Q1. A common base transistor amplifier has an input resistance of 20 Ω 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 α_{ac} to be nearly one.

Solution :

Fig.1 shows the conditions of the problem. 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.

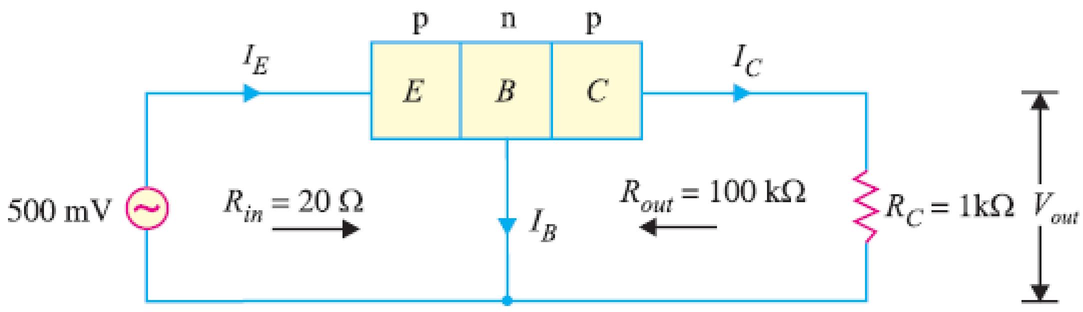

Fig. 1

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.

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

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

Q2. In a common base connection, I_E = 1mA, I_C = 0.95mA. Calculate the value of I_B .

Solution :

$$\text{Using the relation,} \quad I_E = I_B + I_C$$

$$1 = I_B + 0.95$$

$$I_B = 1 - 0.95 = 0.05\text{ mA}$$

Q3. In a common base connection, current amplification factor is 0.9. If the emitter current is 1mA, determine the value of base current.

Solution :

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

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

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

$$\text{Also} \quad I_E = I_B + I_C$$

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

Q4. In a common base connection, IC = 0.95 mA and IB = 0.05 mA. Find the value of α.

Solution:

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

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

Q5. 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 :

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

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

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

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 :

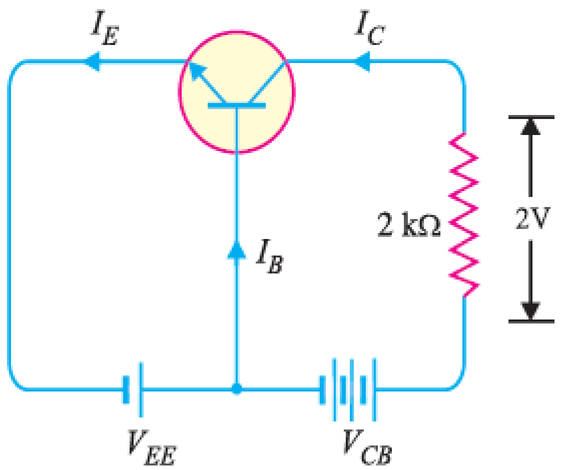

Fig. 2

Fig. 2 shows the required common base connection.

The voltage drop across RC (= 2 kΩ) is 2V.

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

$$\text{Now} \quad \alpha = I_C/I_E$$

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

Using the relation, $I_E = I_B + I_C$

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

$$= 0.05 \text{ mA}$$

Q7. For the common base circuit shown in Fig. 3, determine I_C and V_{CB}. Assume the transistor to be of silicon.

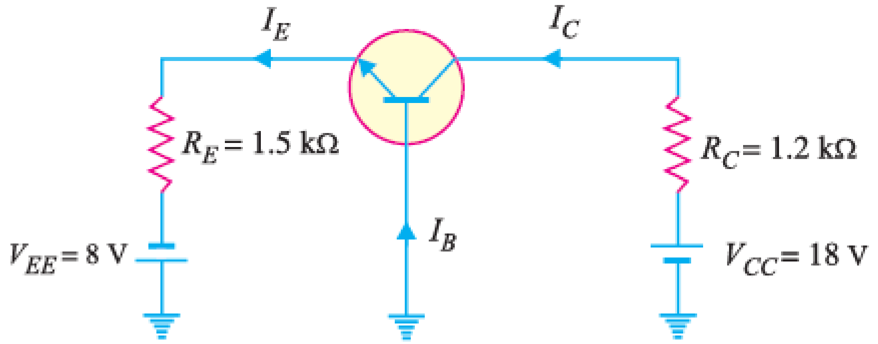

Fig. 3

Solution :

Since the transistor is of silicon, $V_{BE} = 0.7$V.

