Transistor :-

↳ Transfer resistor

Two types :- (1) n-p-n transistor

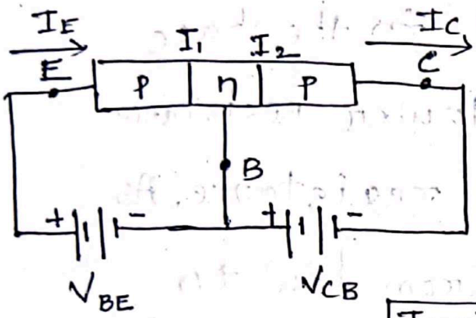
(2) p-n-p transistor

Three terminals of transistor :-

→ Emitter

→ Base

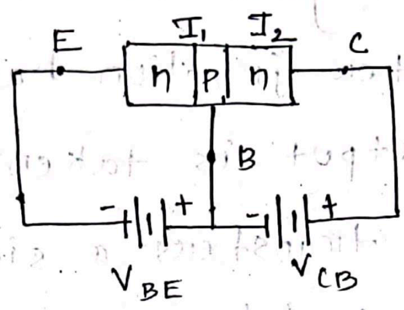
→ ~~Collection~~ collector.



(p-n-p)

$\boxed{I_E = I_B + I_C}$

$\boxed{I_C = I_{Majority} + I_{Minority}}$



(n-p-n)

Width : C > E > B

Doping : E > C > B

I_1 = Base emitter junction (Forward based)

I_2 = collector base junction (Reverse based)

→ In BJT (Bipolar junction transistor) both e^- & holes are responsible for conduction.

∴ It is called as bipolar junction transistor.

→ Here base is thiner than collector & emitter. Emitter is heavily dopped so that it can eject a large no. of charge carriers i.e e^- or holes into the base.

→ Base is slightly dopped & very thin. So, it passes most of the emitter ejected charge carrier to the collector.

→ Collector is moderately dopped.

→ Size & width is max^m, bcoz it has to collect the e^-.

→ For transistor operation, the emitter based junction is always forward base & collector based junction is always reversebase.

→ Weak signals are introduced in the base emitter junction having lower resistance & output is taken high resistance. As BJT transfers a signal from low to high resistance, it is known as transistor, ~~it is known a~~ or transfer resistance.

→ BJT generally used in amplification of weak signals & in switching operations.

→ $I_E = I_B + I_C$

$I_C = I_{Majority} + I_{minority}$

$I_C = I_M + I_{CO}$

I_{CO} = Collector current with emitter open.

I_E & I_C is is mA range.

I_B is in μA range.

Types of transistor configuration:-

(1) Common base (CB):-

(2) Common Emitter (CE):-

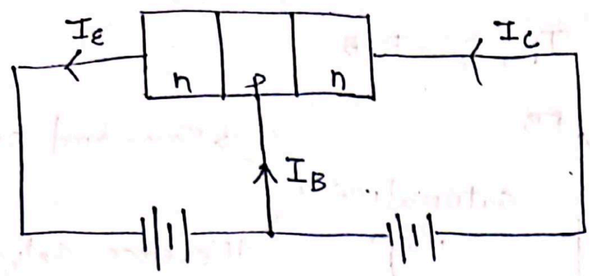
(3) Common Collector (CC):-

COMMON BASE :-

19/09/19

$I_E = I_B + I_C$

$I_E \leftarrow$ p, $\downarrow$ n I_B, $\rightarrow I_C$ p



$$\boxed{I_C = I_{C\,maj} + I_{C\,min}}$$

$$I_C \cong I_{C\,maj}$$

$$\boxed{I_C = I_{C\,maj} + I_{CBO}}$$ [when input side is open]

Here; $\boxed{\alpha = \frac{I_C}{I_E}}$

$\Rightarrow I_{C\,maj} = \alpha I_E$

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

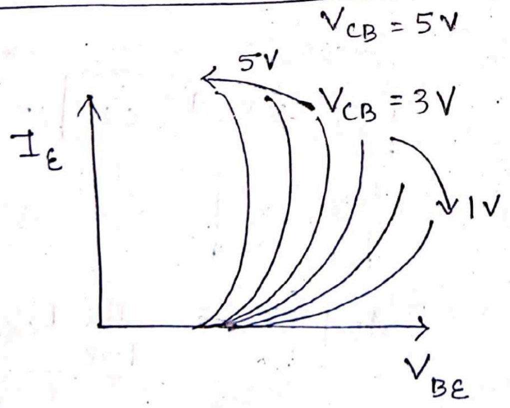
$\Rightarrow I_C = \alpha(I_C + I_B) + I_{CBO}$

