Chapter : 8

Ezaz Ahmed

C223009

Important Ques:

(i) Working principle of n-p-n transistor.

(ii) Common emitter circuit and its input output characteristics.

(iii) How transistor acts as an amplifier.

(iv) Transistor 3 region and transistor can act as a switch and amplifier. (v) α and β relation.

Article:

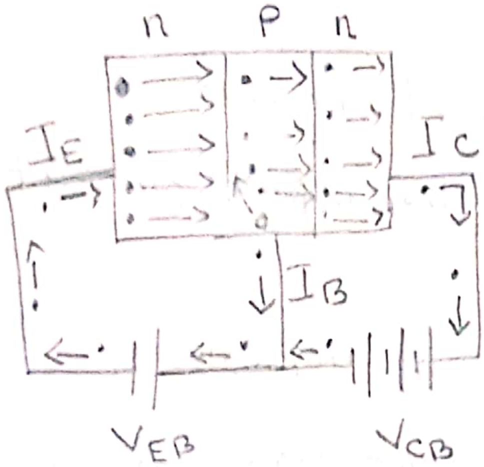
8.6, 8.8, 8.9, 8.12, 8.22

Math:

8.1 - 8.12

Book: Principles of electronics (V.K. Mehta)

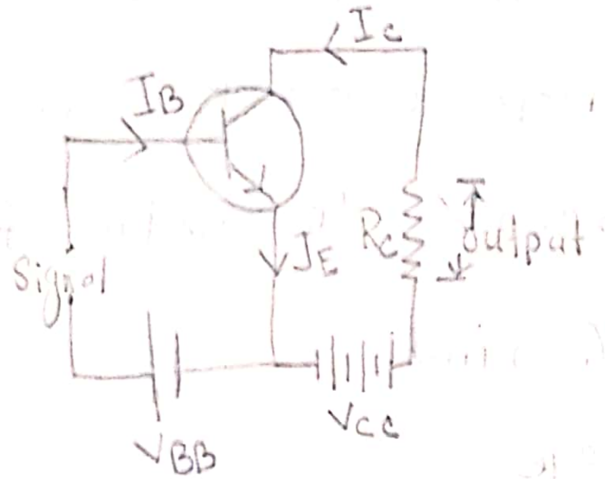
Working principle of n-p-n transistor:



This is a 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 constitudes the emitter current I_E. As these electrons flow through the p-type base, they tend to combine the holes. As the base is lightly doped and very thin therefore only a few electrones combine with holes to constitute base current I_B. The remainder cross over into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows in the collector circuit.

$$I_E = I_C + I_B$$

Relation of α and β:



input current is I_B, 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.

$$\beta = \frac{\Delta I_C}{\Delta I_B} \quad \text{——} \; (i)$$

We know,

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \quad \text{——} \; (ii)$$

Now, $I_E = I_B + I_C$ or, $\Delta I_E = \Delta I_B + \Delta I_C$

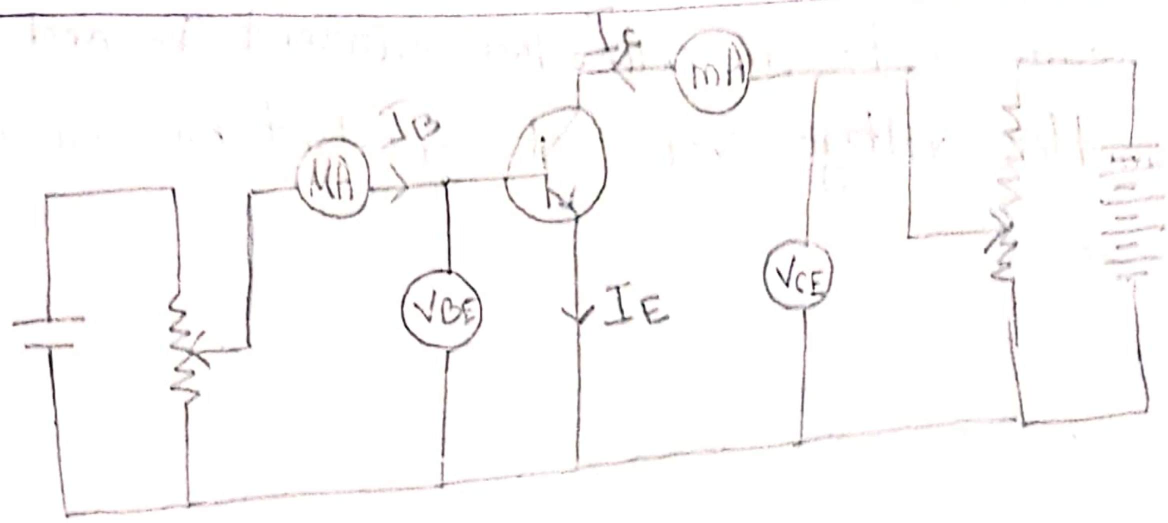
$\therefore \Delta I_B = \Delta I_E - \Delta I_C$