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

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

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

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

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

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

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

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

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

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

Solution :

(i) α = 0.9

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

(ii) α = 0.98

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

(iii) α = 0.99

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

Q9. Calculate I_E in a transistor for which β = 50 and I_B = 20 µA.

Solution :

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

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

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

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

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

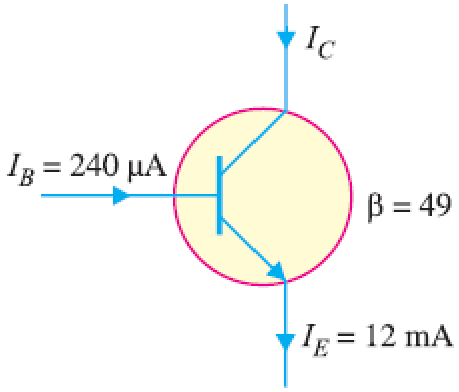

Fig. 4

Solution :

Fig. 8.20 shows the conditions of the problem.

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

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 :

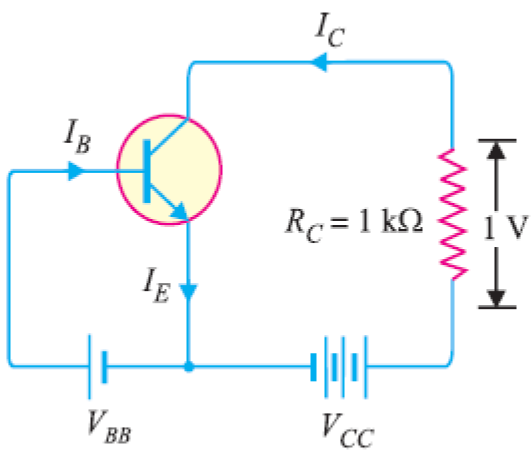

Fig. 5

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

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

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

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

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

Solution :

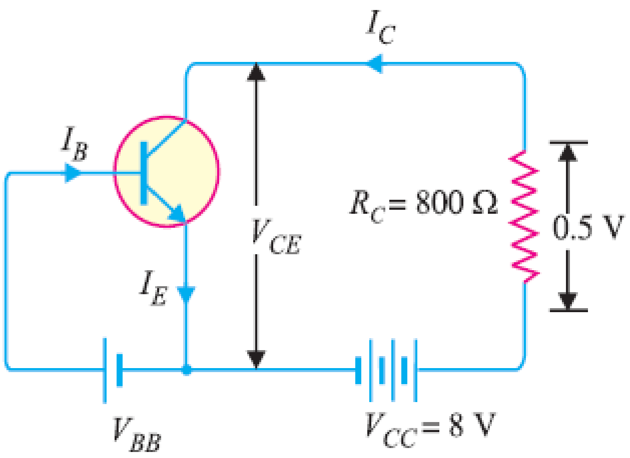

Fig.6

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

Collector-emitter voltage,

(i) $$V_{CE} = V_{CC} - 0.5 = 8 - 0.5 = \mathbf{7.5\ V}$$

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

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

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. Find α, I_E and I_B when collector current is 1 mA.

Solution :