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

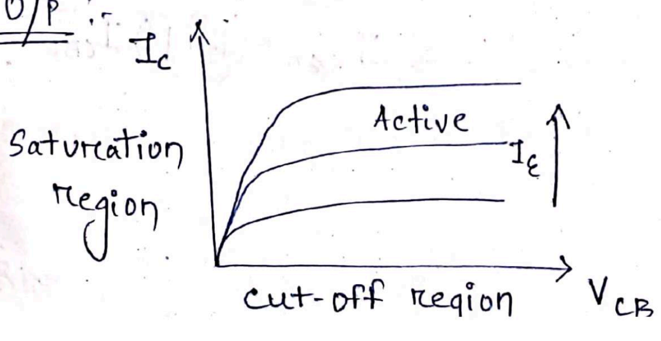
$\Rightarrow I_C(1-\alpha) = \alpha I_B + I_{CBO}$

$$\Rightarrow \boxed{I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}} \quad \text{—— (1)}$$

i/p :-



O/P :-



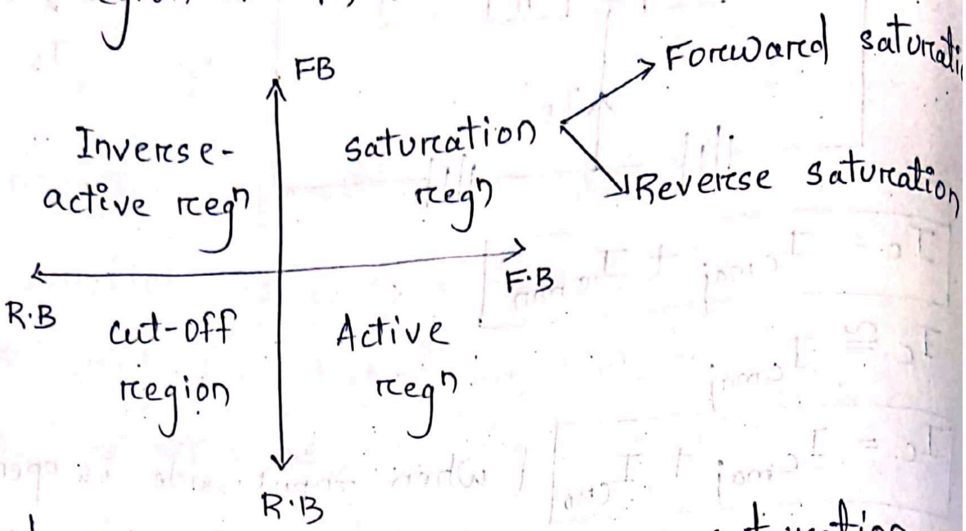
I_E = Constant

Output

Saturation region → J_i, J_o = F·B

Active region → J_i = F·B, J_o = RB

Cut-off region → J_i, J_o = R·B



Forward saturation;

$i_o = I_E \uparrow + \cancel{I_C} \to 0$

when $V_{BE} > V_{BC}$

$J_i > J_o$

Reverse saturation;

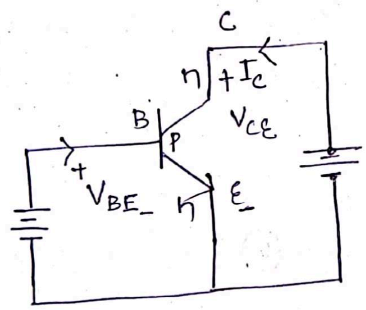
$i_o = I_C \uparrow + \cancel{I_E} \to 0$

