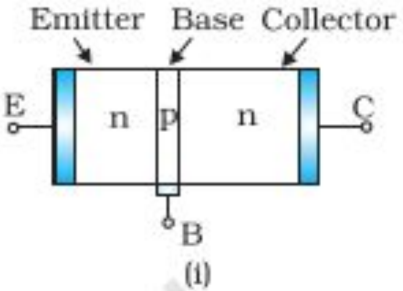
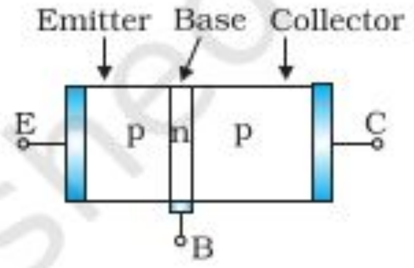
JUNCTION TRANSISTOR

Bipolar Junction Transistor (BJT)

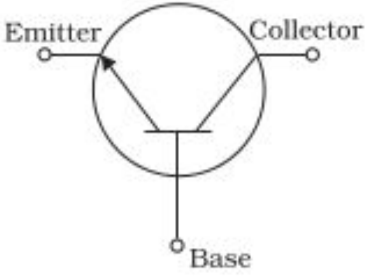
A transistor has three doped regions forming two p-n junctions between them.

Obviously, there are two types of transistors





n-p-n transistor : Here two segments of n-type semiconductor (emitter and collector) are separated by a segment of p-type semiconductor (base).



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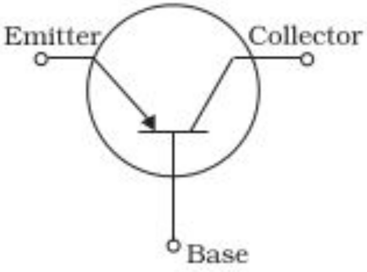
p-n-p transistor : Here two segments of p-type semiconductor (termed as emitter and collector) are separated by a segment of n-type semiconductor (termed as base)



Emitter

It is of moderate size and heavily doped. It supplies a large number of majority carriers for the current flow through the transistor.

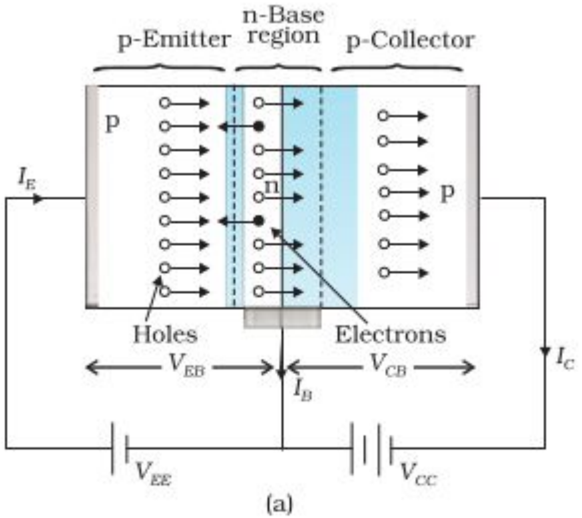
Base: This is the central segment. It is very thin and lightly doped.

Collector

This segment collects a major portion of the majority carriers supplied by the emitter. The collector side is moderately doped and larger in size as compared to the emitter.

Action of a p-n-p transistor

Holes are the majority carriers in p-n-p transistor. Since highly doped Emitter is in forward biased, it emits Holes (I_E). Since the base is thin and lightly doped, very few Holes combine with the Electrons making small base current (I_B).