Putting value of ΔI_B in (i):

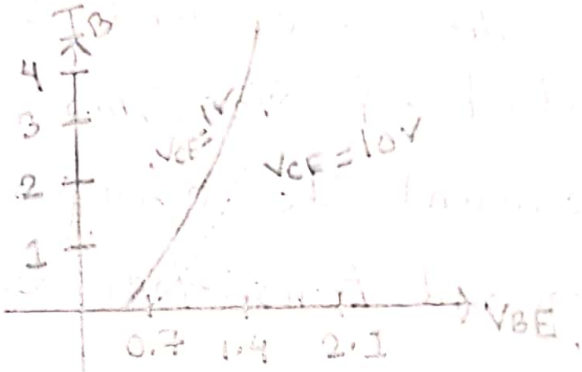
$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C} = \frac{\Delta I_C / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{\alpha}{1-\alpha}$$

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

Characteristics of common-emitter connection:



Input Characteristics: It is the curve between base current I_B and base-emitter voltage V_{BE} at constant collector-emitter voltage V_{CE}.

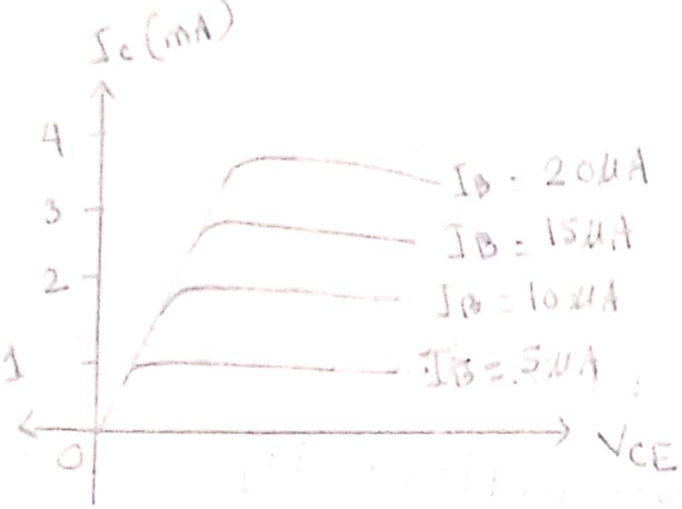


① The input characteristics of a CE connection can be determined by the circuit drawn. Keeping V_{CE} constant. The characteristics resembles that of a forward biased diode curve. A compared to CB arrangement I_B increases less rapidly with V_{BE}. Input resistance of a CE circuit is higher than that of CB circuit.

Input resistance $r_i = \dfrac{\Delta V_{BE}}{\Delta I_B}$

Output Characteristics:

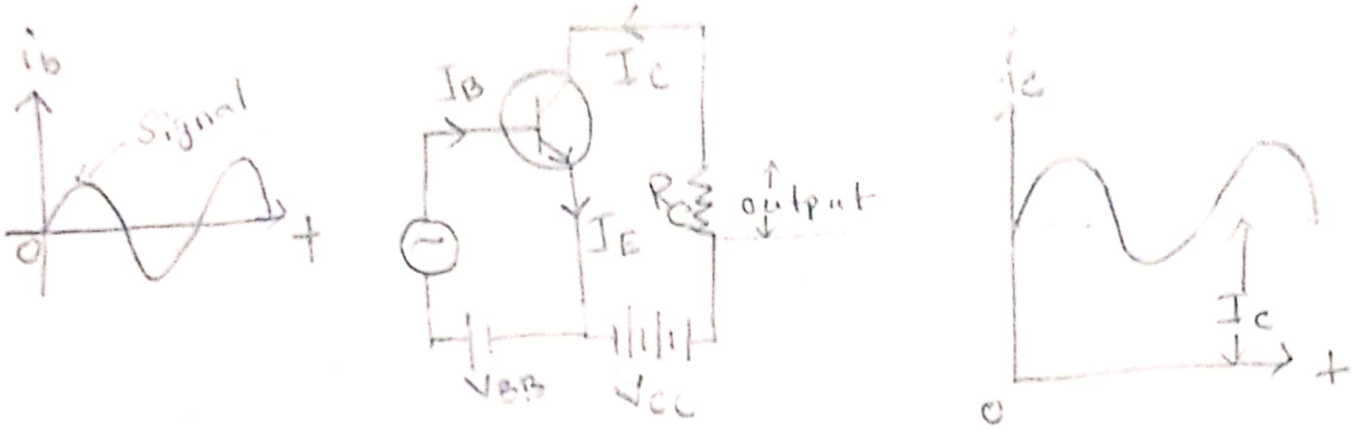
It is the curve between collector current I_c and collector emitter voltage V_{CE} at constant base current I_B.



The collector current I_c varies with V_{CE} between 0 and 1V only. After this ~~curr~~ collector current becomes almost constant and independent of V_{CE}. This value of V_{CE} upto which collector current I_c changes with V_{CE} is called Knee voltage and transistors works above it. $I_c \approx \beta \times I_B$, for any value of V_{CE} above Knee voltage.

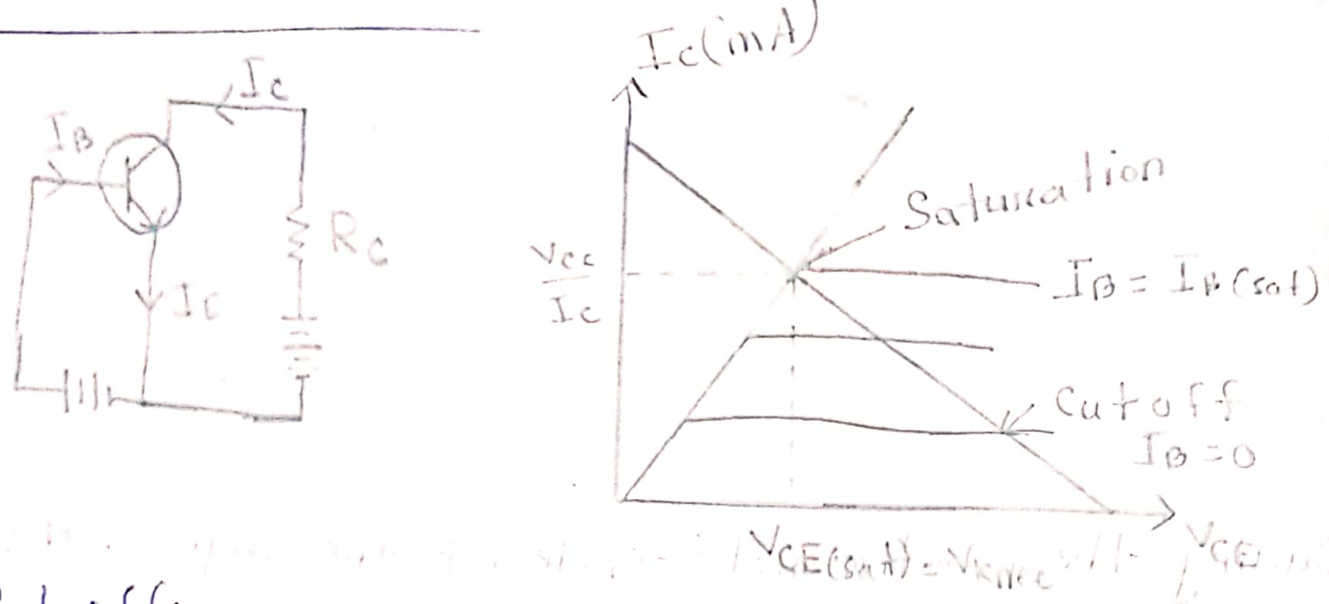
Output resistance $r_o = \dfrac{\Delta V_{CE}}{\Delta I_c}$ at I_B constant.

