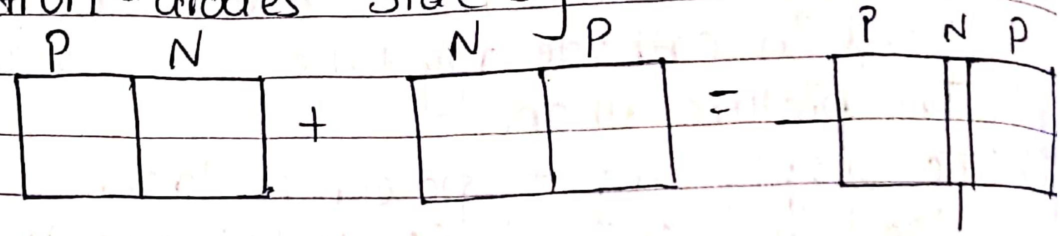
Chapter-3

Bipolar Junction Transistor (BJT)

It is a three terminal device formed by suitably joining two P-N junction diodes side by side.



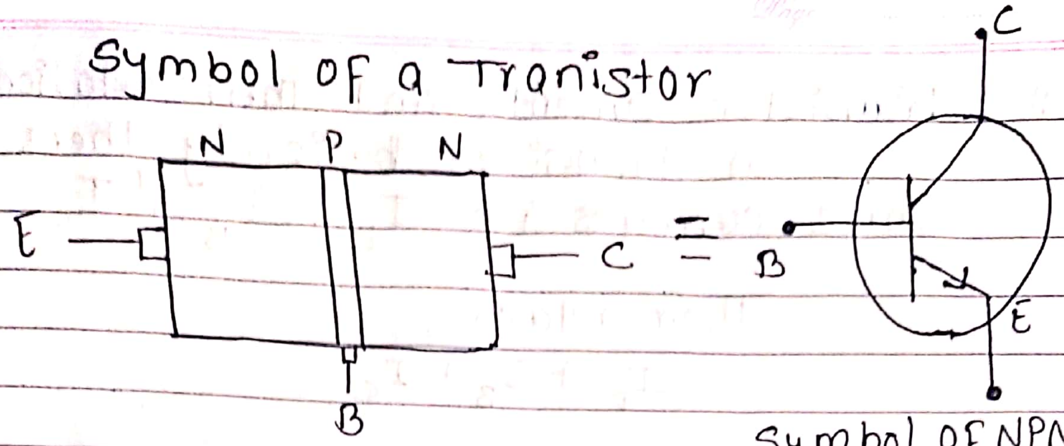
Transistor has three terminals. They are as follow.

i) Emitter (E)
- It lies at left region of a transistor
- It is heavily doped
- It's main function is to supply majority charge carriers (electron or holes) to base.

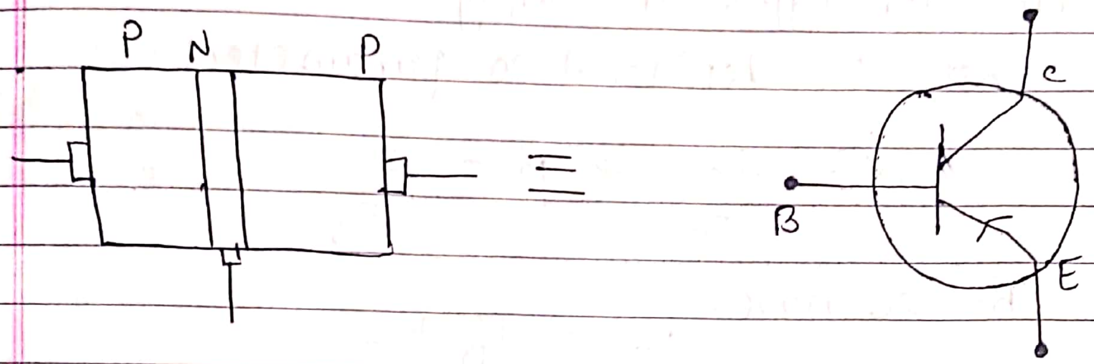
ii) Base
- It lies at the middle of transistor
- It is lightly doped
- It is very thinest region
- It just provides a medium to supply charge carriers emitted by emitter.

iii) Collector
- It lies at right side of a Transistor
- It is moderately doped
- It is thickest region
- It's main function is to collect charge carriers.