when $V_{BC} > V_{BE}$

$J_o > J_i$

Imp

COMMON EMITTER :-



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

$I_{C\,maj} = \beta I_B$

When it opens,

I_{CEO}

$$\boxed{I_C = \beta I_B + I_{CEO}} \quad \text{—— (2)}$$

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

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

$\Rightarrow (\beta+1) = \frac{\alpha}{1-\alpha} + 1$

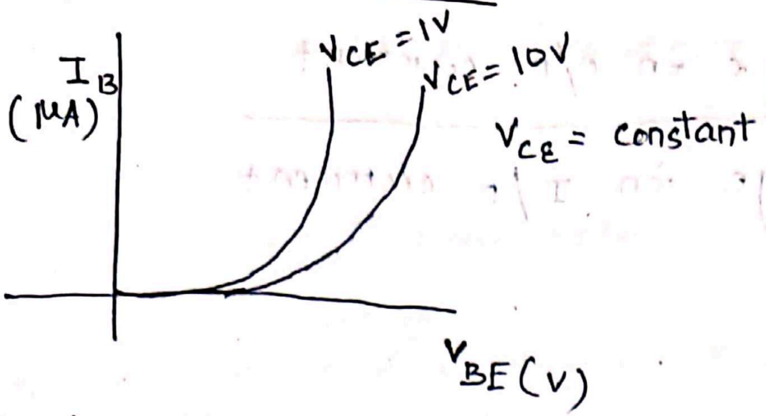
$$\Rightarrow \boxed{(\beta+1) = \frac{1}{1-\alpha}}$$

And $\boxed{I_{CEO} = \frac{1}{1-\alpha} I_{CBO}}$

$\Rightarrow I_{CEO} = (\beta+1) I_{CBO}$.

23/09/2019

Input V-I characteristic :-

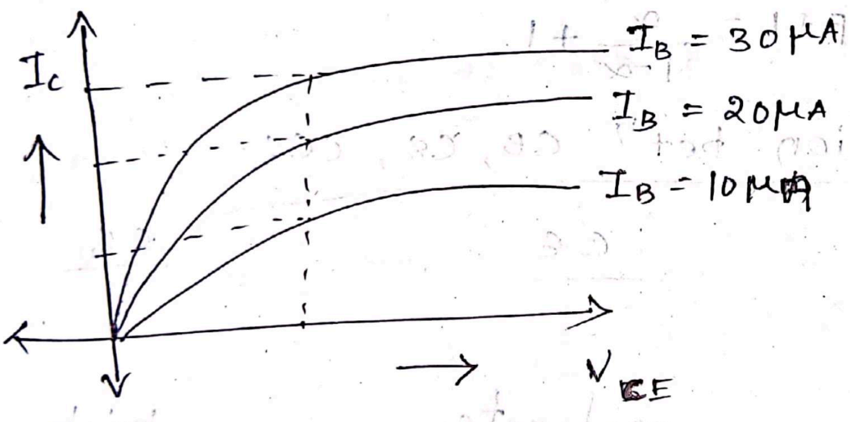


→ Input V-I characteristic curve is curve betn i/p ~~vot~~ current I_B & o/p voltage V_{CE} keeping constant.

→ By increasing V_{CE}, V_{BE} is increasing.

Output V-I characteristic :-

→ It is the characteristic betn o/p voltage V_{CE} & output current I_{CE} keeping input current I_B constant..



→ By increasing I_B, I_C current is increasing also.

→ In o/p characteristics, the bend shape is because of early effect.

Common Collector (CC conn):-

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Amplification factor:-

$$\gamma = \frac{\text{change in o/p current}}{\text{change in I/p current}}$$

$$= \frac{\Delta I_E}{\Delta I_B}$$

$$= \frac{\Delta (I_C + I_B)}{\Delta I_B}$$

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

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

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

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

Comparision betn CB, CE, CC:-

	CB	CE	CC
I/p impendance:-	Low	moderate	high
O/p impendance:-	High	Moderate	Low
voltage gain:-	High	moderate	Low
Current gain:-	Low	moderate	high
power gain:-	NO	moderate	NO

→ Out of this 3 configuration, CE is mostly used. Bcoz, CE has both voltage as well as current gain.

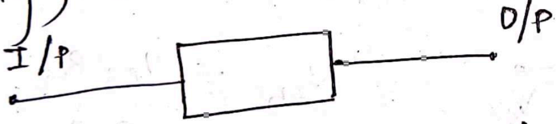
→ Any amplifier having both current & voltage gain. It is ~~called~~ having power gain.

