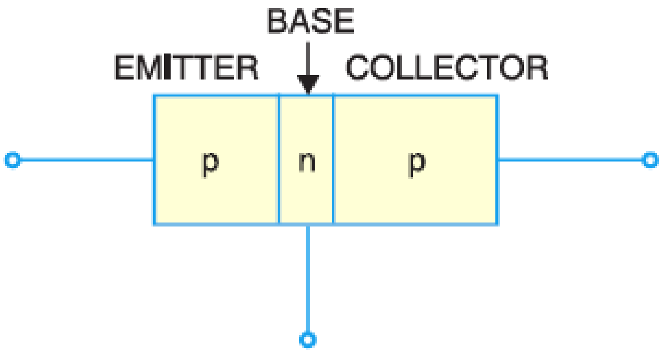
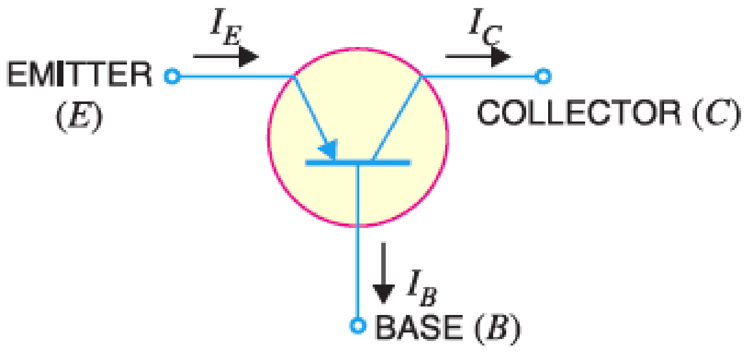
Transistor

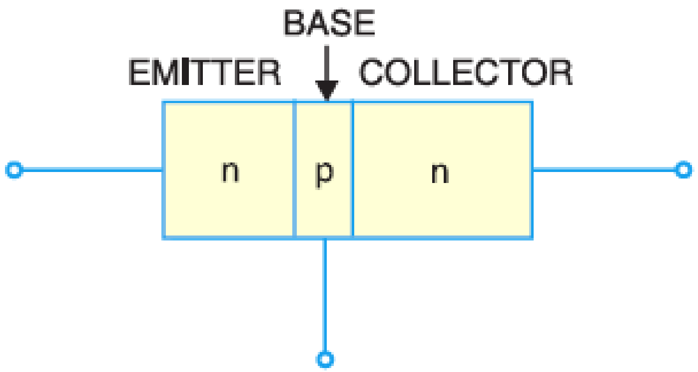
Transistor

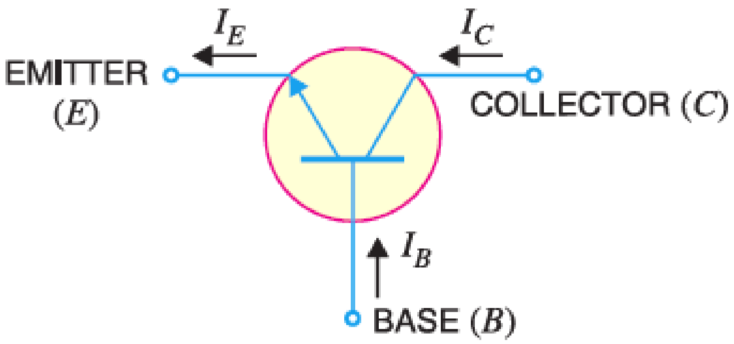
- A transistor consists of two pn junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.

- Accordingly, there are two types of transistors, namely; (i) n-p-n transistor and (ii) p-n-p transistor