Symbol of a Tranistor



Symbol of NPN



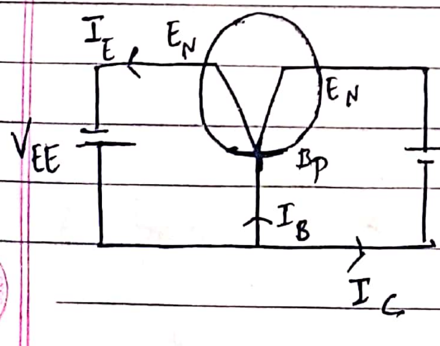
symbol of PNP

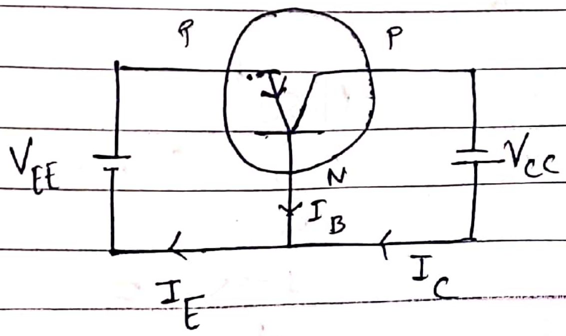
Transistor Biasing

Connecting an external battery to a transistor is called transistor battery.

For normal operation of a transistor.

i) Emitter base Junction is forward biased
ii) Collector base Junction is reverse biased





Transistor currents and Their relationship

In transistor basically there are three currents i.e I_E, I_B & I_C

Their relation,

$$I_E + I_B + I_C$$

This statement is true regardless of transistor type or configuration.

Let, us define two parameters

$$\alpha = \frac{I_c}{I_E} \quad \& \quad \beta = \frac{I_C}{I_B}$$

As we have,

$$I_E = I_B + I_C$$

Dividing both side by I_c

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

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

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

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

Also,

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

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

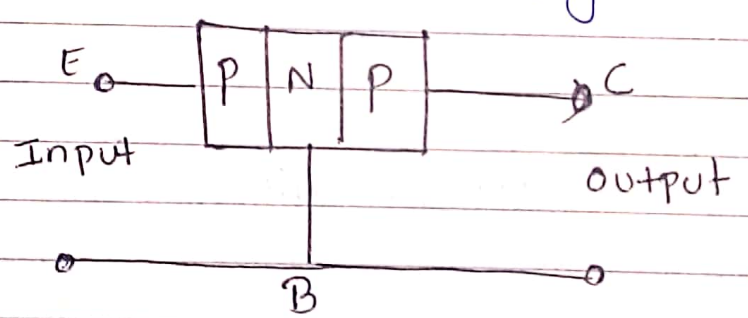
$$\boxed{\beta = \frac{\alpha}{1-\alpha}}$$