Region of operation :-

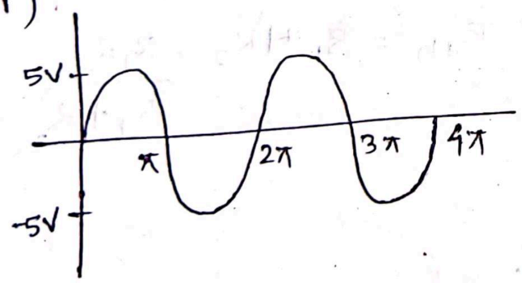
	J_E	J_C
① Active (Amplifier) →	Forward bias →	Reverse bias.
② Saturation (ON switch) →	FB →	FB
③ Cut off (OFF switch) →	RB →	RB
④ Inverse active (Attenuation) →	RB →	FB

Biasing in BJT :-

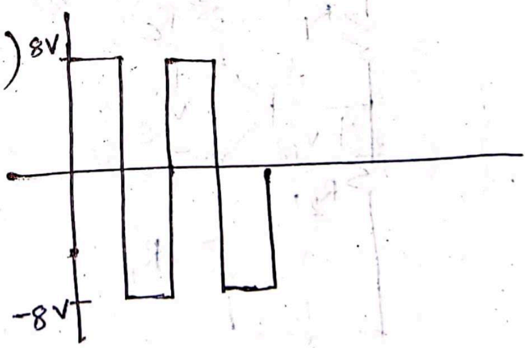
→ Because, $cond^n$ is due to both e^- & poles. (both polarity).



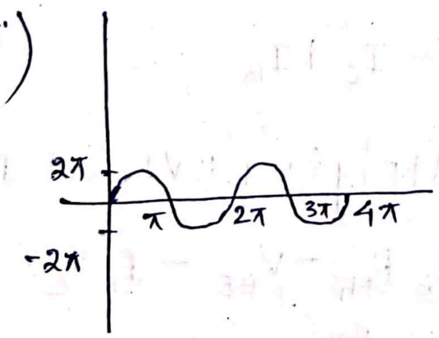
(i)



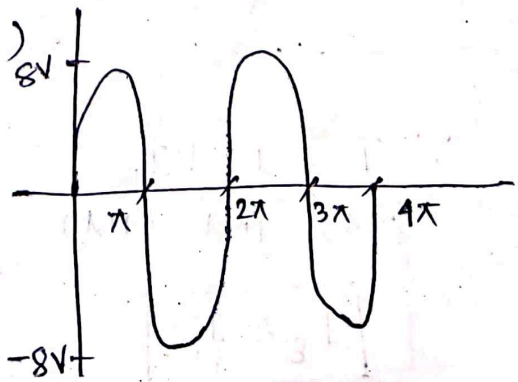
(ii)



(iii)



(iv)



→ For faithful amplification o/p of amplifier should be exact replica reproduction of i/p and input should be multiplied by factor, which is greater than 1. which is the output.

Ex:- In 3rd case (iii) exact replica reproduction

→ For faithful amplification, the operating point should be at the middle of ~~ampl~~ active region.

→ For faithful amplification I_c (dc) should be independent of β.

→ To achieve the above 2 cond^n we need biasing. There are 2 types of biasing.

(1) Fixed bias

(2) Voltage divider bias.

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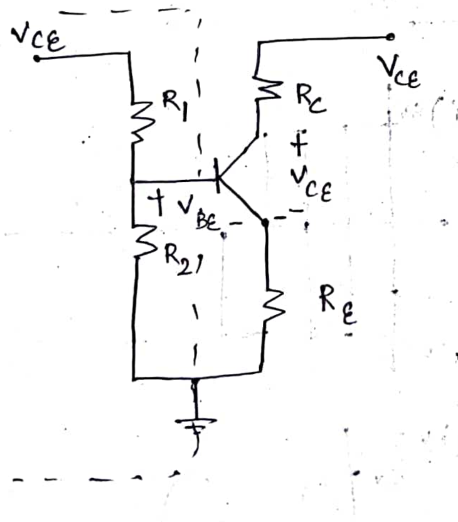
Voltage divider bias:-



$$V_{th} = \frac{V_{CE} R_2}{R_1 + R_2}$$

$$R_{th} = R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

$\because I_C = \beta I_B$

$I_E = I_C + I_B$

$\because I_E = I_C + I_B$
(mA) (mA) (μA)

$\boxed{I_E \approx I_C}$

So; Applying KVL at I/p loop

$V_{th} - I_B R_{th} - V_{BE} - I_E R_E = 0$ —(1)