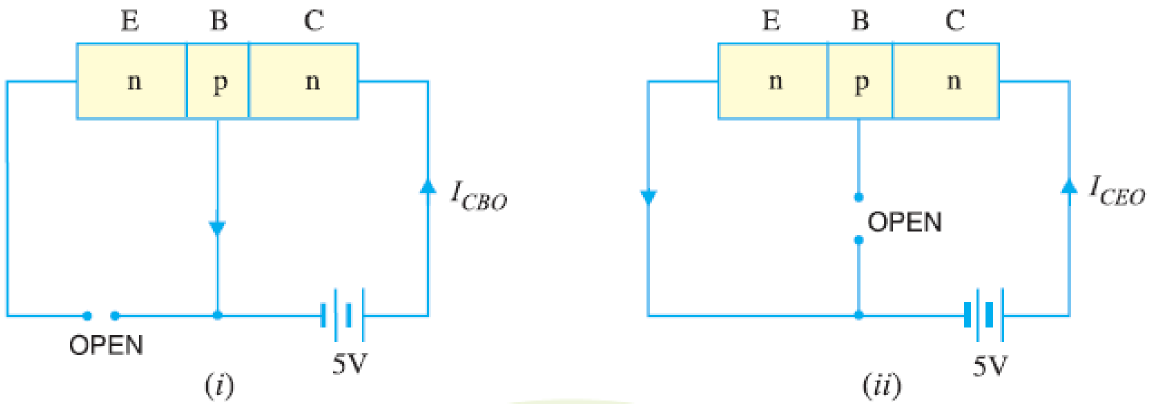

Fig. 7

When the emitter circuit is open as shown in Fig.7 (i) , the collector-base junction is reverse biased. A small leakage current I_{CBO} 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 $\quad 20 = \dfrac{0.2}{1-\alpha}$

$\therefore \quad \alpha = \mathbf{0.99}$

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

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

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

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

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, I_B = 20 μA; I_C = 2 mA and β = 80. Calculate I_{CBO}.

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

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

Q16. Using diagrams, explain the correctness of the relation I_{CEO} = (β + 1)I_{CBO}.

Solution :

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

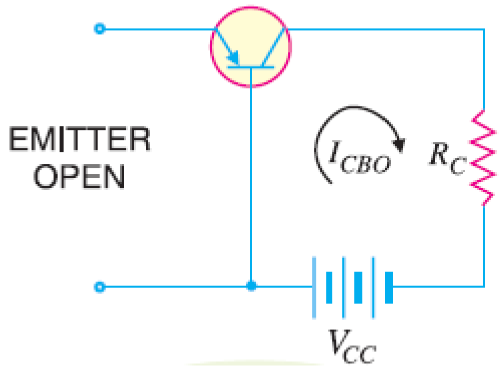

Fig. 8

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

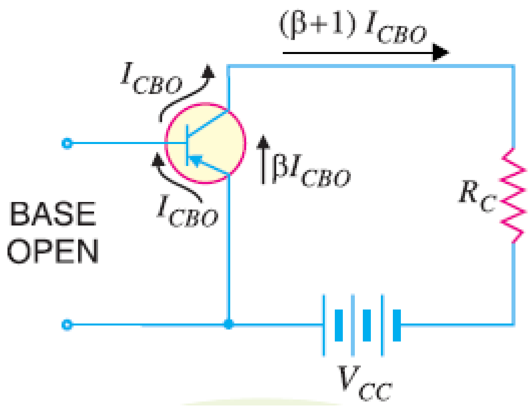

Fig.9

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

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

Solution :

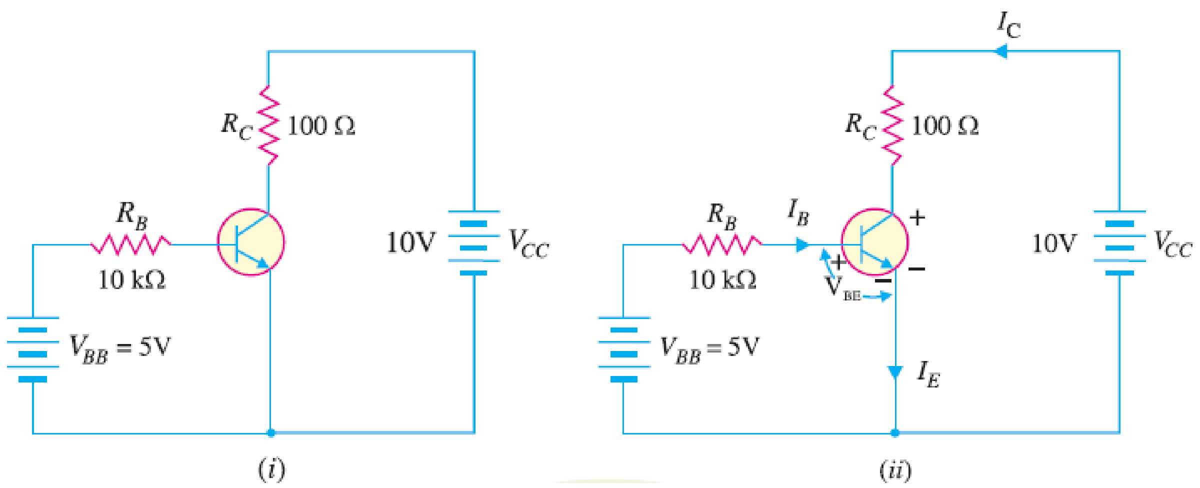

Fig.10

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

$\therefore$ $$I_C = \beta I_B = (150)(430\ \mu\text{A}) = 64.5\ \text{mA}$$

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

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

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

$\therefore$ $$V_{CB} = V_{CE} - V_{BE} = 3.55 - 0.7 = 2.85\text{V}$$

Q18. In a transistor, I_B = 68 µA, I_E = 30 mA and β = 440. Determine the α rating of the transistor. Then determine the value of I_C 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 : $I_{C\ (max)}$ = 500 mA and β_{max} = 300. Determine the maximum allowable value of I_B for the device.