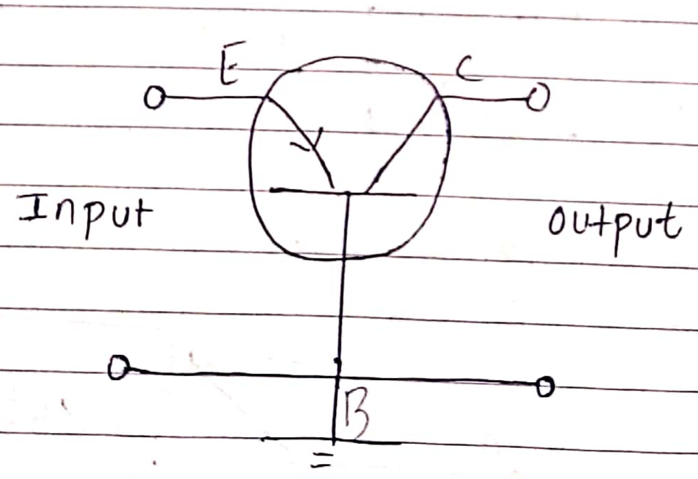
Transistor configuration

Basically there are three types of transistor configuration. They are :-

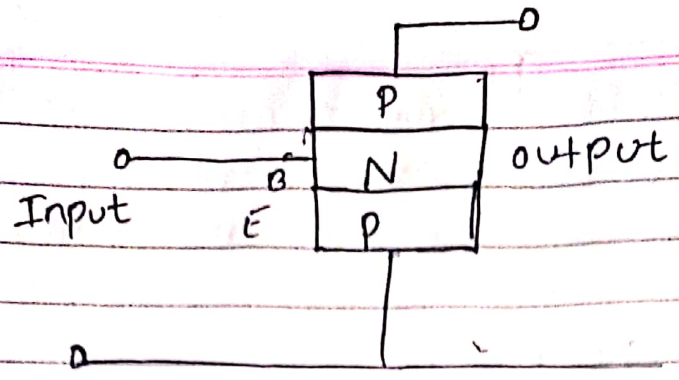
i) Common Base (C.B) Configuration
ii) Common Emitter (CE) "
iii) Common Collector (CC) "