$I_E = I_C + I_B$

$= \beta I_B + I_B$

$= (\beta + 1) I_B \Rightarrow \boxed{I_B = \frac{I_E}{\beta + 1}}$

eq^n ① can be written as;

$$V_{th} = \frac{I_E}{\beta+1} R_{th} - V_{BE} - I_E R_E = 0$$

$$\Rightarrow V_{th} - V_{BE} = I_E \left(R_E + \frac{R_{th}}{\beta+1} \right)$$

$$\Rightarrow I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta+1}} \approx I_C$$

$$I_C = \frac{V_{CC} - V_{th}}{R_E + \frac{R_{th}}{\beta+1}}$$

$$R_E >> \frac{R_{th}}{\beta+1}$$

$$I_C = \frac{V_{CC} - V_{th}}{R_E}$$

To make $I_{C(dc)}$ independent of β;

$$\boxed{R_E >> \frac{R_{th}}{\beta+1}}$$

Applying KVL at output loop;

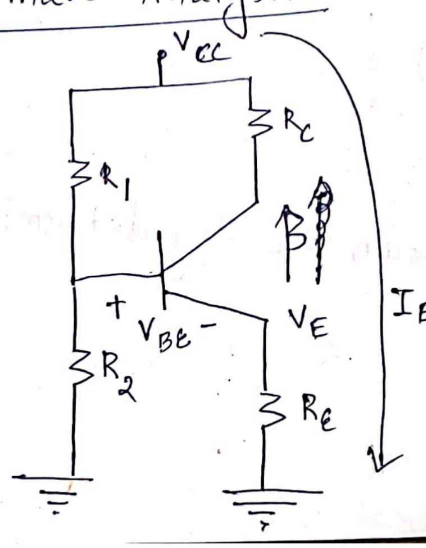
$$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$$

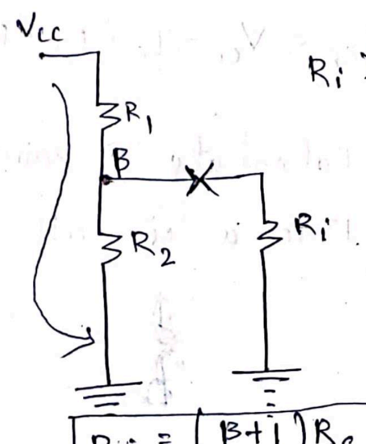
$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

$$= V_{CC} - I_C R_C - I_C R_E$$

$$V_{CE} = V_{CE} - I_C (R_C + R_E) = V_{CEQ} = V_{CE(dc)}$$

Approximate Analysis :-





$R_i >> R_2$

$$\boxed{R_i = (\beta+1) R_E} \approx \beta R_E$$

For good accureing:

$$R_i \geq 10 R_2$$

$$\Rightarrow \beta R_E \geq 10 R_2$$

$$V_B = \frac{V_{cc} R_2}{R_1 + R_2}$$

$$V_{BE} = V_B - V_E$$

$$V_E = V_B - V_{BE}$$

$$V_E = \frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}$$

$$I_E = \frac{V_E - 0}{R_E} = \frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E}$$