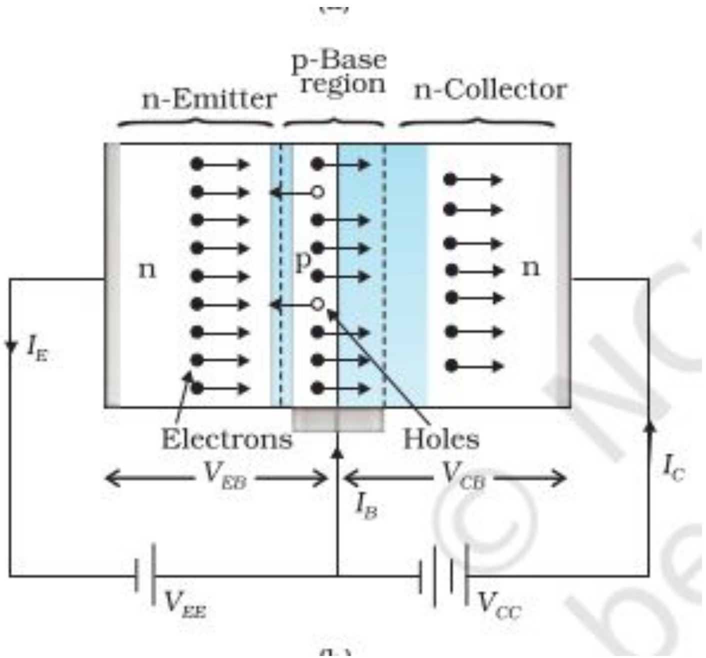
Collector current

Since Collector region is moderately doped and reverse biased, Holes that can't be combined to the Electrons move to the collector region making collector current.

Clearly we can write **$I_E=I_B+I_C$**

Since I_B is very small $I_E= I_B$ (nearly)

Action of an n-p-n transistor



Transistor characteristics

The transistor can be connected in either of the following three configurations:

Common Emitter (CE)

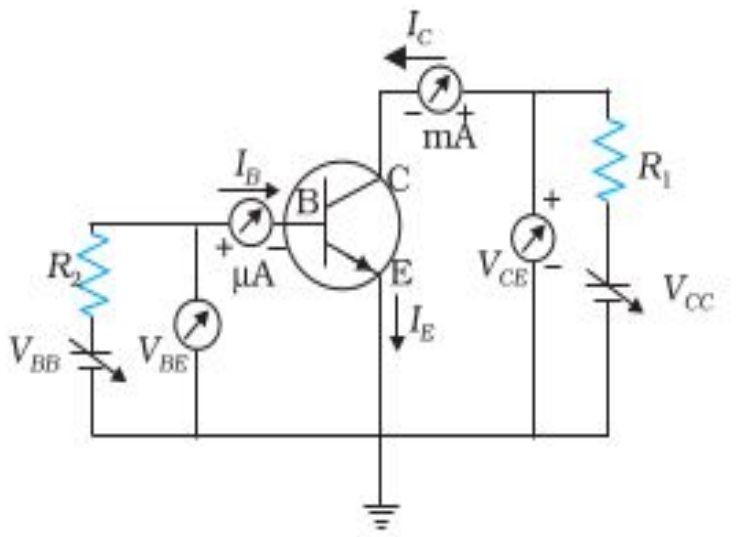
Common Base (CB)

Common Collector (CC)

Common emitter transistor characteristics

Here Emitter is common for both input and output circuits.

The input is between the base and the emitter and the output is between the collector and the emitter.



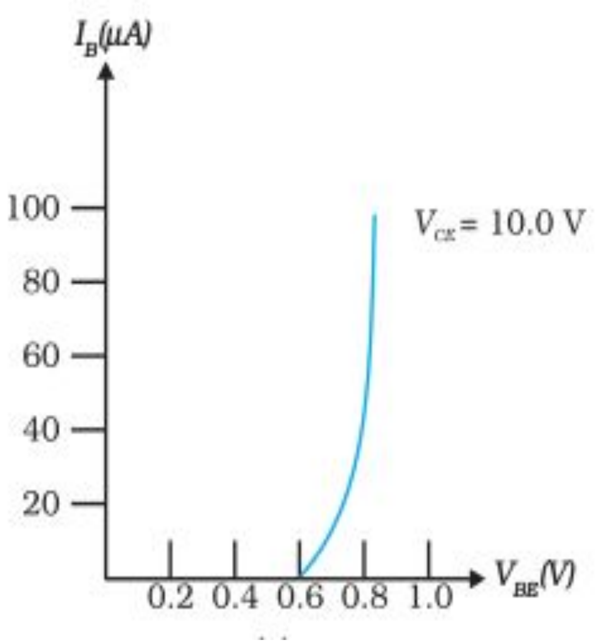
input characteristic

The variation of the base current I B with the base-emitter voltage V_{BE} is called the input characteristic.