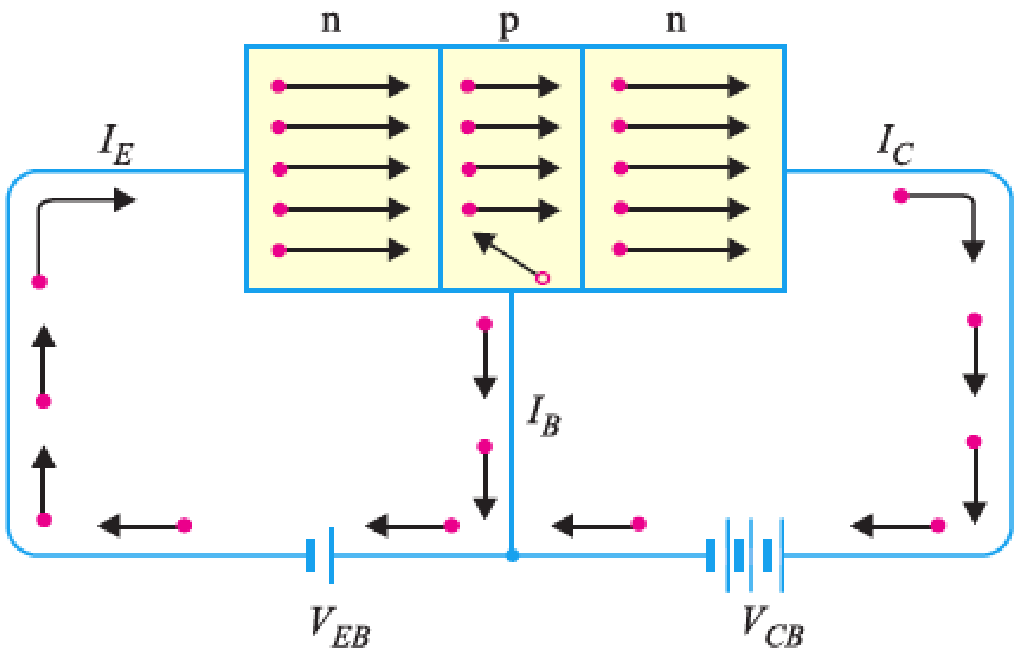
Working of npn Transistor

- Fig. shows the *npn* transistor with forward bias to emitter-base junction and reverse bias to collector-base junction.

- The forward bias causes the electrons in the *n*-type emitter to flow towards the base. This constitutes the emitter current I_E.

- As these electrons flow through the *p*-type base, they tend to combine with holes. As the base is lightly doped and very thin, therefore, only a few electrons (less than 5%) combine with holes to constitute base current I_B.

- The remaining (more than 95%) cross over into the collector region to constitute collector current I_C.

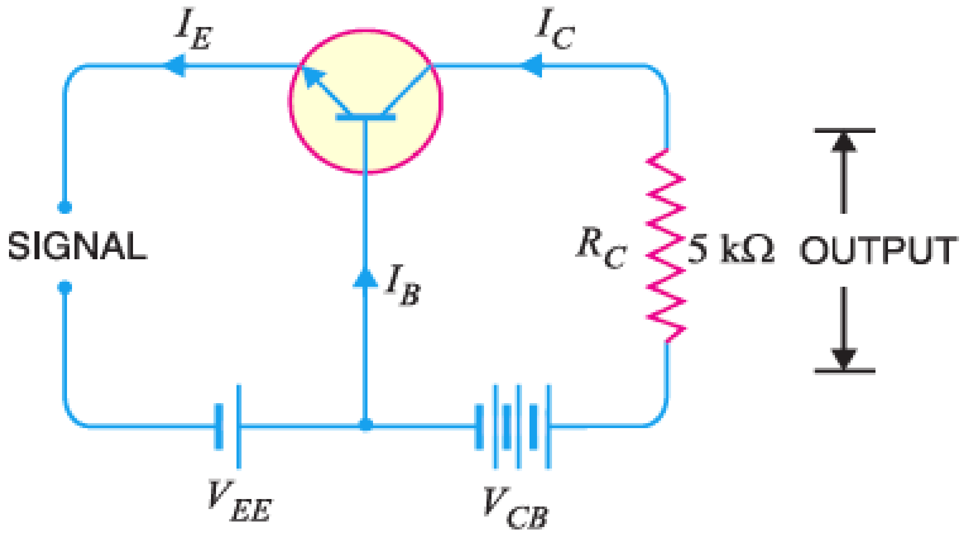


$$I_E = I_B + I_C$$

- In this way, almost the entire emitter current flows in the collector circuit. Therefore, emitter current is the sum of collector and base currents.