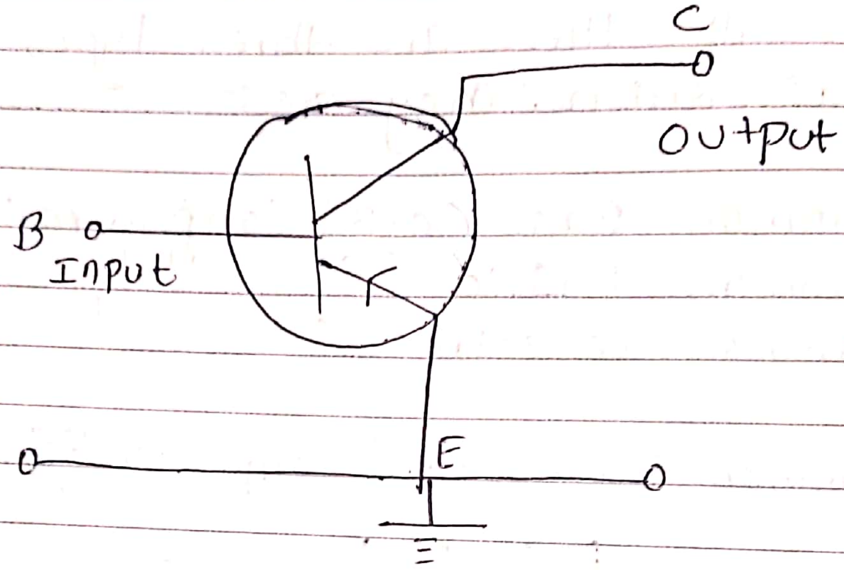
i) Common Base (C.B) Configuration



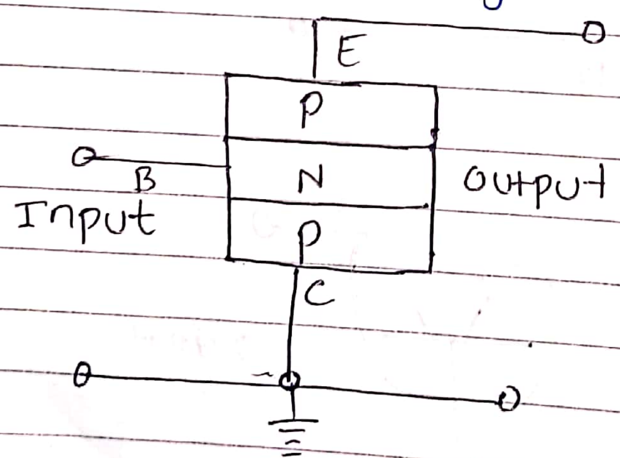


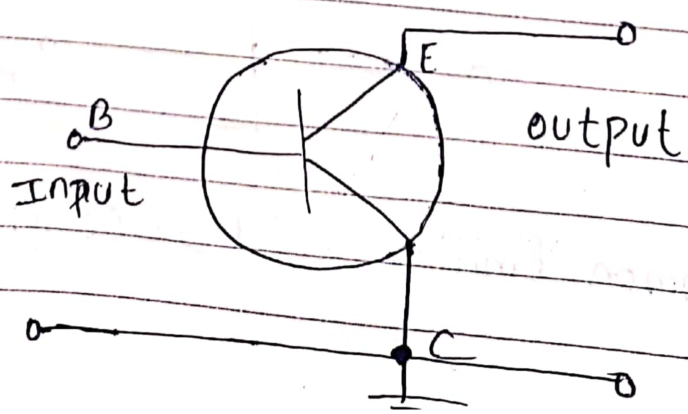
ii) Common Emitter (CE) Configuration





iii) Common Collector configuration





NPN

PNP

Transistor characteristics

Transistor characteristics are the curves which represents relationship betⁿ different DC current and voltages of a transistor.

Three important characteristics of a transistor are :-

i) Input characteristics
ii) Output ,,
iii) Current transfer ,,

Common Base Characteristics

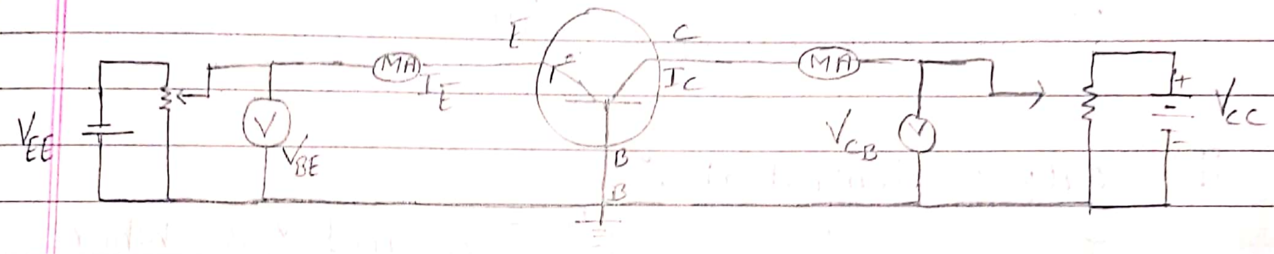
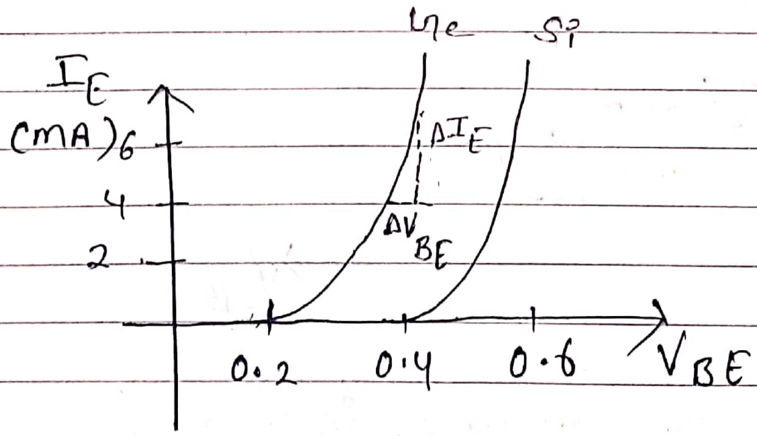


Fig: Circuit diagram for C·B circuit

i) Input characteristics



It is the graph showing the relation betⁿ I_E and V_{BE} when voltage V_{CB} held constant.