Since $V_{CE} = V_{CB} + V_{BE}$

and for Si transistor V_{BE} is 0.6 to 0.7 V,

Then V_{CE} must be sufficiently larger than 0.7 V



Input resistance (r_i)

This is defined as the ratio of change in base- emitter voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE})

$$r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B}\right]_{V_{CE}}$$

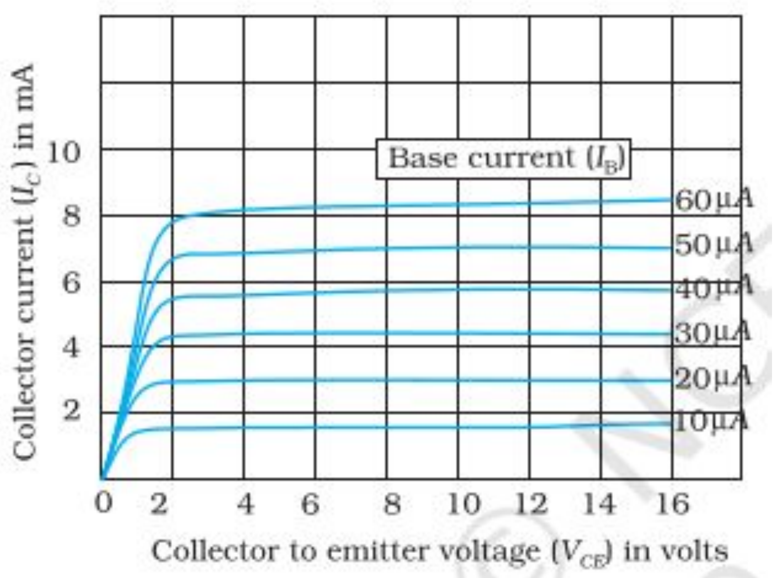
The value of r_i can be anything from a few hundreds to a few thousand ohms.

Output Characteristics

The variation of the collector current I_C with the collector-emitter voltage V_{CE} is called the output characteristic.

Output characteristics are controlled by the input characteristics.

This implies that the collector current changes with the base current.



Output resistance (r_o)

This is defined as the ratio of change in collector-emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a constant base current I_B.

$$r_o = \left[\frac{\Delta V_{CE}}{\Delta I_C}\right]_{I_B}$$

The output resistance of the transistor is mainly controlled by the bias of the base-collector junction.

Current amplification factor (β)

The ratio of the change in collector current to the change in base current at a constant collector-emitter voltage (V_{CE}) when the transistor is in active state.

$$\beta_{ac} = \left[\frac{\Delta I_C}{\Delta I_B} \right]_{V_{CE}}$$

This is also known as small signal current gain and its value is very large.