$$\cancel{I_E = I_C = \frac{\frac{V_{cc} R_2}{R_1+R_2} - V_{BE}}{}}$$

$$I_E = I_C = \frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E}$$

$$= I_{CQ} = I_{C(dc)}$$

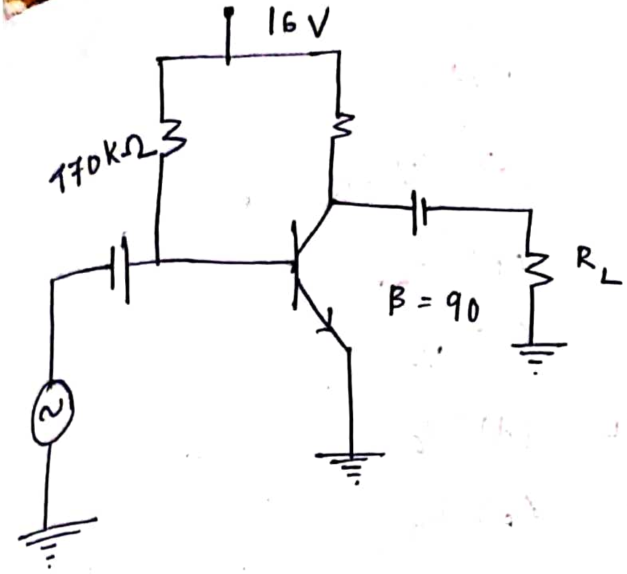
<u>Applying KVL at o/p :-</u>

$$V_{cc} - I_C R_C - V_{CE} - I_E R_E = 0$$

$$\Rightarrow \boxed{V_{CE} = V_{cc} - I_C (R_C + R_E)}$$

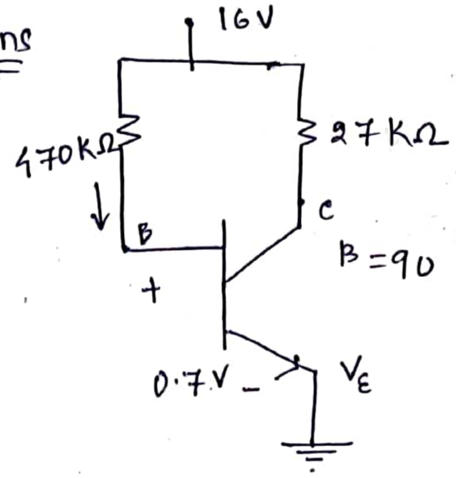
Q:- Calculate Q point.

For a circuit shown in fig determine.



Determine Q ($V_{CE(dc)}$, $I_{C(dc)}$), I_{BQ}, V_C, V_B, V_E ?

Ans



$$V_{BE} = 0.7\,V$$

$$\Rightarrow V_B - \cancel{V_E}^{0} = 0.7\,V$$

$$\Rightarrow V_B = 0.7\,V$$

$$I_B = \frac{16-0.7}{470K} = \frac{15.3}{470}\ mA$$

or $16 - 470K\, I_B - V_{BE} = 0$

$I_B = \ldots$

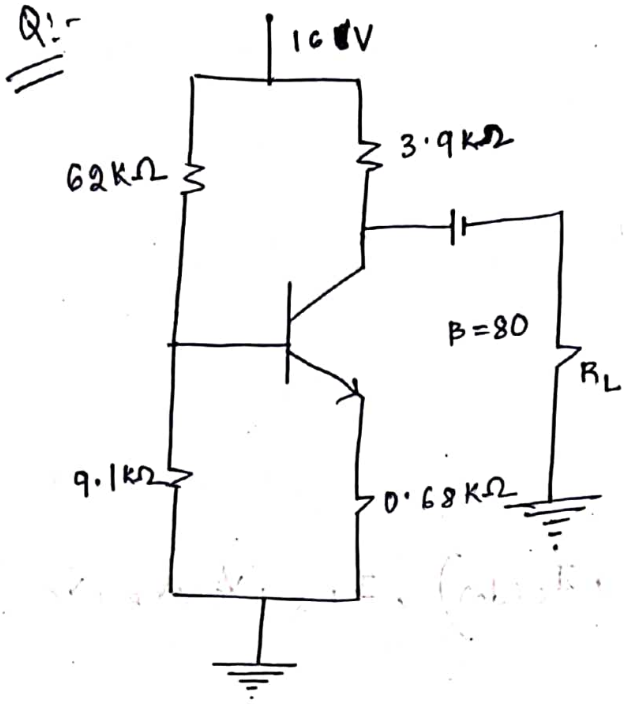
$$\boxed{I_C = \beta I_B}$$

Apply KVL of O/P :-

$$16 - I_C \times 27K = V_{CE} - V_C = 0$$

$Q(V_{CE}, I_C)$

Q:-



Determine

(a) (V_{CEQ}, I_{CQ})