Transistor Circuit as an Amplifier

- A transistor raises the strength of a weak signal and thus acts as an amplifier.
- Fig. shows the basic circuit of a transistor amplifier.
- The weak signal is applied between emitter-base junction and output is taken across the load R_C connected in the collector circuit.
- In order to achieve faithful amplification, the input circuit should always remain forward biased.



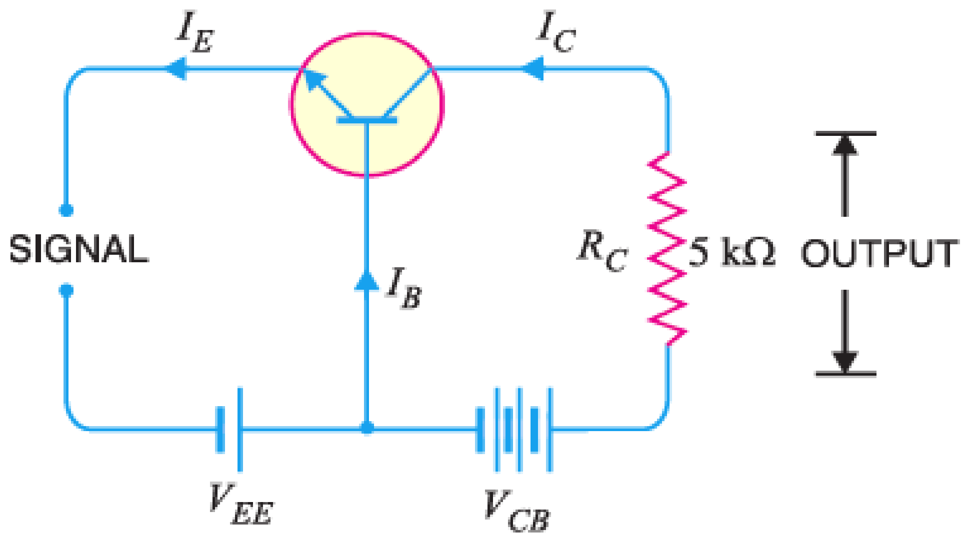
Transistor Circuit as an Amplifier

- to achieve faithful amplification, a d.c. voltage V_{EE} is applied in the input circuit in addition to the signal as shown. This d.c. voltage is known as bias voltage and its magnitude is such that it always keeps the input circuit forward biased regardless of the polarity of the signal.

- As the input circuit has low resistance, therefore, a small change in signal voltage causes an appreciable change in emitter current. This causes almost the same change in collector current due to transistor action.

- The collector current flowing through a high load resistance R_C produces a large voltage across it.

- Thus, a weak signal applied in the input circuit appears in the amplified form in the collector circuit. It is in this way that a transistor acts as an amplifier.



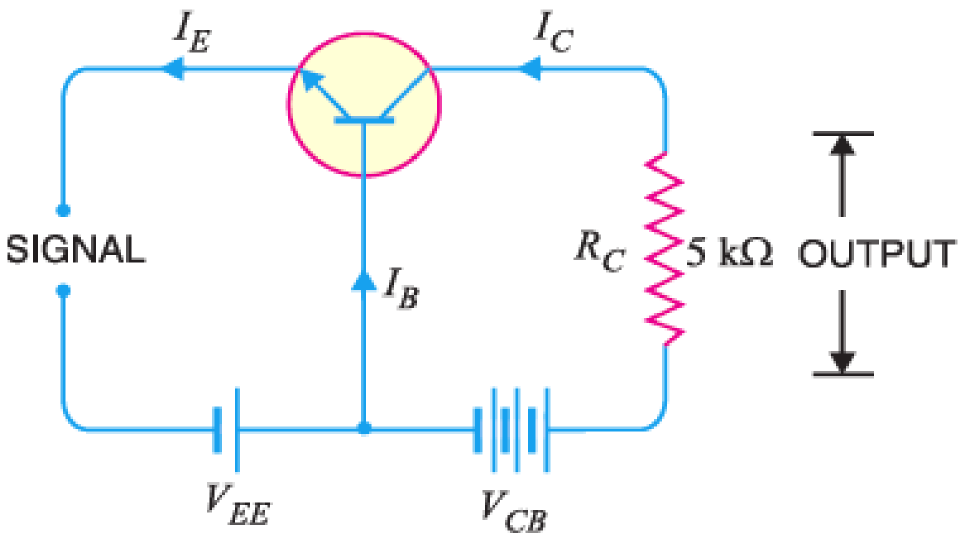
Transistor Circuit as an Amplifier

- The action of a transistor as an amplifier can be made more illustrative if typical circuit values are considered.

