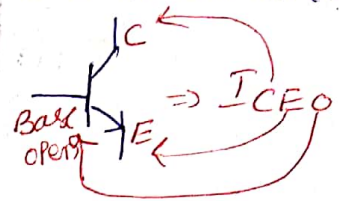


I_{CE0} : It is the collector current, when base terminal is open circuited, when $I_B = 0$

base = 0

$$I_{CE0} = I_C | I_B = 0$$



we know $I_C = \beta I_B + (1 + \beta) I_{C0}$
 $= \beta(0) + (1 + \beta) I_{C0}$

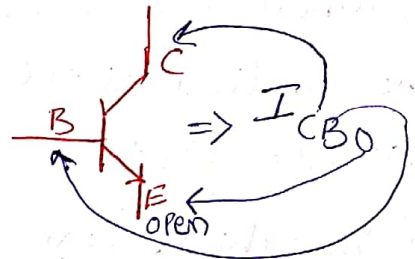
$$\therefore I_{CE0} = (1 + \beta) I_{C0}$$

I_{CBO} : It is the collector current, when emitter terminal is open circuited

emitter open

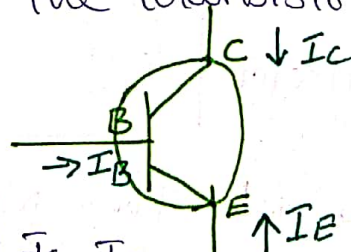
$$I_{CBO} = I_C | I_E = 0$$

we know $I_C = -\alpha I_E + I_{C0}$
 $= -\alpha(0) + I_{C0}$



$$\frac{I_{CBO} = I_{C0}}{I_{CE0} = (1 + \beta) I_{CBO}}$$

NOTE: ① when currents I_E , I_B and I_C are assumed to be flowing into the transistor, their sum must be zero.



$$I_E + I_B + I_C = 0$$

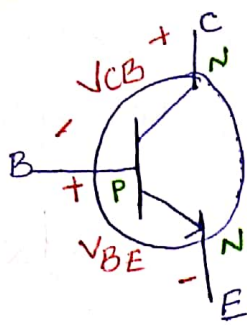
$$I_E = -(I_B + I_C)$$

as I_E negative, so it's flowing outside

① for NPN-transistor I_C , I_B are +ve and I_E is -ve

② The opposite is true for PNP-transistor.

NOTE (2):

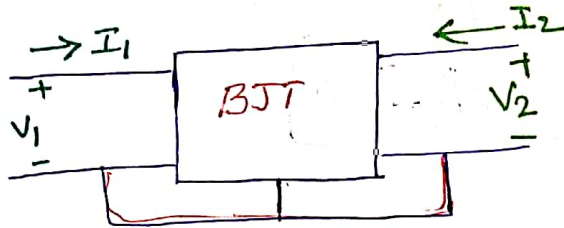


It is closed circuit the ⁽⁸⁾
 Sum of voltage should be zero
 EXPT
 APPLY KVL

$$-V_{CE} + V_{CB} + V_{BE} = 0$$

$$V_{CB} = V_{CE} - V_{BE}$$

⊙ BJT Characteristics:-



→ when a BJT is used in any circuit, I/P signal will be applied at one terminal known as "i/p node", O/P signal can be taken as another node known as "o/p node". And the third terminal will be used as Reference / common node.

→ BJT configuration implies, how the 3 terminals are utilized. It can be used in 3 configurations:-

configuration	I/P node	O/P node	common node
① common Base	E	C	B
② common Emitter	B	C	E
③ common collector	B	E	C

→ currents, which flow into i/p & o/p nodes are called i/p & o/p currents ' I_1 ' & ' I_2 '.

→ voltages of i/p & o/p nodes w.r.t. common node are called "i/p & o/p voltages" ' V_1 ' & ' V_2 '.

→ These four Parameters I_1, I_2, V_1, V_2 are interdependent; and these dependencies can be known by plotting "I-v graphs" known as BJT characteristics. ⑨

→ For our convenience, 2 Parameters I/P current I_1 & o/p voltage V_2 are assumed to be independent; whereas i/p voltage V_1 & o/p current I_2 are considered dependent.

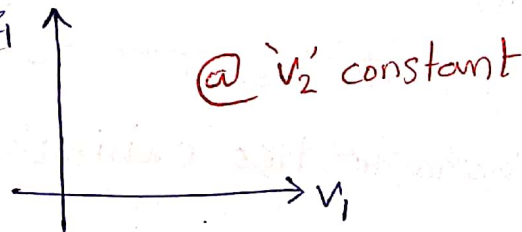
{ These assumption helps in h-parameter modelling of a transistor }

$$V_1 = f_1(I_1, V_2)$$

$$I_2 = f_2(I_1, V_2)$$

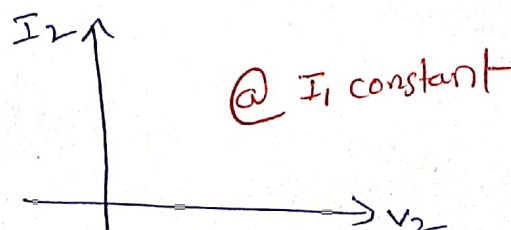
Now $V_1 = f_1(I_1)$ → If V_2 constant

→ A graph plotted b/w I/P current (I_1) & I/P voltage (V_1), while maintaining o/p voltage (V_2) constant is called "I/P characteristics".



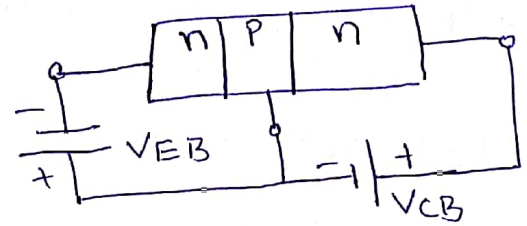
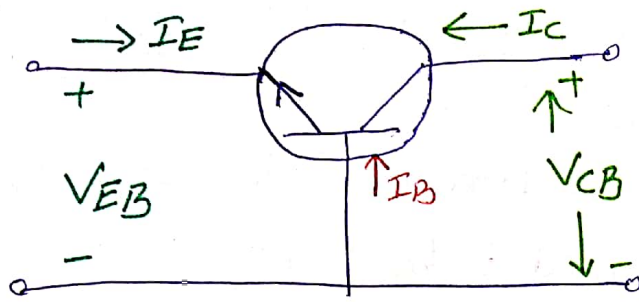
$V_2 = f_2(I_2)$ if I_1 constant

→ A graph plotted b/w o/p current (I_2) & o/p voltage (V_2) maintaining I/P current I_1 constant is called "output characteristics".



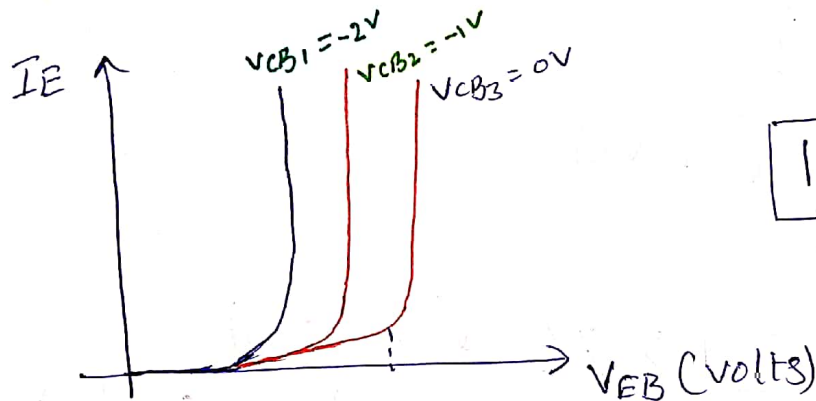
① "Common Base Characteristics":-

(10)



I/P characteristics:-

I_E v/s V_{EB} plot maintaining ' V_{CB} ' constant



$$|V_{CB3}| < |V_{CB2}| < |V_{CB1}|$$

→ For a transistor V_{EB} represents "voltage across emitter junction" and I_E is current through emitter junction. hence I_E v/s V_{EB} plot resembles junction characteristics.

→ I/P characteristics exhibits cut in voltage

→ For a given V_{EB} emitter current increases, with increase in V_{CB} due to Early effect. [V_{CB} keep on $\uparrow \rightarrow \Delta x \downarrow \rightarrow I_E \uparrow$ (effective base width)]

→ If V_{CB} is increased I/P characteristics shift left.

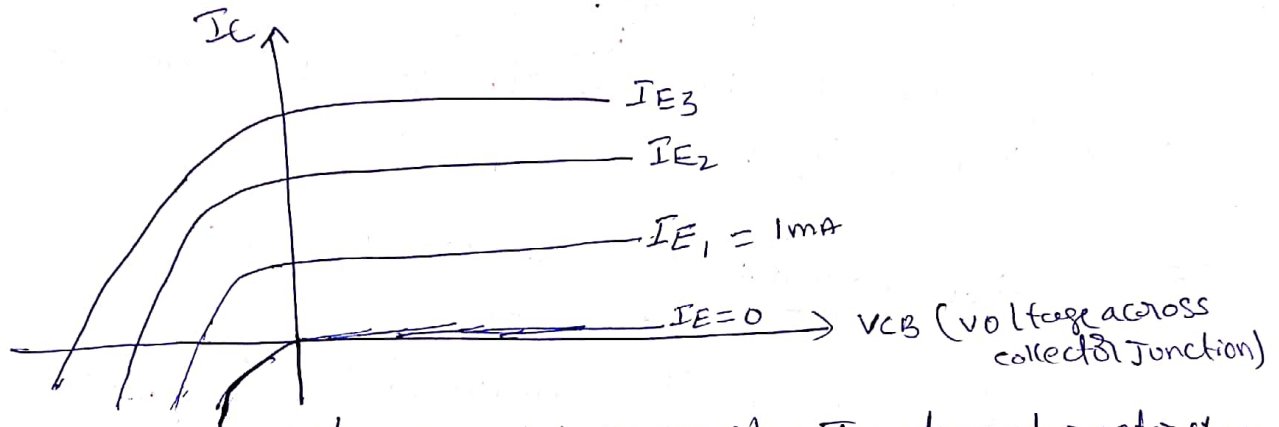
→ for a given I_E , higher the V_{CB} , lower the V_{EB}

($V_{CB} \uparrow, I_E \uparrow, @$ less V_{EB}).

o/p characteristics:-

(11)

I_C v/s V_{CB} plot maintaining I_E constant



→ If $I_E = 0$; I_C v/s V_{CB} plot resembles Junction characteristics.
 $I_E = 0 \rightarrow$ curve is plotted by taking, the Reverse bias current in 1st quadrant & ~~forward~~ forward bias current in 3rd quadrant.

→ when $I_E > 0 \rightarrow J_E$ in F.B $I_C = I_E + I_{C0}$ $I_C = -I_E + I_{C0}$
 current I_C will be the super position of 2 currents

(1) current coming from emitter Junction

(2) current because of V_{CB} .

→ o/p characteristics are divided into 3 regions

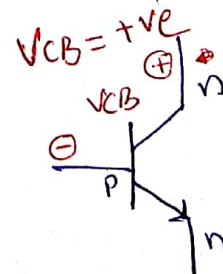
(a) Cut-off region: region of graph where $I_C = 0$.

It lies on $I_E = 0$ curve and to the right of $V_{CB} = 0$

In cut-off region J_E in R.B; J_C is also R.B

if $I_E = 0 \rightarrow J_E$ is in R.B

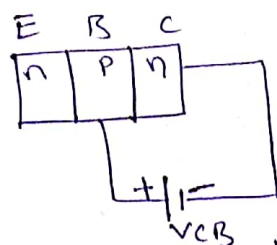
$V_{CB} > 0 \rightarrow J_C$ is in R.B
 $\downarrow$
 +ve



(b) saturation region: Region of graph, where I_C changes with V_{CB} . Here $I_E > 0 \rightarrow J_E$ is F.B

$V_{CB} < 0 \rightarrow J_C$ is in R.B } saturation mode
 ($V_{CB} \Rightarrow -ve$ means $V_{CB} < 0$)
 $\downarrow$
 E B C
 n p n

$$V_{CB} = -V_E$$



I_C in Forward Bias

(12)

→ In saturation region o/p current I_C depends upon both V_{CB} & I_E .

③ Active region:- Region of graph where I_C becomes constant.

$I_E > 0 \Rightarrow I_E$ forward bias } active mode.
 $V_{CB} > 0 \Rightarrow I_C$ is in R.B }

Here " I_C is independent on V_{CB} but depends on I_E "

BJT behaves as "current dependent-current source"

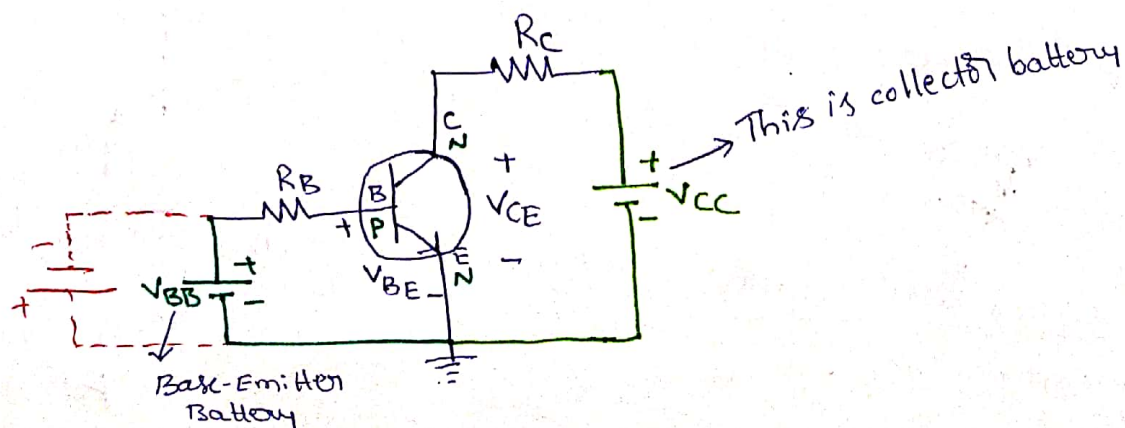
in active Region

$$\begin{aligned} I_C &= -\alpha I_E + I_{C0} \\ I_C &\approx -\alpha I_E \end{aligned}$$

we are often talking about common emitter circuit is most widely used common emitter.

② Common Emitter characteristics:-

Let us consider a simple circuit to measure current-voltage characteristics of the transistor in a common emitter circuit.



$V_{BE} \rightarrow$ voltage drop b/w base & emitter

$V_{CE} \rightarrow$ voltage b/w collector & emitter

There are two sides of the circuit, such as input & output that means input and output characteristics.

we can see in the above circuit, I_E is connected in forward bias and I_C is connected in Reverse bias.

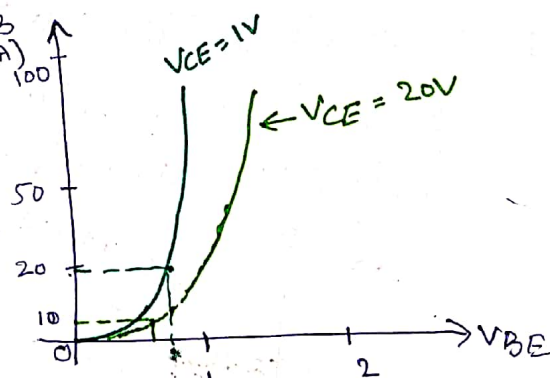
(i) Input Characteristics:-

This is Plotted $I_B = f(V_{BE})$ maintaining the o/p voltage V_{CE} is constant
 $\swarrow$
 function

Now we can plot this V_{BE} & I_B ; Here we can change the base current I_B by changing V_{BB} , then we can plot I_B v/s V_{BE} .

This graph just like forward biased Pn Junction diode.

Now keep $V_{CE} = 1V$ then we can change V_{BB} and we get current I_B this current is the exponential rise.



$\rightarrow$ Now we can change V_{CE} from 1V to 20V then there is a some change in these characteristics.

$\rightarrow$ If $V_{CE} = 20V$, This represents for the same voltage, but current will be decreased.

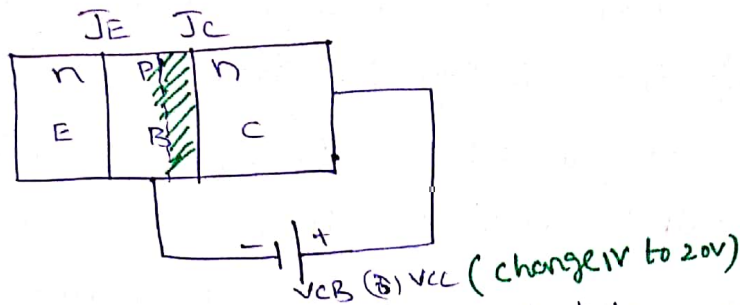
EX:- @ $V_{CE} = 1V$ then $I_B = 20mA$

@ $V_{CE} = 20V$ then $I_B = 10mA$

there is a small change in the base current because of effective base width is depend upon V_{CE} .