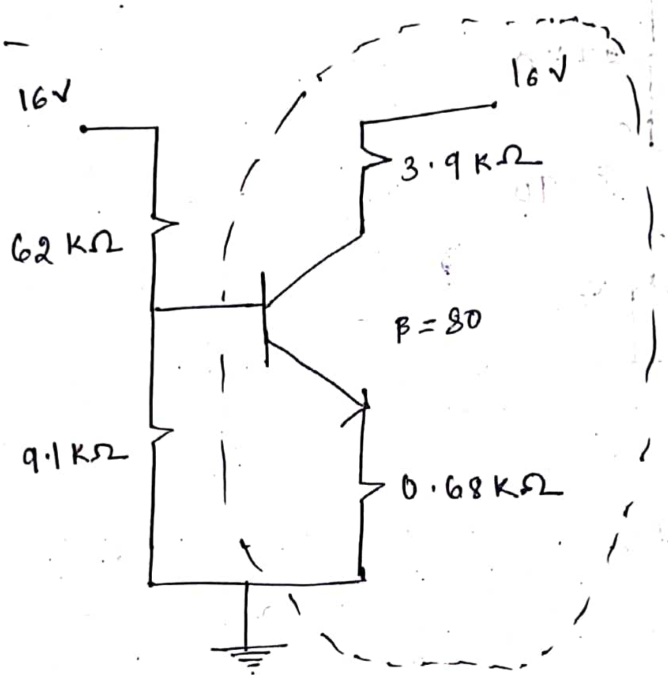
(b) I_{BQ}

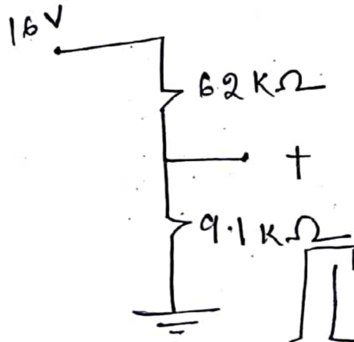
(c) V_C

(d) V_E

(e) V_B

Ans :-





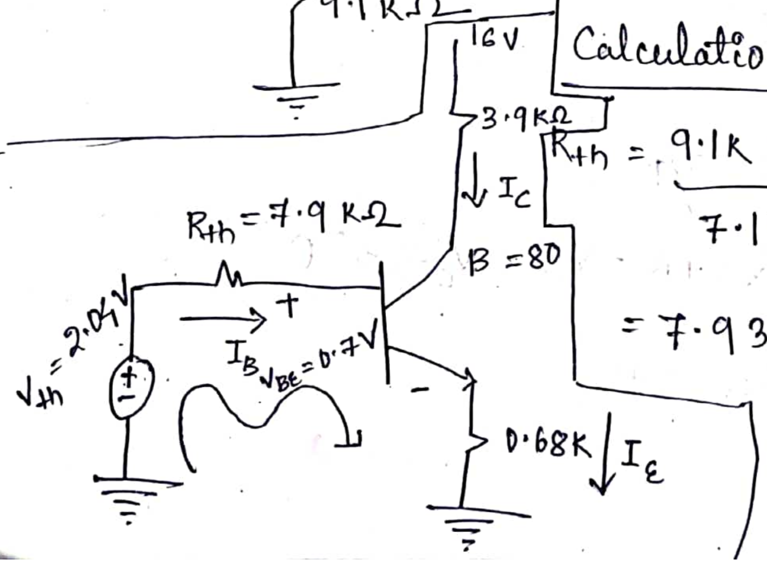
Calculation of V_{th} :-

$$V_{th} = \frac{16 \times 9.1K}{62K + 9.1K} = 2.04V$$

Calculation of R_{th} :-

$$R_{th} = \frac{9.1K \times 62K}{7.1K + 62K}$$

$$= 7.936 \, K\Omega$$



$$2.04 - \cancel{7.9K I_B} - 0.7 - I_E \times 0.63K = \frac{I_E}{\beta+1}$$

$I_E \approx I_C$

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

BJT :-
operation, constⁿ (doping, width)
operⁿ (for amplification
schematic diagram
(npn & pnp)

$$I_E = \frac{V_E - 0}{0.68K}$$

$V_E = ?$

$V_{BE} = 0.7$

$\Rightarrow V_B - V_E = 0.7$

$\Rightarrow \boxed{V_B = 0.7 + V_E}$

Applying KVL at o/p :-

$$16 - I_C \times 3.9K - V_{CE} - I_E \times 0.68K = 0$$

$V_{CE} = ?$

$V_{CE} = V_C - V_E$

$\boxed{V_C = V_{CE} + V_E}$

Q:- Determine β & γ for $\alpha = 0.99$.

$\alpha = 0.99$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = 99$$

$\gamma = \beta + 1$

$= 99 + 1 = 100$.