- Suppose collector load resistance R_C = 5 kΩ. Let us further assume that a change of 0.1V in signal voltage produces a change of 1 mA in emitter current.

- Obviously, the change in collector current would also be approximately 1 mA. This collector current flowing through collector load R_C would produce a voltage = 5 kΩ × 1 mA = 5 V.

- Thus, a change of 0.1 V in the signal has caused a change of 5 V in the output circuit. In other words, the transistor has been able to raise the voltage level of the signal from 0.1 V to 5 V *i.e.* voltage amplification is 50.



Common Base Amplifier

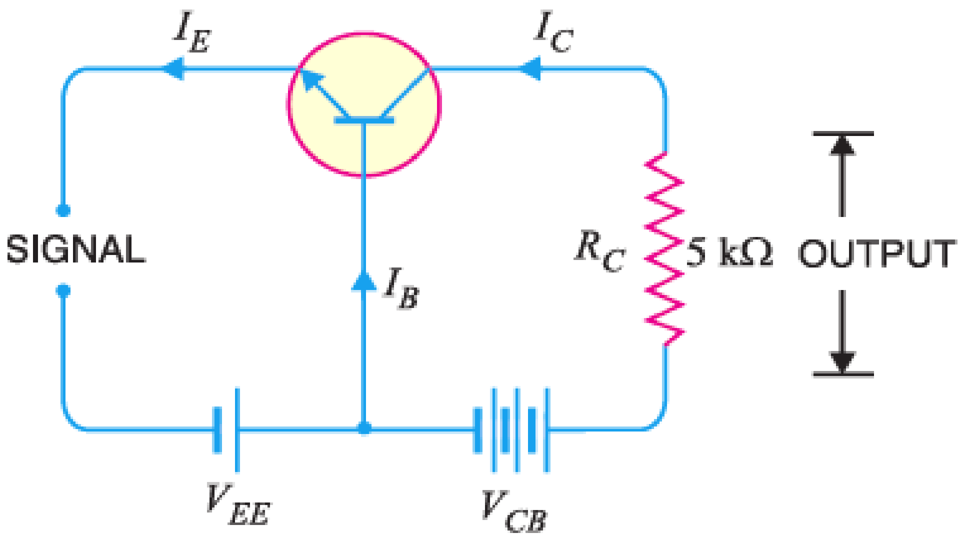
- **Current amplification factor (α)** is the ratio of output current to input current.

- In a common base connection, the input current is the emitter current I_E and output current is the collector current I_C.
- The ratio of change in collector current to the change in emitter current at constant collector-base voltage V_{CB} is known as current amplification factor i.e.

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at constant } V_{CB}$$

- It is clear that current amplification factor is less than unity.

- This value can be increased (but not more than unity) by decreasing the base current. This is achieved by making the base thin and doping it lightly. Practical values of α in commercial transistors range from 0.9 to 0.99.