Solution :

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

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 ?

Solution :

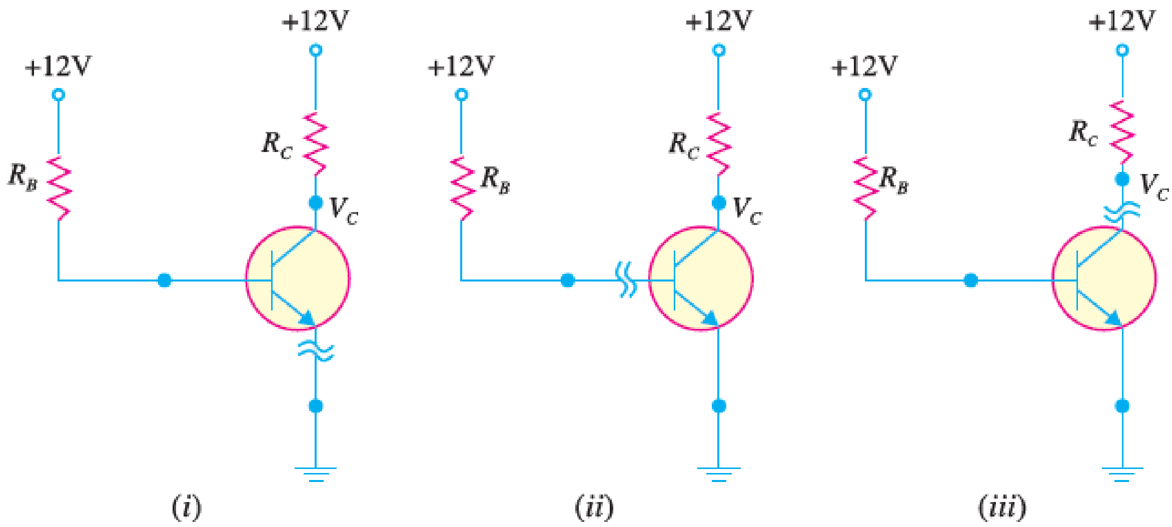

Fig. 11

Fig 11 shows the open circuit failures in a transistor. We shall discuss the circuit behaviour in each case.

(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.

Q21. For the circuit shown in Fig. 12 , draw the d.c. load line.

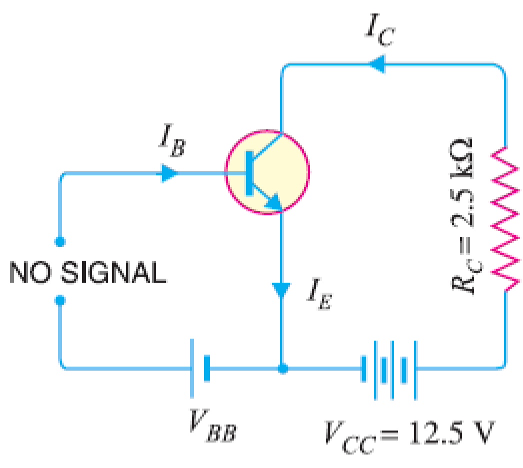

Fig.12

Solution :

The collector-emitter voltage V_{CE} is given by ;

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

$$\text{When } I_C = 0, \text{ then,}$$

$$V_{CE} = V_{CC} = 12.5\ V$$

This locates the point *B* of the load line on the collector-emitter voltage axis.

$$\text{When } V_{CE} = 0, \text{ then,}$$

$$I_C = V_{CC}/R_C = 12.5\ V/2.5\ k\Omega = 5\ mA$$

This locates the point A of the load line on the collector current axis. By joining these two points, we get the d.c. load line AB as shown in Fig. 13.