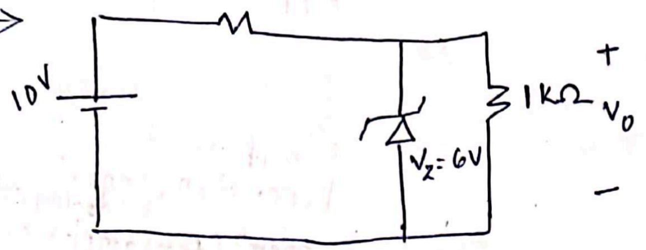
Q:- Determine α & γ for $\beta = 99$.

Here, $\gamma = 99 + 1 = 100$

$$\alpha = \frac{\beta}{\beta+1} = \frac{99}{99+1}$$

$$= \frac{99}{100} = 0.99$$

Solution of midterm exam paper :-

→ 

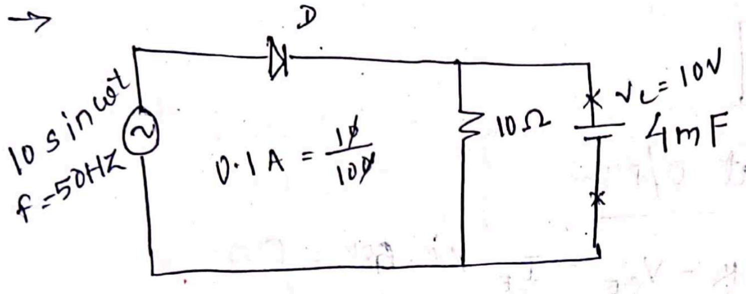
$R_{eq} = \frac{10 \times 1}{1+1}$

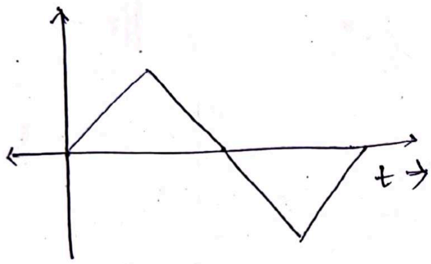
$= \frac{10}{2} = 5V.$

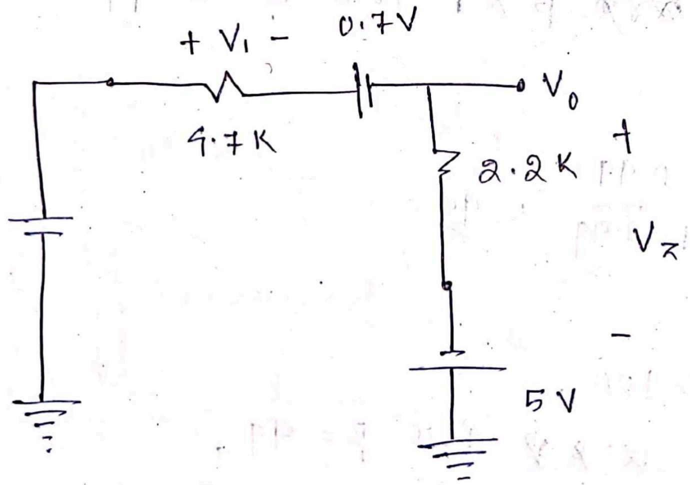
→ R_c is used to make the transistor safe.

→ R_E is used to make I_c dc independent of β

or used to produce -ve feedback.

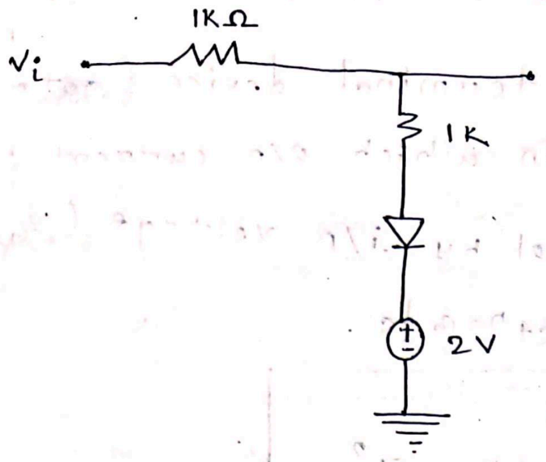
→ 

→ 

→ 

10 - 4.7KI

(d)



$V_{ON} = 0.7V$

$V_i = 5 \sin \omega t \ V$

$V_0 = ?$