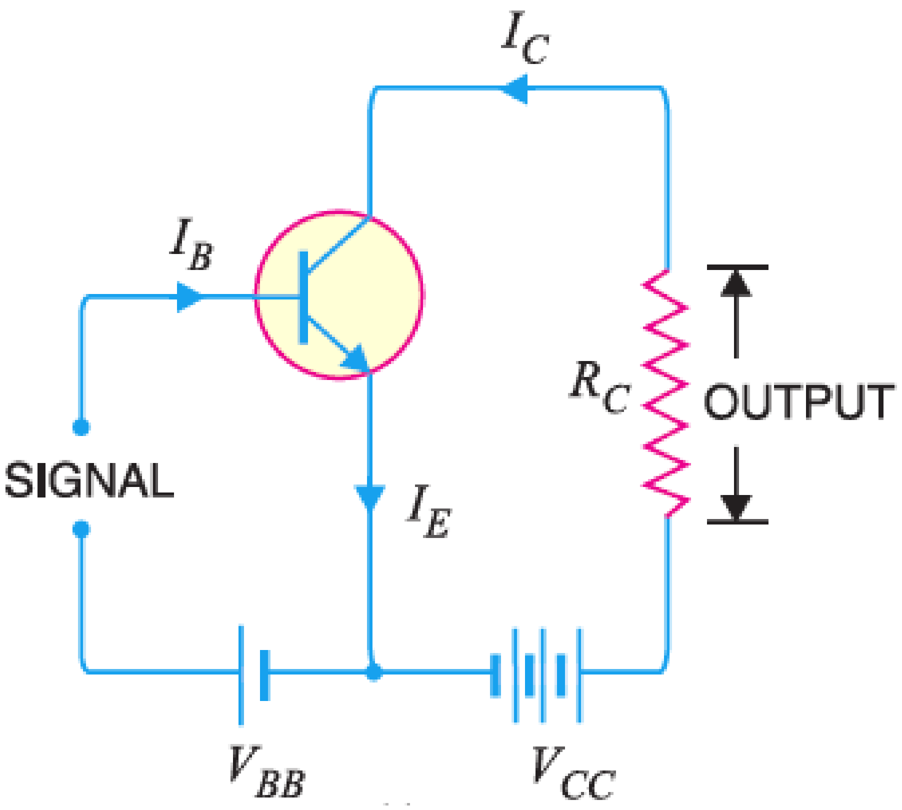
Common Emitter Connection

- In this circuit arrangement, input is applied between base and emitter and output is taken from the collector and emitter.
- Here, emitter of the transistor is common to both input and output circuits and hence the name common emitter connection.

- **Base current amplification factor (β):** In common emitter connection, input current is I_B and output current is I_C. The ratio of change in collector current (ΔI_C) to the change in base current (ΔI_B) is known as base current amplification factor i.e.

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

- In almost any transistor, less than 5% of emitter current flows as the base current. Therefore, the value of β is generally greater than 20. Usually, its value ranges from 20 to 500. This type of connection is frequently used as it gives appreciable current gain as well as voltage gain.



Relation between β and α.

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

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

$$I_E = I_B + I_C$$

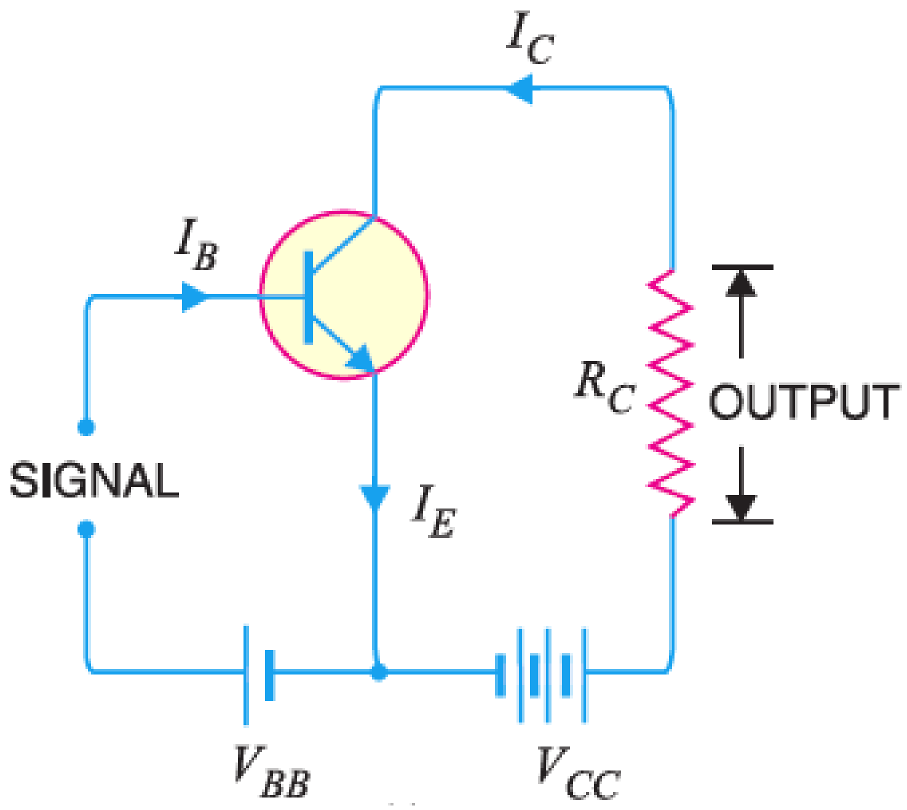
$$\Delta I_E = \Delta I_B + \Delta I_C$$