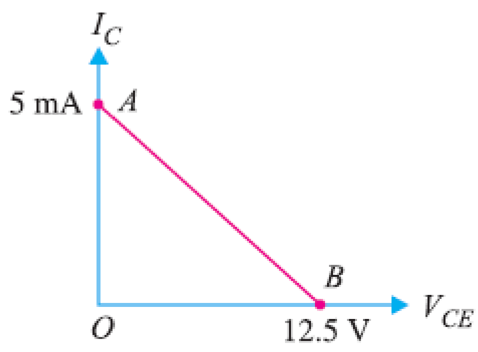

Fig.13

Q22. In the circuit diagram shown in Fig. 14, if V_{CC} = 12V and R_C = 6 kΩ, draw the d.c. load line. What will be the Q point if zero signal base current is 20μA and β = 50 ?

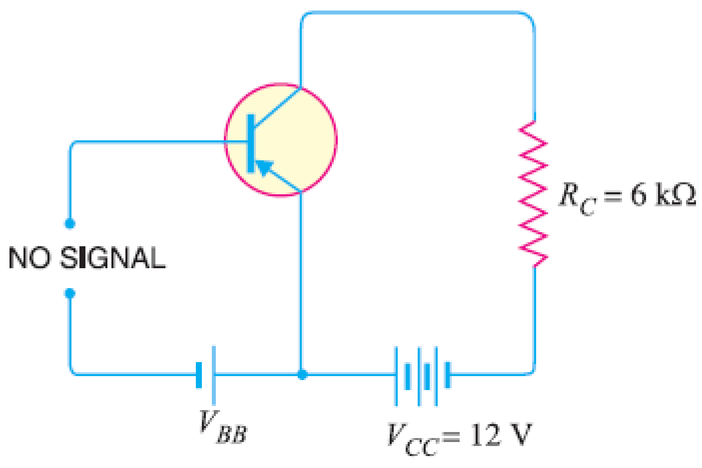

Fig.14

Solution :

The collector-emitter voltage V_{CE} is given by :

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

When $I_C = 0$, $V_{CE} = V_{CC} = 12$ V. This locates the point B of the load line.

When $V_{CE} = 0$, $I_C = V_{CC} / R_C = 12$ V/6 kΩ = 2 mA.

This locates the point A of the load line. By joining these two points, load line AB is constructed as shown in 15.

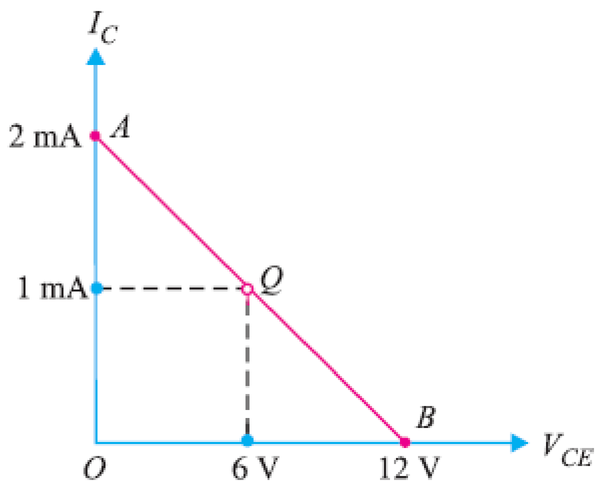

Fig. 15

Zero signal base current, $I_B = 20\ \mu A = 0.02$ mA

Current amplification factor, $\beta = 50$

$\therefore$ Zero signal collector current, $I_C = \beta I_B = 50 \times 0.02 = 1$ mA

Zero signal collector-emitter voltage is

$$V_{CE} = V_{CC} - I_C R_C = 12 - 1 \text{ mA} \times 6 \text{ k}\,\Omega = 6 \text{ V}$$

∴ Operating point is **6 V, 1 mA**.

Fig. 15 shows the Q point. Its co-ordinates are $I_C = 1$ mA and $V_{CE} = 6$ V.

Q23. In a transistor circuit, collector load is 4 kΩ whereas quiescent current (zero signal collector current) is 1 mA. (i) What is the operating point if $V_{CC} = 10$ V ? (ii) What will be the operating point if $R_C = 5$ kΩ ?

Solution : $V_{CC} = 10 \text{ V}, I_C = 1 \text{ mA}$

(i) When collector load $R_C = 4$ k Ω , then,

$$V_{CE} = V_{CC} - I_C R_C = 10 - 1 \text{ mA} \times 4 \text{ k}\,\Omega = 10 - 4 = 6\ V$$

∴ Operating point is **6 V, 1 mA**.