if $V_{CE} \uparrow \rightarrow V_{CB} \uparrow \rightarrow$ effective Base width $\downarrow \rightarrow$ no. of recombination $\downarrow \rightarrow I_B \downarrow$
 $(V_{CB} = V_{CE} - V_{BE})$

Ex:-



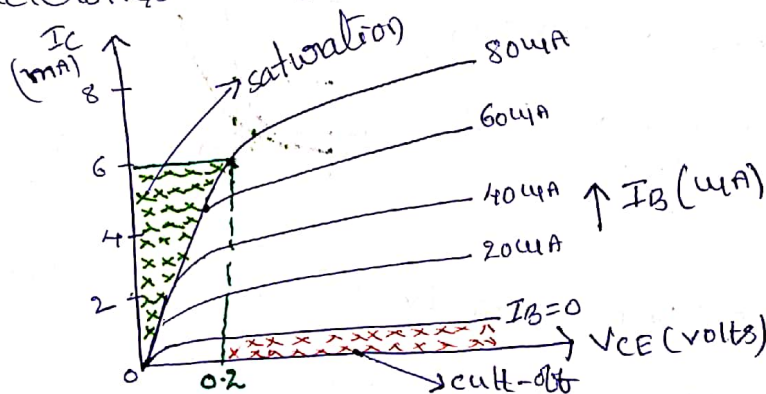
when we increase reverse voltage then depletion width increasing more into base side because of base is lightly doped.

(ii) output characteristics:

→ It is a plot b/w I_C v/s V_{CE} maintaining I_B constant.

It is $I_C = f(V_{CE}, I_B)$
 ↓
 collector current

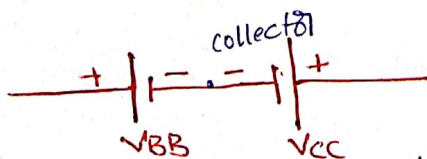
→ First we change I_B , and V_{CE} is constant then find I_C then we keep on changing the voltage V_{CC} and we get set of characteristics like this.



this output characteristics divided into three different region.

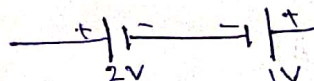
1. Saturation region:

In this region both junctions are forward biased. when this V_{CC} is very small then $V_{CE} = 0.2V$, for silicon transistor just $0.2V$.



if V_{CC} is very small then V_{BB} will be dominating

Ex:- if we take



then effective potential is difference of the two battery $2-1=1V$

(15)

V_{BB} is dominating and hence V_{CE} is negative.

→ collector is n type, when it is gets n battery connection it becomes forward biased. so for very small value of this V_{CE} the collector junction will be forward biased, and emitter junction is already forward biased.

→ In this region I_C current does not vary linearly with input current that's why we are not used for amplification purpose.

$$\left. \begin{array}{l} V_{CE}(\text{sat}) = 0.2 \text{ V} \\ V_{BE}(\text{sat}) = 0.8 \text{ V} \end{array} \right\} \text{ Si}$$

$$\left. \begin{array}{l} V_{CE}(\text{sat}) = 0.1 \text{ V} \\ V_{BE}(\text{sat}) = 0.3 \text{ V} \end{array} \right\} \text{ Ge}$$

2. Cut-off region:- This is the region below $I_B = 0$ is called cut-off region.

→ In this region both junctions are reverse biased.

$$\left. \begin{array}{l} I_B = 0 \Rightarrow I_E = 0 \Rightarrow J_E \text{ in R.B} \\ V_{CE} > V_{CE(\text{sat})} \Rightarrow J_C \text{ in R.B} \end{array} \right\} \text{ cut-off}$$

as $V_{CB} = V_{CE} - V_{BE}$

$V_{BC} = -V_{CB} = V_{BE} - V_{CE}$

[if we want to go below $I_B = 0$ then change the polarity p-type base is getting negative voltage] so that J_E is reverse biased, and J_C is already reverse biased. so both junctions are reverse biased. This is also not used for amplification purpose.

Note:- Two regions are useful, which are used in digital circuit, when transistor acts as a Switch.

③ Active region:- above $I_B = 0$ and the right side of saturation region this is called active region. (16)

In active region I_E is $F \cdot B$

I_C is $R \cdot B$

In the active region, increased the input current, the output current is changing for larger values, corresponding to small change in input current.

NOTE: we expected in the amplifying circuit output current should vary proportionally to the input current only the magnitude should change, but not shape.