$$\Delta I_B = \Delta I_E - \Delta I_C$$

$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

$$\beta = \frac{\Delta I_C / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{\alpha}{1-\alpha}$$

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



- It is clear that as α approaches unity, β approaches infinity. In other words, the current gain in common emitter connection is very high.
- It is due to this reason that this circuit arrangement is used in about 90 to 95 percent of all transistor applications.

Example *Calculate I_E in a transistor for which $\beta = 50$ and $I_B = 20\ \mu A$.*

Solution. Here $\beta = 50, \quad I_B = 20\mu A = 0.02$ mA

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

$\therefore$ $I_C = \beta I_B = 50 \times 0.02 = 1$ mA

Using the relation, $I_E = I_B + I_C = 0.02 + 1 =$ **1.02 mA**

Example *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, $\alpha = 0.9, \quad I_E = 1$ mA

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

or $I_C = \alpha I_E = 0.9 \times 1 = 0.9$ mA

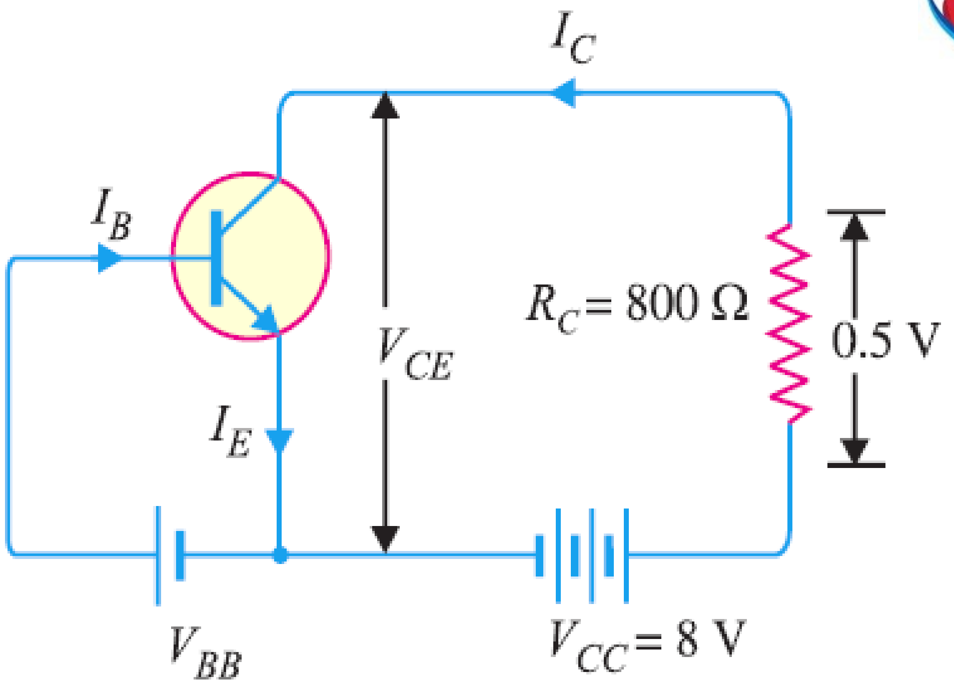
Also $I_E = I_B + I_C$

$\therefore$ Base current, $I_B = I_E - I_C = 1 - 0.9 =$ **0.1 mA**

Example *A transistor is connected in common emitter (CE) configuration in which collector supply is 8V and the voltage drop across resistance R_C connected in the collector circuit is 0.5V. The value of $R_C = 800\ \Omega$. If $\alpha = 0.96$, determine :*

(i) collector-emitter voltage

(ii) base current



(*i*) Collector-emitter voltage,

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

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

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

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

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

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