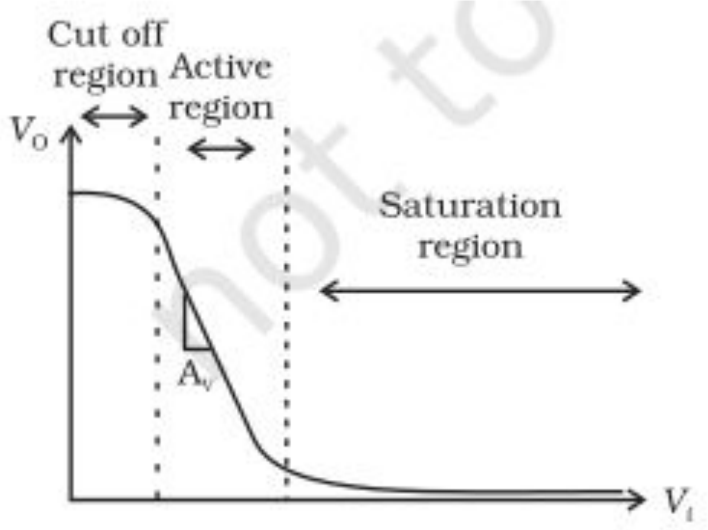
Without signal

$$\beta_{dc} = \frac{I_C}{I_B}$$

Since I_C increases with I_B almost linearly and $I_C = 0$ when $I_B = 0$, the values of both β dc and β ac are nearly equal.

Transistor as a device

When the transistor is used in the cutoff or saturation state it acts as a switch. On the other hand for using the transistor as an amplifier, it has to operate in the active region



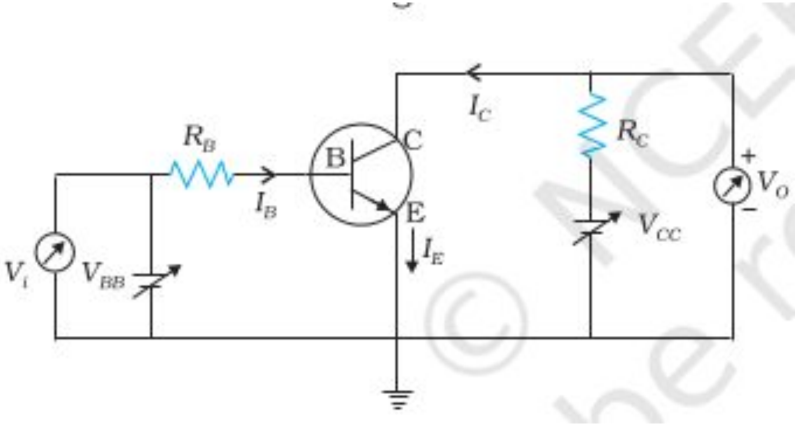
Transistor as a switch

Applying Kirchhoff's voltage rule to the input and output sides of this circuit, we get

$$V_i = V_{BB} = I_B R_B + V_{BE}$$

And

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



V_i is less than 0.6 V, the transistor will be in **cut off state** and current **I_c** will be zero. Hence $V_o = V_{CC}$

Output voltage is found to decrease towards zero in the saturation state, and **I_c** tends to maximum.

When the transistor is **not conducting** it is said to be **switched off** and when it is driven into **saturation** it is said to be **switched on**.

Transistor as an amplifier

Active region of the V_o versus V_i curve makes the transistor as amplifier.

We have, $\mathbf{V_o = V_{CC} - I_C R_C}$

And $\mathbf{\Delta V_o = 0 - R_C \Delta I_C}$ since $\mathbf{V_{CC}}$ is a constant

Voltage gain

Similarly, from $V_i = I_B R_B + V_{BE}$

Then $\Delta V_i = R_B \Delta I_B + \Delta V_{BE} = R_B \Delta I_B$ since ΔV_{BE} is neglible

Then voltage gain

$$A_v = \frac{\Delta V_o}{\Delta V_i} = \frac{-R_C \Delta I_C}{R_B \Delta I_B} = -\beta_{ac} \frac{R_C}{R_B}$$