Transistor as an Amplifier:



During the positive half-cycle of the signal, the forward bias across the emitter-base junction is increased. Therefore more electrons flows from the emitter to the collector via the base. This causes an increase in the collector current Ic. It produces a greater voltage drop across the collector load resistance Rc. During the negative half cycle of the signal collector current decreases. This results in the decreased output voltage. Hence an amplified output is obtained across the load.

Transistor 3 region:



(i) Cut off: The point where the load line intersects the $I_B = 0$ curve is known as cut off. At this point $I_B = 0$ and only a small collector current exists. The collector - emitter voltage is nearly equal to Vcc.

$V_{CE(cutoff)} = V_{CC}$ (Emitter diode and collector diode are off.)

(ii) Saturation: The point where the load line intersects the $I_B = I_{B(sat)}$ curve is called saturation. At this point the base current is maximum and so the collector current.

$I_{C(sat)} \simeq \frac{V_{CC}}{R_C}$; $V_{CE} = V_{CE(sat)} = V_{knee}$

(Emitter diode and collector diode on)

(iii) Active region: The region between cut off and saturation is called active region. Collector-base junction remains reverse biased while base-emitter junction stays forward biased. The transistor will function normally. (Emitter diode is ON and collector diode is OFF

In saturation the transistor ~~works~~ act as ~~an~~ a switch.
In active region the transistor ~~works~~ act as an amplifier.
So a transistor can ~~work~~ act both switch and amplifier.

Example 8.1: 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 α_{ac} to be nearly one.

Solution:

Input current $I_E = \frac{\text{Signal}}{R_{in}} = \frac{500\ mV}{20\Omega} = 25\ mA$

Since, α_{ac} is nearly 1, output current $I_C = I_E = 25\ mA$

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

$= 25\ V$

Voltage amplification $A_V = \frac{V_{out}}{\text{Signal}} = \frac{25\ V}{500\ mV}$

$= 50$

Ans:

Example 8.2: In a common base connection $I_E = 1\ mA$, $I_C = 0.95\ mA$. Calculate the value of I_B.

Solution: Using the relation, $I_E = I_B + I_C$

or, $I_B = I_E - I_C$

$= 1mA - 0.95mA$

$\therefore I_B = 0.05mA$

Ans:

Example: 8.3 - In a common base connection, current amplification factor is 0.9. If the emitter current is 1 mA, determine the value of base current.

Solution:

Here, $\alpha = 0.9$, $I_E = 1mA$

Now, $\alpha = \frac{I_C}{I_E}$ or, $I_C = \alpha I_E = 0.9 \times 1 = 0.9mA$

$\therefore I_C = 0.9mA$

Again, $I_E = I_B + I_C$ or, $I_B = I_E - I_C = (1-0.9)mA$

$= 0.1 mA$

$\therefore I_B = 0.1 mA$

Ans:

Example 8.4: In a common base connection $I_C = 0.95mA$ and $I_B = 0.05mA$. Find the value of α.

Solution: $I_E = I_B + I_C = 0.05 mA + 0.95 mA = 1 mA$

$\therefore \alpha = \frac{I_C}{I_B} = \frac{0.95mA}{1mA} = 0.95$ Ans:

Example 8.5: In a common base connection the emitter current is 1mA. If the emitter circuit is open, the collector current is $50\mu A$. Find the total collector current, $\alpha = 0.92$

Solution:

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

$\therefore$ Total collector current, $I_C = \alpha I_E + I_{CBO}$

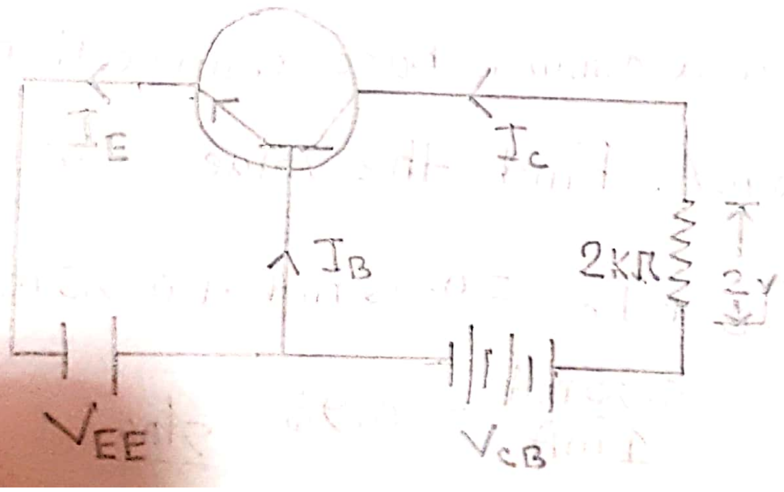
$= 0.92 \times 1 + 50 \times 10^{-3}$

$= 0.97\ mA$

Ans:

Example 8.6:- In a common base connection $\alpha = 0.95$. The voltage drop across $2K\Omega$ resistance which is connected in the collector is 2V. Find the base current.

Solution:



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The voltage drop across R_C ($2k\Omega$) is $2V$

$$\therefore I_C = \frac{2V}{2k\Omega} = 1\,mA$$

$$\alpha = \frac{I_C}{I_E} \quad \text{or,} \quad I_E = \frac{I_c}{\alpha} = \frac{1\,mA}{0.95} = 1.05\,mA$$

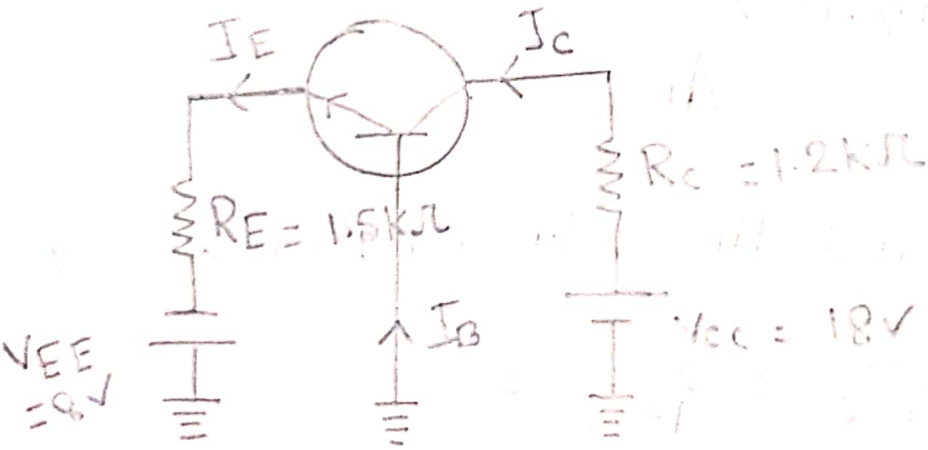
Now,

$$I_E = I_B + I_c \quad \text{or,} \quad I_B = I_E - I_c = (1.05 - 1)\,mA$$

$$\therefore I_E = 0.05\,mA$$

Ans:

Example 8.7: Determine I_C and V_{CB}. Assume the transistor to be of silicon.



Solution: Since the transistor is of silicon $V_{BE} = 0.7V$

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

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

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

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

$$\therefore I_C \cong I_E = 4.87\ mA$$

Applying KVL to the collector-side loop, we have,

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

or, $$V_{CB} = V_{CC} - I_C R_C$$

$$= 18V - 4.87\ mA \times 1.2K\Omega$$

$$\therefore V_{CB} = 12.16V$$

Ans.

Example 8.8: - Find the value of β if $\alpha = 0.9$

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

Example 8.9: Calculate I_E in a transistor for which $\beta = 50$ and $I_B = 20\mu A$.