(ii) When collector load $R_C = 5$ k Ω , then,

$$V_{CE} = V_{CC} - I_C R_C = 10 - 1 \text{ mA} \times 5 \text{ k}\,\Omega = 10 - 5 = 5\ V$$

∴ Operating point is **5 V, 1 mA**.

Q24. Determine the Q point of the transistor circuit shown in Fig. 16. Also draw the d.c. load line. Given β = 200 and V_{BE} = 0.7V.

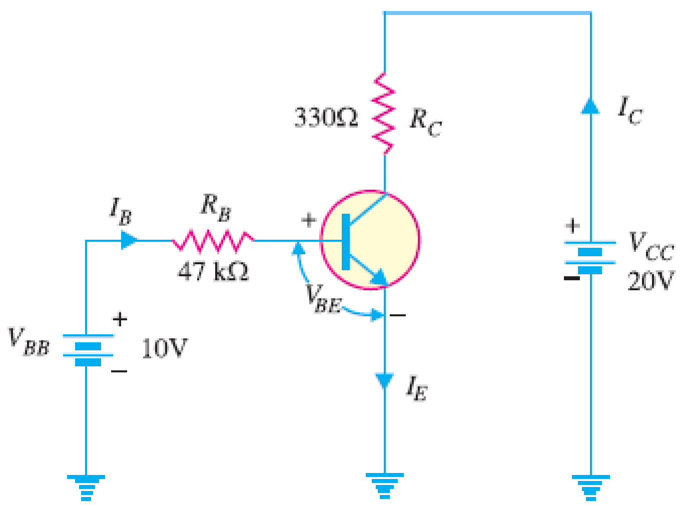

Fig. 16

Solution :

The presence of resistor R_B in the base circuit should not disturb you because we can apply Kirchhoff's voltage law to find the value of I_B and hence I_C (= βI_B). Referring to Fig. 16 and applying Kirchhoff's voltage law to base-emitter loop, we have,

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

$$\therefore \quad I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{10V - 0.7V}{47\,k\Omega} = 198\ \mu A$$

Now $\quad I_C = \beta I_B = (200)(198\ \mu A) = 39.6\ mA$

Also $\quad V_{CE} = V_{CC} - I_C R_C = 20V - (39.6mA)\ (330\ \Omega) = 20V - 13.07V = 6.93V$

Therefore, the Q-point is I_C = **39.6 mA** and V_{CE} = **6.93V.**

D.C. load line:

In order to draw the d.c. load line, we need two end points.

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

When $I_C = 0$, $V_{CE} = V_{CC} = 20V$. This locates the point B of the load line on the collector-emitter voltage axis as shown in Fig. 17.

When $V_{CE} = 0$, $I_C = V_{CC} / R_C = 20V/330\Omega = 60.6$ mA. This locates the point A of the load line on the collector current axis.

By joining these two points, d.c. load line AB is constructed as shown in Fig. 17.

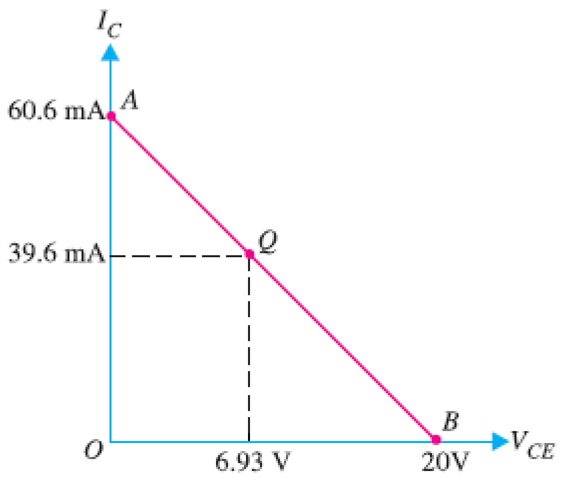

Fig. 17

Q25. Determine the Q point of the transistor circuit shown in Fig. 18. Also draw the d.c. load line. Given β = 100 and V_{BE} = 0.7V.