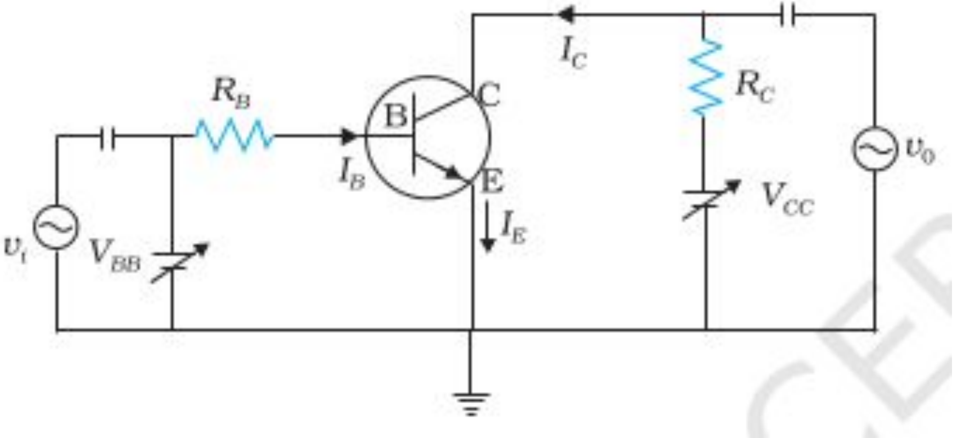
Where

$$\beta_{ac} = \left[\frac{\Delta I_C}{\Delta I_B}\right]_{V_{ce}}$$

Transistor as an Amplifier (CE-Configuration)

To operate the transistor as an amplifier it is necessary to fix its operating point somewhere in the middle of its active region.

The operating values of V_{CE} and I_B determine the operating point, of the amplifier.



Applying Kirchhoff’s law

$V_{cc} = V_{CE} + I_c R_L$ where R_L is the total load resistance

$\Delta V_{CC} = \Delta V_{CE} + R_L \Delta I_C = 0$, since V_{CC} is a constant

That is output voltage $\mathbf{v_o = \Delta V_{CE} = - R_L \Delta I_C}$

$V_{BB} = V_{BE} + I_B R_B$ where V_{BE} is a constant

That is input voltage $v_i = \Delta V_{BB} = 0 + (R_B + r_i)\Delta I_B = r\Delta I_B$

Where $r = (R_B + r_i)$ total input resistance

The voltage gain of the amplifier

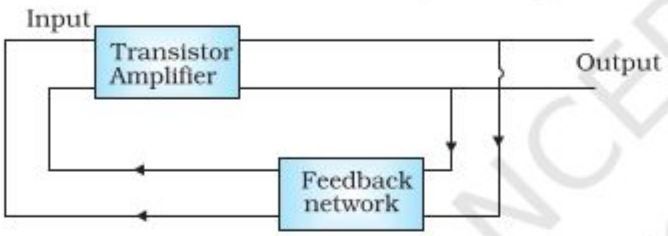
$$A_v = \frac{v_o}{v_i} = \frac{-R_L \Delta I_C}{r \Delta I_B} = -\beta_{ac} \frac{R_L}{r}$$

The negative sign represents that output voltage is opposite with phase with the input voltage.

Power gain A_p

Power gain = current gain x voltage gain

$$\mathbf{A_p = \beta_{ac} \times A_v}$$



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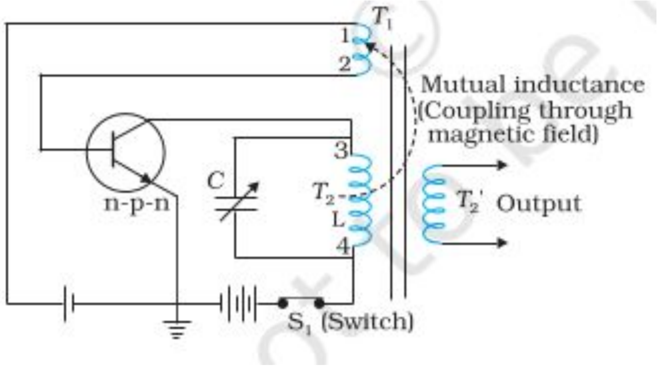
T1
1
2
Mutual inductance
(Coupling through
magnetic field)
3
C
T2
L
4
n-p-n
T2' Output
S1 (Switch)