ $\quad V_C = 7.6V$ $\quad V_{CC} = 12V$

$\beta = 80$ $\quad V_E = 2.4V$

Sol : e) $V_{BE} = 0.7V$ (Si)

$$V_B - V_E = 0.7V$$

$$V_B = 2.4V + 0.7V$$

$$V_B = 3.1V$$ Ans

d) $V_{CE} = V_C - V_E$

$$= 7.6V - 2.4V$$

$$V_{CE} = 5.2V$$ Ans

c) $+12V - I_B R_B = 3.1V$

$$I_B = I_C/\beta$$

$$= \frac{3mA}{80}$$

$$I_B = 37.5\mu A$$

$$R_B = \frac{12V - 3.1V}{37.5\mu A}$$

$$R_B = 237.4k\Omega$$

For the emitter-bias circuit, determine:

(a) R_C

(b) R_E

(c) R_B

(d) V_{CE} (o/p)

(e) V_B

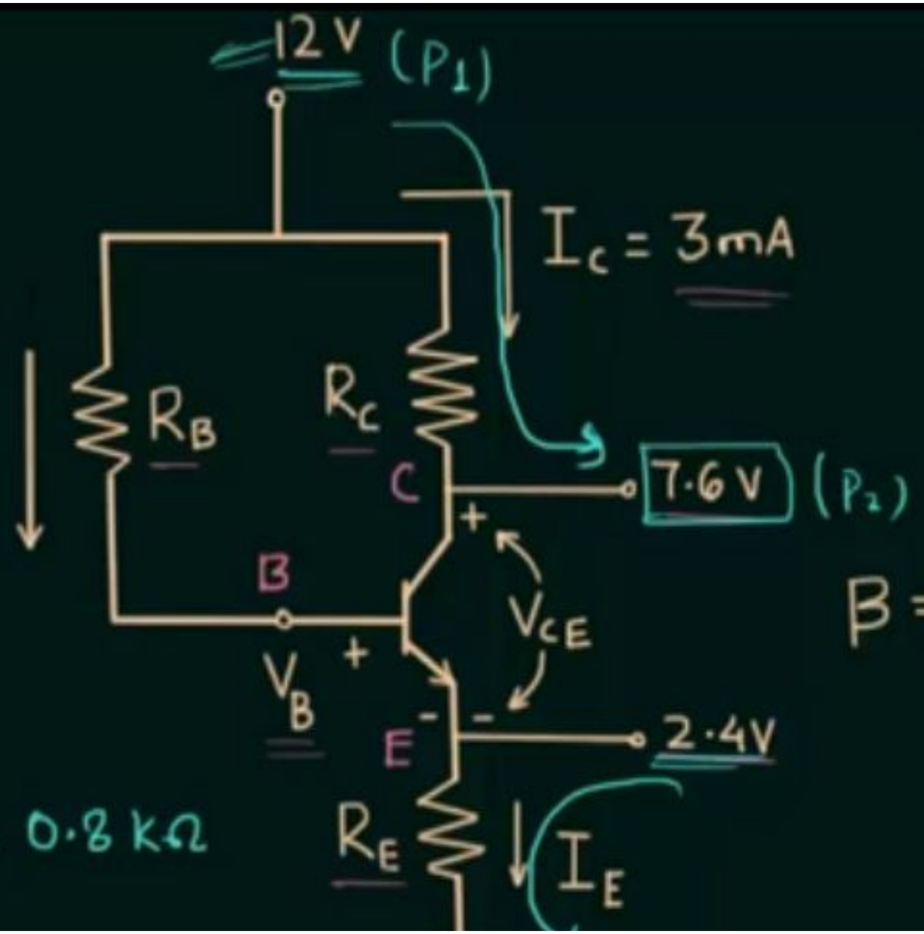
a) $12V - I_C R_C = 7.6V$

$R_C = \dfrac{12V - 7.6V}{3mA}$

$R_C = 1.47k\Omega$

b) $2.4V - \overset{I_C}{\cancel{I_E}} R_E = 0V$

$R_E = \dfrac{2.4V}{3mA} = 0.8k\Omega$



KVL

P.d.

$\beta = 80$