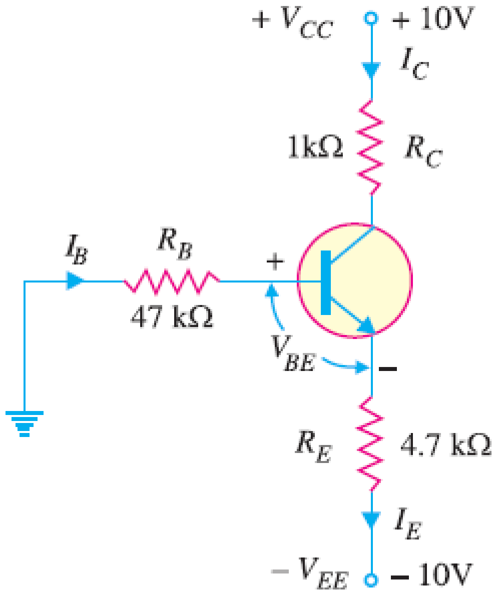

Fig.18

Solution :

The transistor circuit shown in Fig. 18 may look complex but we can easily apply Kirchhoff's voltage law to find the various voltages and currents in the circuit.

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

$$-I_B R_B - V_{BE} - I_E R_E + V_{EE} = 0 \quad \text{or} \quad V_{EE} = I_B R_B + I_E R_E + V_{BE}$$

Now $I_C = \beta I_B$ and $I_C \simeq I_E$. $\therefore$ $I_B = I_E/\beta$. Putting $I_B = I_E/\beta$ in the above equation, we have,

$$V_{EE} = \left(\frac{I_E}{\beta}\right) R_B + I_E R_E + V_{BE}$$

or $$I_E\left(\frac{R_B}{\beta} + R_E\right) = V_{EE} - V_{BE} \quad \text{or} \quad I_E = \frac{V_{EE} - V_{BE}}{R_E + R_B/\beta}$$

Since $I_C \simeq I_E$, $$I_C = \frac{V_{EE} - V_{BE}}{R_E + R_B/\beta} = \frac{10\text{V} - 0.7\text{V}}{4.7\text{ k}\Omega + 47\text{ k}\Omega/100} = \frac{9.3\text{ V}}{5.17\text{ k}\Omega} = 1.8\text{ mA}$$

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

$$V_{CC} - I_C R_C - V_{CE} - I_E R_E + V_{EE} = 0$$

or $$V_{CE} = V_{CC} + V_{EE} - I_C (R_C + R_E) \qquad (\because I_E \simeq I_C)$$

$$= 10\text{V} + 10\text{V} - 1.8\text{ mA}\,(1\text{ k}\Omega + 4.7\text{ k}\Omega) = 9.74\text{V}$$

Therefore, the operating point of the circuit is I_C = 1.8 mA and V_{CE} = 9.74V.

D.C. load line :

The d.c. load line can be constructed as under :

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

When $I_C = 0$; $V_{CE} = V_{CC} + V_{EE} = 10V + 10V = 20V$. This locates the first point B ($OB = 20V$) of the load line on the collector-emitter voltage axis. When $V_{CE} = 0$,

$$I_C = \frac{V_{CC} + V_{EE}}{R_C + R_E} = \frac{10V + 10V}{1\,k\Omega + 4.7\,k\Omega} = \frac{20V}{5.7\,k\Omega} = 3.51 \text{ mA}$$

This locates the second point A (OA = 3.51 mA) of the load line on the collector current axis. By joining points A and B, d.c. load line AB is constructed as shown in Fig. 19.

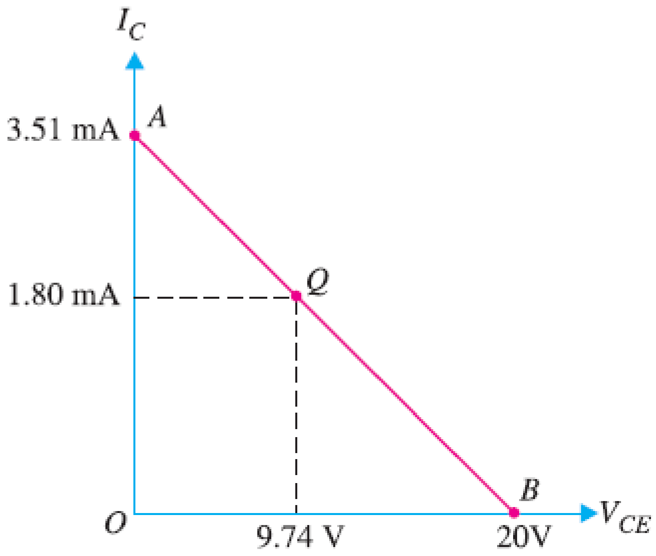

Fig.19