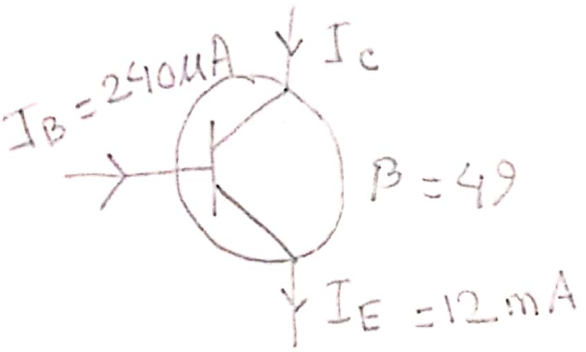
Solution: Here, $\beta = 50$, $I_B = 20\mu A = 0.02 mA$

$\beta = \frac{I_C}{I_B}$ or, $I_C = \beta I_B = 50 \times 0.02 = 1 mA$

$I_E = I_B + I_C = 0.02 + 1 = 1.02 mA$

Ans:

Example 8.10: Find α and I_C (using α and β)



Solution:

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

$I_C = \alpha I_E = 0.98 \times (12 mA) = 11.76 mA$

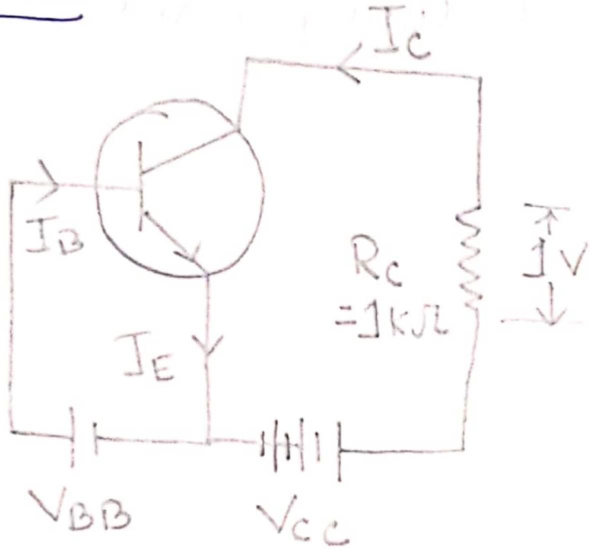
Also,

$I_C = \beta I_B = 49 (240 \mu A) = 11.76 mA$

Ans:

Example 8.11: For a transistor $\beta = 45$ and voltage drop accross $1K\Omega$ which is connected in the collector circuit is 1V. Find the base current for common emitter connection.

Solution:



$$I_c = \frac{1V}{1k\Omega} = 1mA$$

Now,

$$\beta = \frac{I_c}{I_B} \quad \text{or,}\ I_B = \frac{I_c}{\beta} = \frac{1}{45} = 0.022mA$$

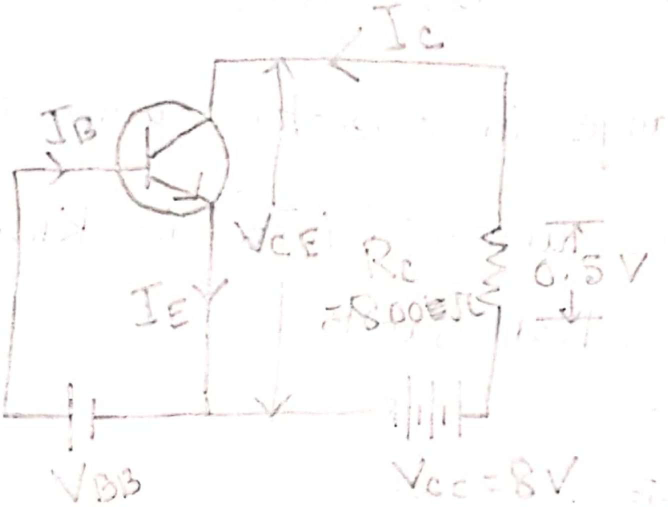
Ans:

Example 8.12: A transistor is connected in common emitter configuration in which collector supply is 8V and the voltage drop accross R_C connected in the collector circuit is 0.5V. The value of $R_C = 800\,\Omega$. If $\alpha = 0.96$ find:

(i) collector emitter voltage

(ii) base current.

Solution:



(i) Collector emitter voltage,

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

(ii) The voltage dropp across R_C is 0.5V

$$\therefore I_C = \frac{0.5V}{800\,\Omega} = 0.625\,mA$$

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

$$I_B = \frac{I_C}{\beta} = \frac{0.625}{24} = 0.026\,mA$$

Ans: