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Unit-2 BJT (Bi-polar junction Transistor)

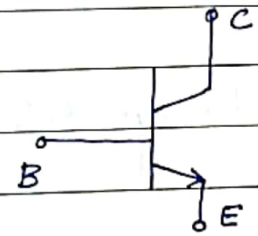
→ BJT stands for Bi-polar Junction Transistor

- Bi-polar → Means both e^- and h^+ participate in current conduction
- Junction → Has-2 p-n junctions
- Transistor → Transfer + Resistor

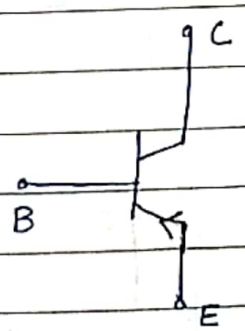
⇒ BJT is a 3-terminal electronic device in which both electrons and holes participate in current conduction.

⇒ **Types of BJT:-** Two types of BJTs are these :-

1. NPN



2. PNP



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Terminals of BJT :-

1. **Emitter :-** Emitter acts like a source. It is heavily doped b'coz it has to provide majority charge carriers.

   For pnp :- Majority charge carriers are holes (h^+).

   For npn :- Majority charge carriers are electrons (e^-).

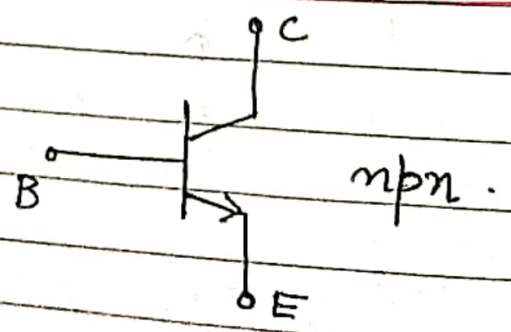
2. **Collector :-** It collects the majority charge carriers, provided by the emitter.

→ It is moderately doped.
→ Its area is largest among three terminals.

3. **Base :-** It acts as a bridge between Emitter and Collector.

→ Its area is smallest among the three terminals.
→ It is lightly doped.

Symbol of BJT :-



npn.

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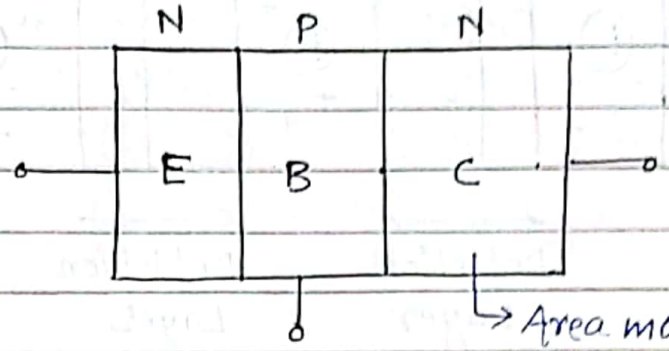
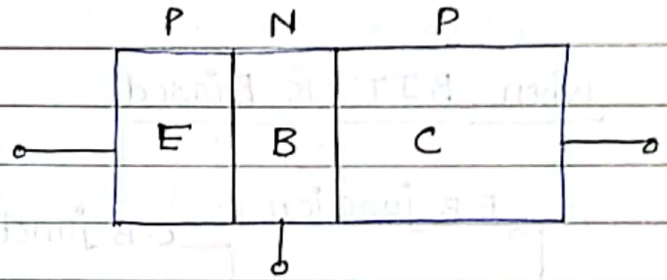
Construction of BJT :-

① NPN :-



→ Area more than Emitter.

② PNP :-



⇒ **Working of BJT :-** (In Active Mode)

CASE-1 When BJT is unbiased :- ① When BJT is unbiased means no external battery is connected to BJT.

② Depletion layer will be formed due to process of Diffusion.

③ Due to Variation in doping Concentration, the width of depletion layer is non uniform.

④ Net diffusion Current is Zero.

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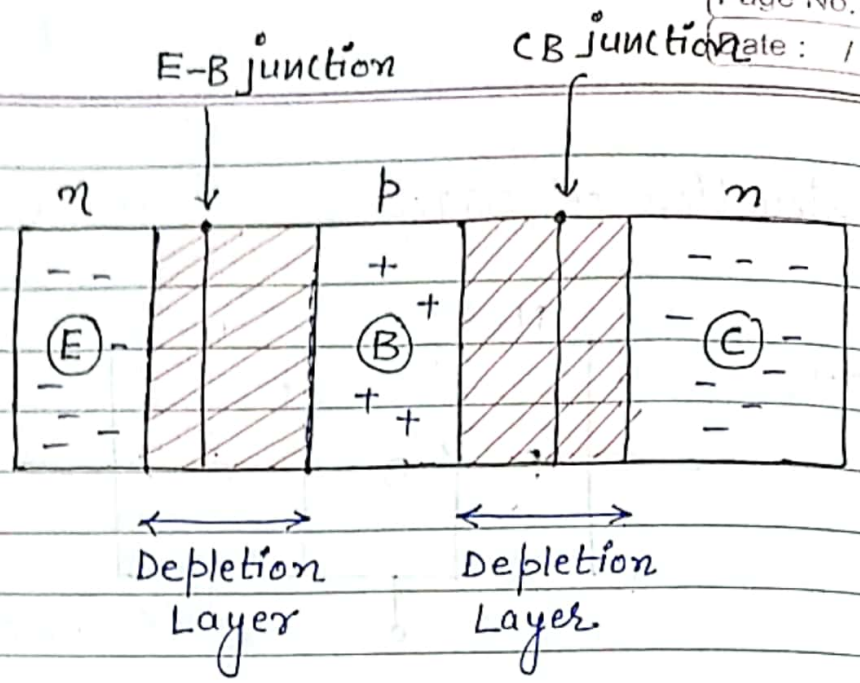
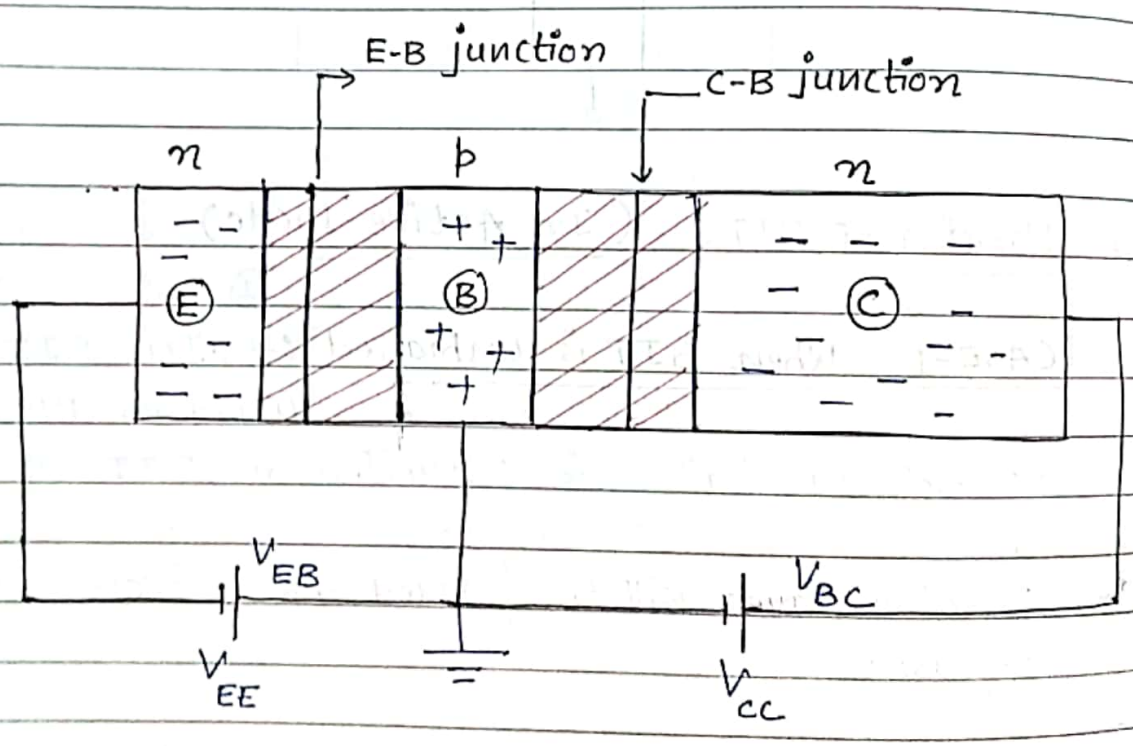


CASE-II When BJT is Biased



Note: ① Lighter is the doping, more will be the penetration of depletion layer, therefore width of depletion layer at EB junction is more towards base and less towards Emitter. Same at CB junction also.

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At EB junction :- ① EB junction is F.B hence Force of repulsion is exerted on majority charge carriers.

② After attaining cut in voltage (V_{EB}) which is 0.7V for Si and 0.3V for Ge, the charge carriers gain enough momentum to break depletion layer, hence current of the order of mA flows.

③ Few electrons get recombined in base and majority of electrons move towards collector.

At CB junction :-

① As CB junction is Reverse biased therefore force of attraction is applied on majority charge carriers (Holes of base and e^- of collector).

② No current flows due to majority charge carriers but a small amount of reverse saturation current flows due to minority charge carriers, therefore width of depletion layer at CB junction will be increased.

③ Reverse saturation current (I_{CO}) is of the order of μA.

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The total collector current

$$I_C = I_{C(majority)} + I_{CO}$$

& BJT Current Equation is $I_E = I_B + I_C$

In mA μA mA

Q No 1 Can two diodes be joined back to back to Form a BJT.

Sol^n No because —

① In BJT doping level and areas of Emitter, Base and Collector are diffrent whereas in diodes areas and doping of p & n-region is same.

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Region OF operation OF BJT :-

SNO	EB junction	CB junction	Region OF operation	Application
1.	F.B	R.B	Active Region	In Analog amplifiers
2.	F.B	F.B	Saturation Region	As ON switch
3.	R.B	R.B	CutOFF	As OFF switch
4.	R.B	F.B	Inverted	Never used.

Configuration OF BJT :-

1. Common Base Configuration (CB)
2. Common Emitter Configuration (CE)
3. Common Collector Configuration (CC)

1. Common Base Configuration :-

P.T.O

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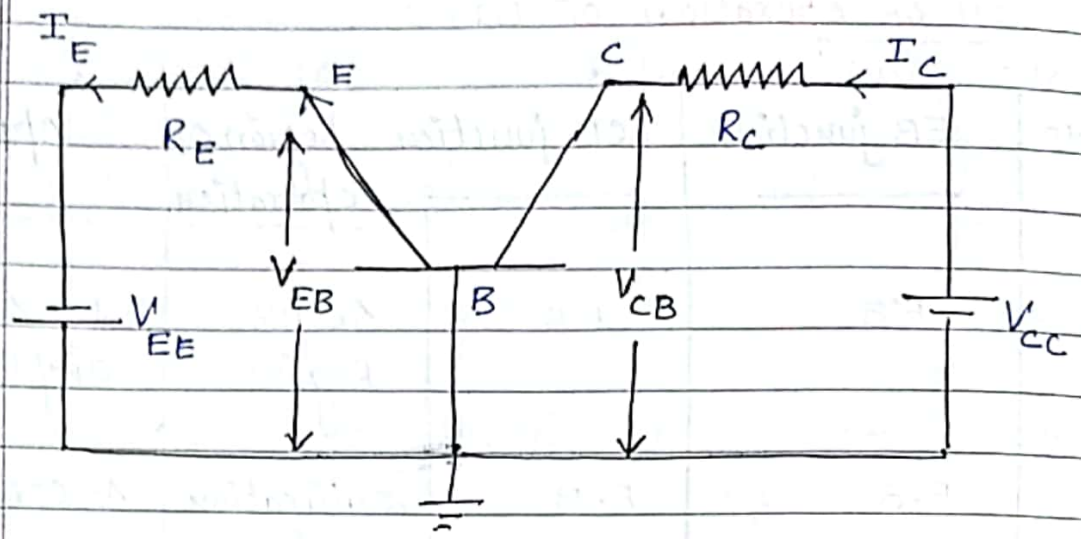


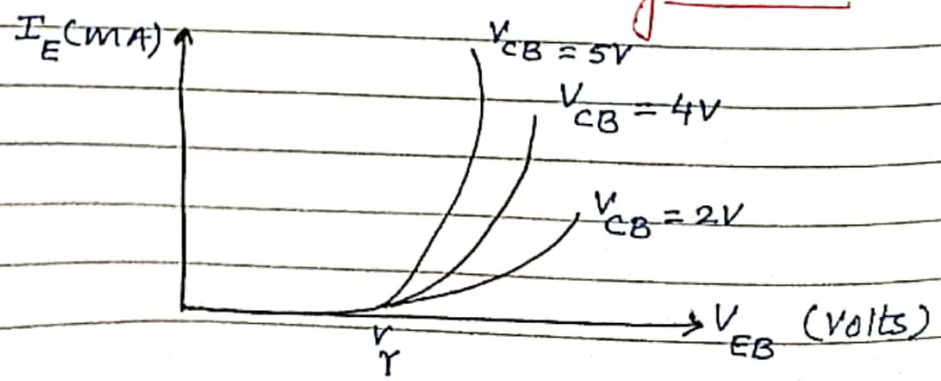
Note :- The direction of arrow of E determines the direction of Flow of Current.

Current Gain of CB Configuration :-

Current Gain $\boxed{\alpha = \frac{I_C}{I_E}}$

⇒ Since I_E is greater than I_C ∴ Value of α will always be Less than 1, Hence Common Base Configuration is never used For Amplification.

Input characteristics of CB Configuration :-



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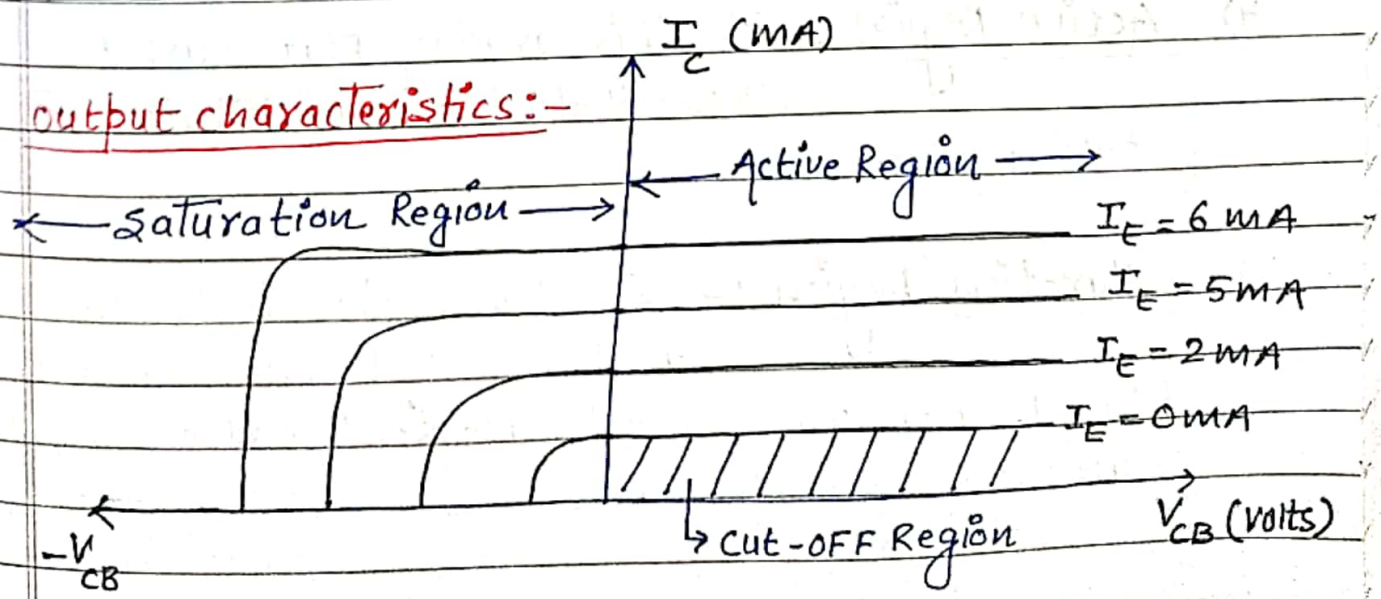
1) Input characteristics are plotted between Input Voltage V_{EB} and Input Current I_E, keeping output Voltage V_{CB} Constant.

2) Input characteristics are also called as Emitter Curves.

3) From the graph, we can see, when I/P Voltage $V_{EB} < V_\gamma$, Current $I_E = 0$, but as V_{EB} increases beyond V_γ, Current increases exponentially.

4) Input resistance $\boxed{r_i = \left.\frac{\Delta V_{EB}}{\Delta I_E}\right|_{V_{CB} \to \text{constant}}}$

output characteristics:-



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1) o/p char^s are plotted between output voltage V_{CB} and output Current I_C, keeping input Current I_E Constant.

2) o/p Curves are also known as Collector Curves.

3) Cut-OFF Region :- In Cut-OFF Region, we Can see if Input Current $I_E = 0$, the o/p Current I_C should be zero. But there, a small amount OF o/p Current I_C Flows.

This o/p current I_C is due to minority charge carriers, called as leakage Current, and this region is called as Cut-OFF Region.

4) Active Region :- In this region, Flat curve shows that no amplification is taking place.

5) Saturation Region :- In this region, both the junctions become Forward biased and o/p current doesn't depend on Input Current.

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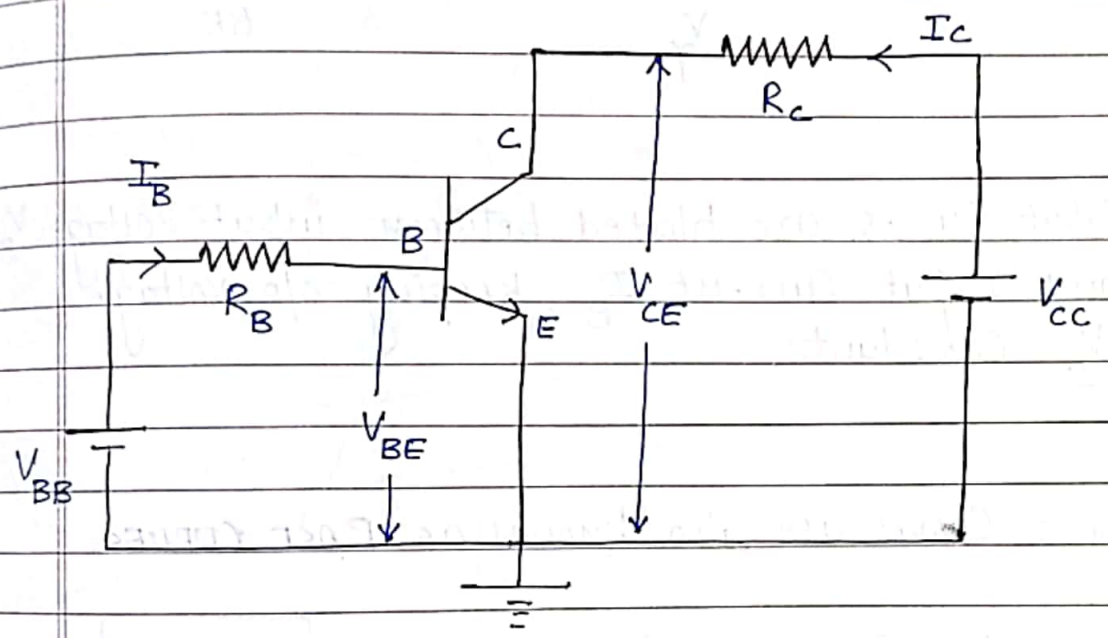
6) o/p resistance $\boxed{r_o = \left.\frac{\Delta V_{CB}}{\Delta I_C}\right|_{I_E \to \text{Constant}}}$

② Common Emitter Configuration :- (CE)



Current Gain :-

$$\beta = \frac{\text{o/p current}}{\text{I/p current}}$$

$$\boxed{\beta = \frac{I_C\ (mA)}{I_B\ (\mu A)}}$$

⇒ Since β is very large in value ∴ o/p current is much larger than I/p current applied, this is one of the major reason why CE configuration is always preferred for amplification.

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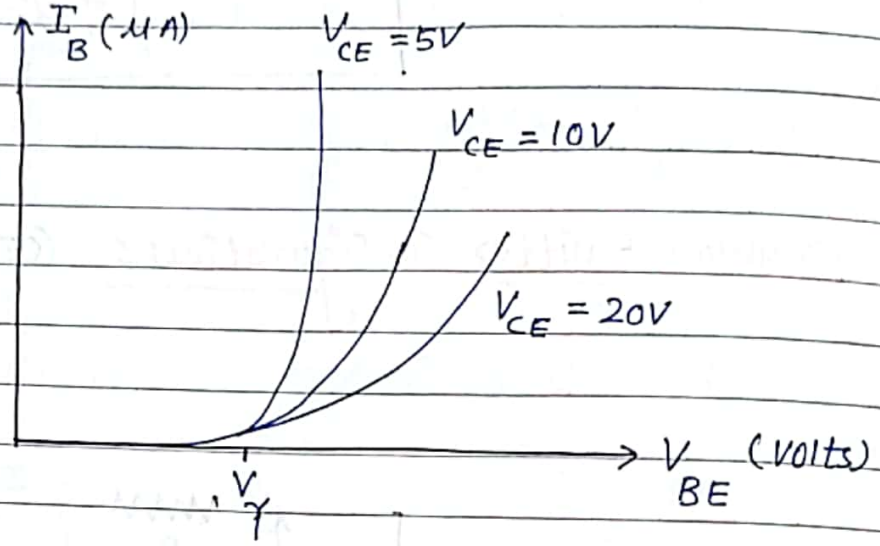
Input characteristics :-



1) Input Curves are plotted between input Voltage V_{BE} and Input Current I_B, Keeping o/p Voltage V_{CE} Constant.

2) These Curves are also known as BASE CURVES.

3) From the Curve we Can see, When $\boxed{V_{BE} < V_\gamma}$, the input Current $\boxed{I_B = 0}$ but when V_{BE} increases V_γ, I/p Current increases exponentially.

4) Input Resistance $\boxed{r_i = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE} \to \text{Constant}}}$

$\Rightarrow r_i = \frac{\text{Volts}}{\text{Amp} \times 10^{-6}} = \frac{V}{A} \times 10^6 = \underline{\underline{\text{mega ohm}}}$

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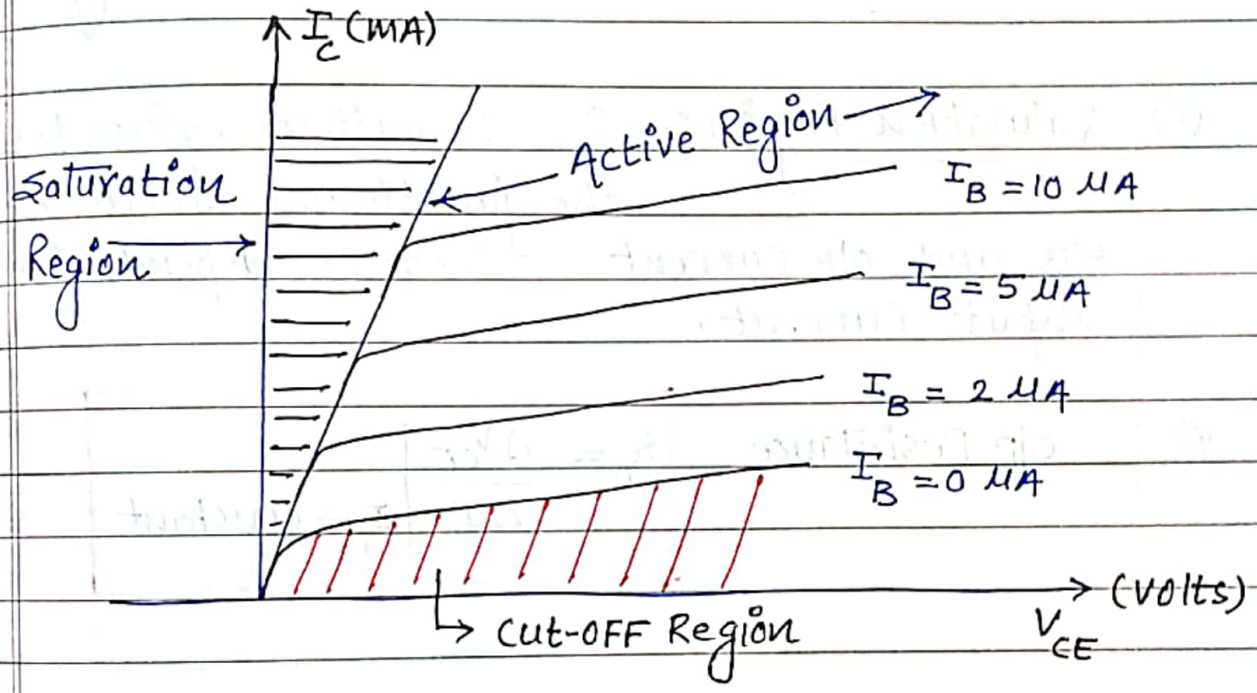
⇒ Due to very high Input impedance, CE Configuration is always preferred in amplification.

o/p characteristics :-



① o/p characteristics are plotted between o/p current I_C and o/p voltage V_{CE}, keeping I/p current I_B constant.

② These curves are also known as collector curves.

③ CutOFF Region - In Cut-OFF region, if I/p current $I_B = 0$, the o/p current I_C should also be zero, but a small amount of o/p current I_C flows, this is due to minority charge carriers

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Called as Leakage Current and this region is Called as Cut-OFF Region.

④ Active Region :- The upward going curves shows that a faithful amplification is taking place

⑤ Saturation Region :- In saturation region, both the junctions become FB and o/p current doesnot depend upon Input Current.

⑥ o/p Resistance $\boxed{r_o = \left.\frac{\Delta V_{CE}}{\Delta I_C}\right|_{I_B \to \text{constant}}}$

Relation Between α and β :-

We know

$$\boxed{I_C = \alpha I_E}$$

but $I_E = I_B + I_C$

$$\therefore \quad I_C = \alpha (I_B + I_C)$$

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$$\Rightarrow \quad I_C - \alpha I_C = \alpha I_B$$

$$I_C (1-\alpha) = \alpha I_B$$

$$\therefore \frac{I_C}{I_B} = \frac{\alpha}{1-\alpha}$$

$$\boxed{\beta = \frac{\alpha}{1-\alpha}} \longrightarrow (1)$$

From Eqn (1) :- $\beta(1-\alpha) = \alpha$

$$\beta - \beta\alpha = \alpha$$

$$\Rightarrow \quad \beta = \alpha(1+\beta)$$

$$\boxed{\alpha = \frac{\beta}{1+\beta}}$$

Expression For Leakage Current in CE Configuration:-

We know

$$\boxed{I_C = I_{C(majority)} + I_{CBO}} \longrightarrow (1)$$

but $I_{C(maj)} = \alpha I_E$, put in eqn (1)

$$I_C = \alpha I_E + I_{CBO}$$

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$\Rightarrow \quad I_C = \alpha (I_B + I_C) + I_{CBO}$

$I_C = \alpha I_B + \alpha I_C + I_{CBO}$

$I_C - \alpha I_C = \alpha I_B + I_{CBO}$

$I_C (1-\alpha) = \alpha I_B + I_{CBO}$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$$

$\Rightarrow$ But $\boxed{\frac{\alpha}{1-\alpha} = \beta}$ and $\boxed{\frac{1}{1-\alpha} = 1+\beta}$

$\therefore \quad \boxed{I_C = \beta I_B + (1+\beta) I_{CBO}}$

Hence Leakage Current $\boxed{I_{CEO} = (1+\beta) I_{CBO}}$

Note :- $\frac{1}{1-\alpha} = \frac{1}{1-\frac{\beta}{1+\beta}} = \frac{1+\beta}{1+\beta-\beta}$

$\therefore \quad \boxed{\frac{1}{1-\alpha} = 1+\beta}$

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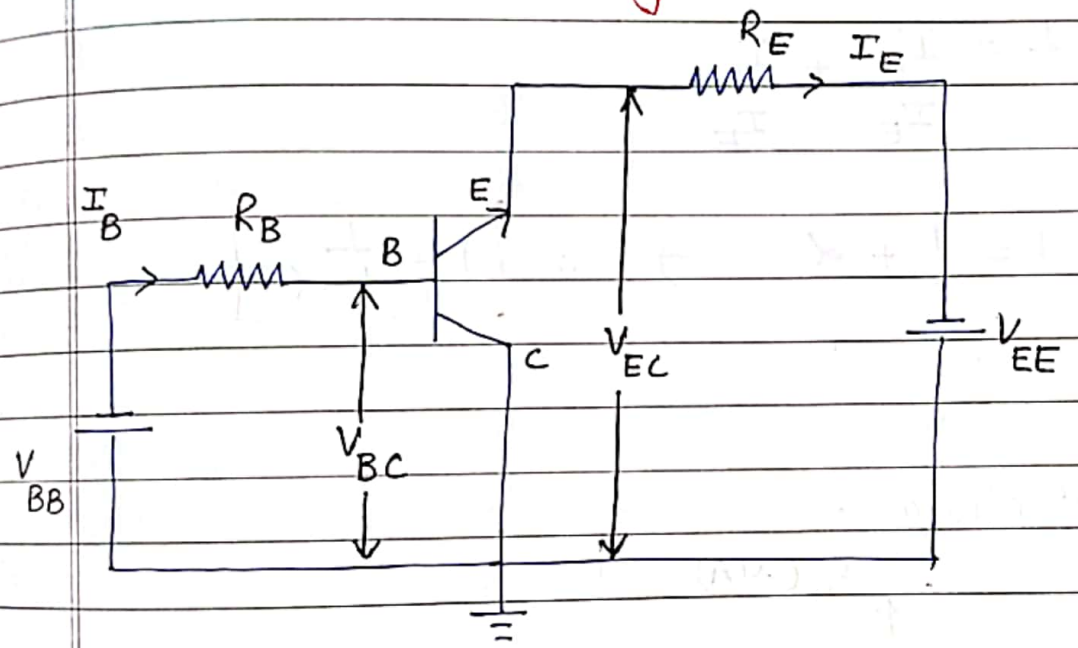
Note: I_{CO} → Leakage Current (General term)

I_{CBO} → Leakage Current in Common Base Configⁿ.

I_{CEO} → Leakage Current in CE Configuration.

I_{CCO} → leakage Current in CC Configuration.

③ Common Collector Configuration :-



Current Gain :-

$$\gamma = \frac{I_E\ (mA)}{I_B\ (\mu A)}$$

Relation Between α, β and γ :- We know

$$I_E = I_B + I_C \longrightarrow ①$$

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⇒ Dividing Eqn ① by I_B :-

$$\frac{I_E}{I_B} = 1 + \frac{I_C}{I_B}$$

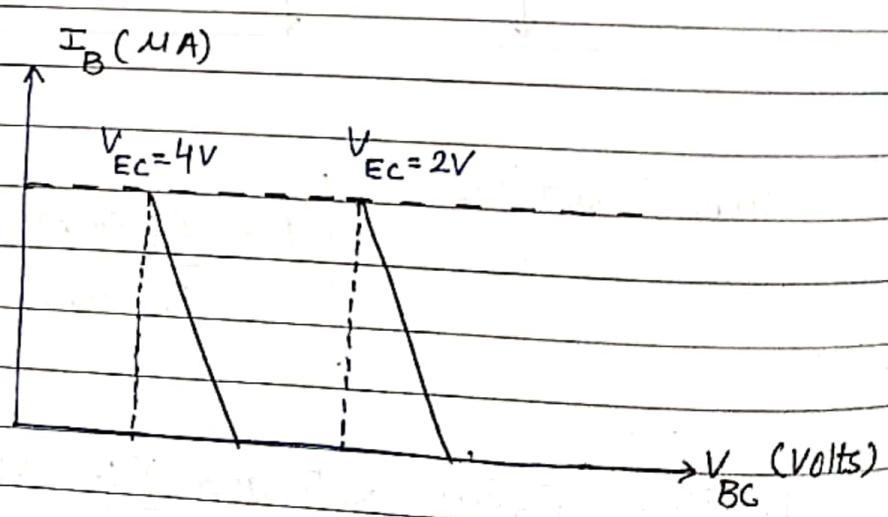
$$\boxed{\gamma = 1+\beta}$$

⇒ Now Dividing Eqn ① by I_E :-

$$1 = \frac{I_B}{I_E} + \frac{I_C}{I_E}$$

$$1 = \frac{1}{\gamma} + \alpha \quad \Rightarrow \quad \therefore \boxed{\gamma = \frac{1}{1-\alpha}}$$

⇒ Input charas :-



① Input Curves are plotted between I/P voltage V_{BC} & I/P Current I_B, keeping o/p voltage V_{EC} constant.

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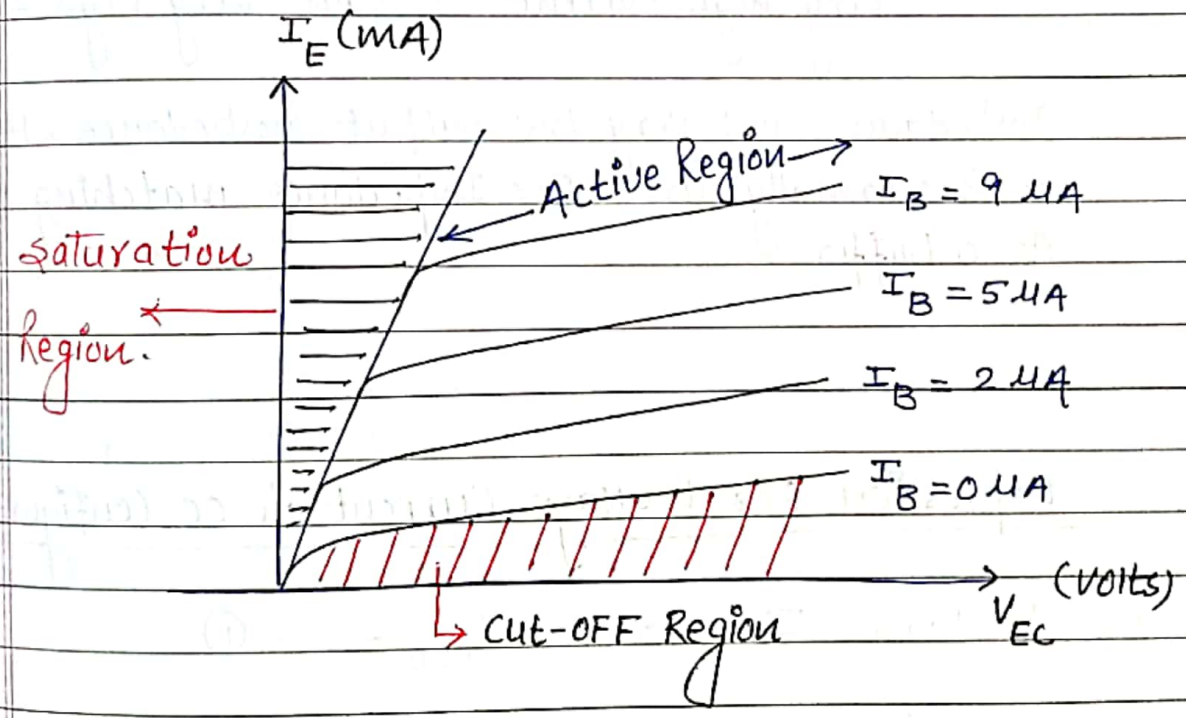
② These Curves are also known as BASE CURVES.

③ Nearly straight line of the Curve shows that the input resistance of CC configuration is very high.

④ Input Resistance $\boxed{r_i = \left.\frac{\Delta V_{BC}}{\Delta I_B}\right|_{V_{EC} \to \text{Constant}}}$

⇒ output characteristics :-



① These Curves are plotted between o/p Voltage V_{EC} & o/p current I_E, keeping I/p Current I_B Constant.

② These Curves are also known as Emitter Curves.

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3. Cut-OFF Region :-

4. Saturation Region :-

5. Active Region :-

Same Explanation As of CE Configuration.

6. O/P Resistance $\boxed{r_o = \left.\frac{\Delta V_{EC}}{\Delta I_E}\right|_{I_B \to \text{Constant}}}$

Note :- Common Collector Configuration has a Very high Current Gain, very high I/P Impedance and very low output impedance. Hence it is normally used For Impedance matching or As a Buffer.

Expression For Leakage Current in CC Configuration:-

⇒ We know $I_C = \alpha I_E + I_{CBO}$ —— ①

and $I_E = I_B + I_C$ —— ②

⇒ From eqn ① & ② :-

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$$\Rightarrow I_E = I_B + \alpha I_E + I_{CBO}$$

$$I_E - \alpha I_E = I_B + I_{CBO}$$

$$I_E (1-\alpha) = I_B + I_{CBO}$$

$$I_E = \frac{I_B}{1-\alpha} + \frac{I_{CBO}}{1-\alpha}$$

$$\boxed{I_E = \gamma I_B + \gamma I_{CBO}}$$

$$\therefore \boxed{I_{CCO} = \gamma I_{CBO}}$$

or

$$\boxed{I_{CCO} = (1+\beta) I_{CBO}} \qquad \because \boxed{\gamma = 1+\beta}$$

QNo Why CE configuration is always preferred for amplification.

OR

Which configuration, among CB, CE & CC is the best & why.

Ans:- CE configuration is always preferred for amplification b'coz :-

1. High Current Gain (β)
2. High I/p Resistance
3. Low O/p Resistance
4. High Voltage Gain

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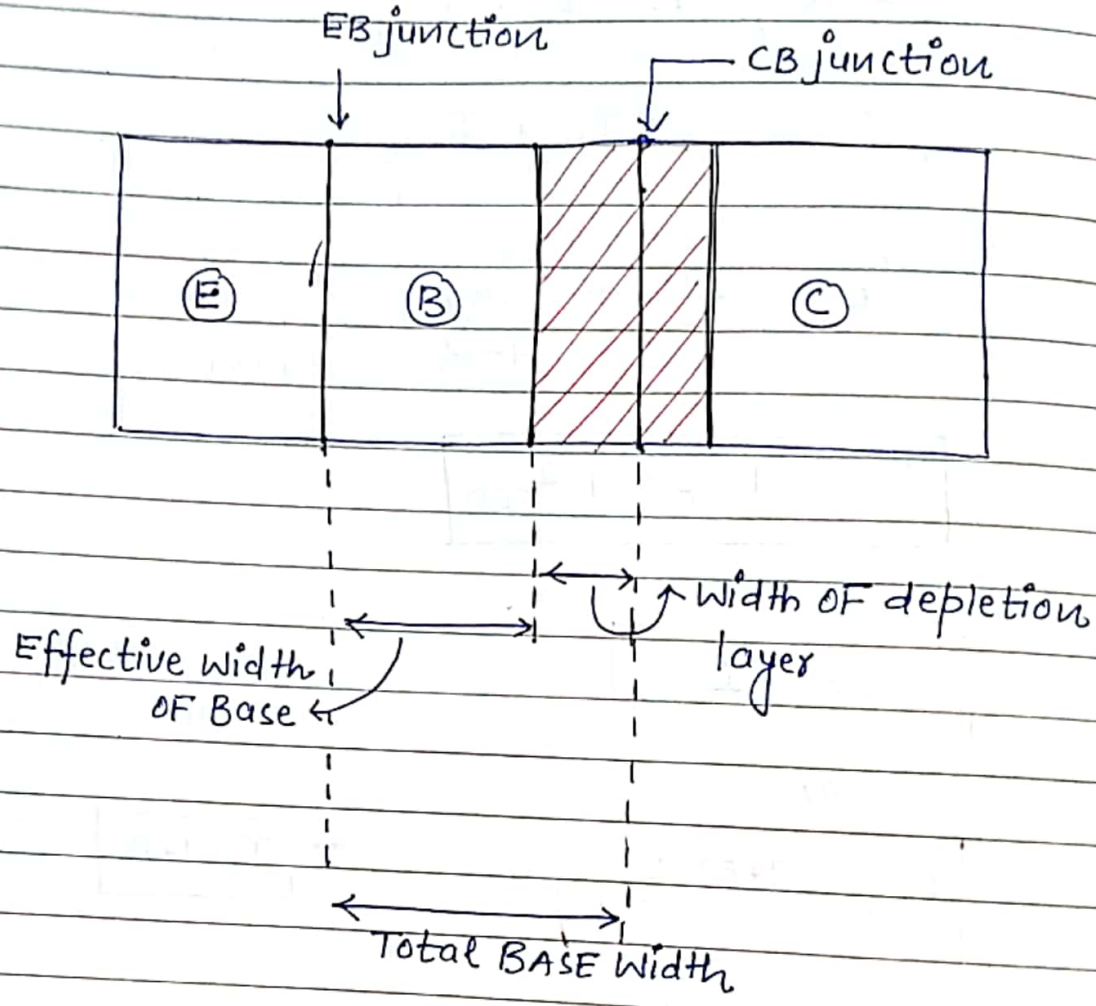
Early Effect OR Base Width Modulation :-



⇒ Total Base Width = Width OF depletion layer at CB junction extended into base
+
Width OF region Containing Free Charge Carriers at EB junction

⇒ Depletion Layer at EB junction is Neglected b'coz EB junction is F.B.

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⇒ As $V_{CB} \uparrow\uparrow$, width of depletion layer also $\uparrow\uparrow$

therefore Effective width of base $\downarrow\downarrow$.

⇒ In order to maintain equlibrium between emitter & base, more no. of electrons diffuse from Emitter to Base.

Hence I_E increases.

Hence As $\boxed{V_{CB} \uparrow\uparrow, I_E \uparrow\uparrow.}$

This is Early Effect or Base width modulation.

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