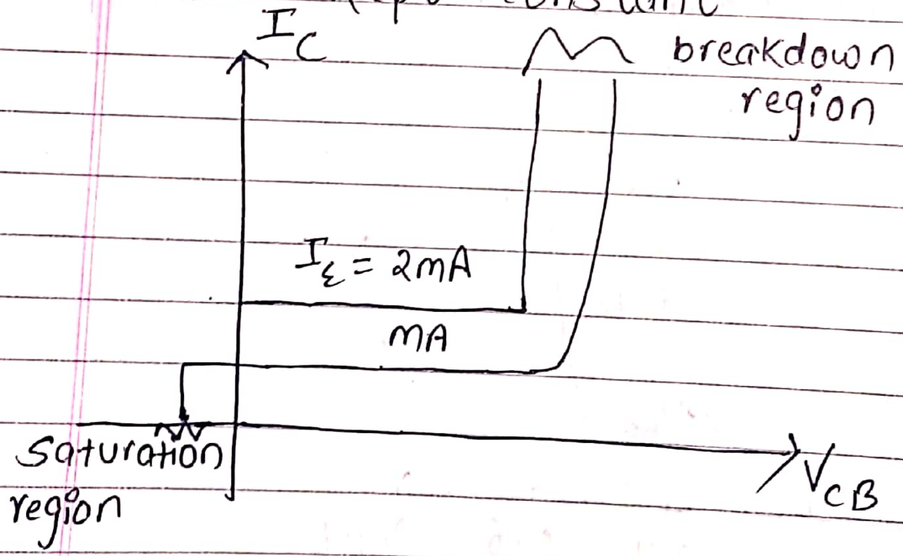
This characteristics is used to find the input resistance of the transistor. Input resistance is given by reciprocal of slope:

i.e. $R_{in} = \frac{\Delta V_{BE}}{\Delta I_E}$

$$\text{Slope} = \tan\theta = \frac{\Delta I_E}{\Delta V_{BE}} = \frac{1}{\frac{\Delta V_{BE}}{\Delta I_E}} = \frac{1}{R_{in}}$$

ii) output characteristics

It is the graph bet^n I_c and V_{CB} when I_c is kept constant.



The slope of curve is $= \frac{\Delta I_c}{\Delta V_{CB}}$

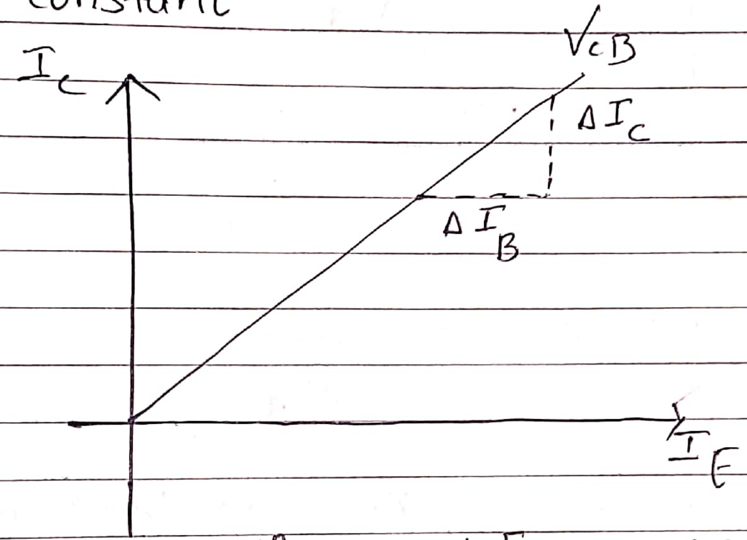
Reciporcal of slope gives the output resistance.

The Saturation region represents the -ve value of V_{CB} at which current (I_c) becomes zero.

The breakdown represents a value of V_{CB} at which current rises rapidly.

iii) Current transfer characteristics

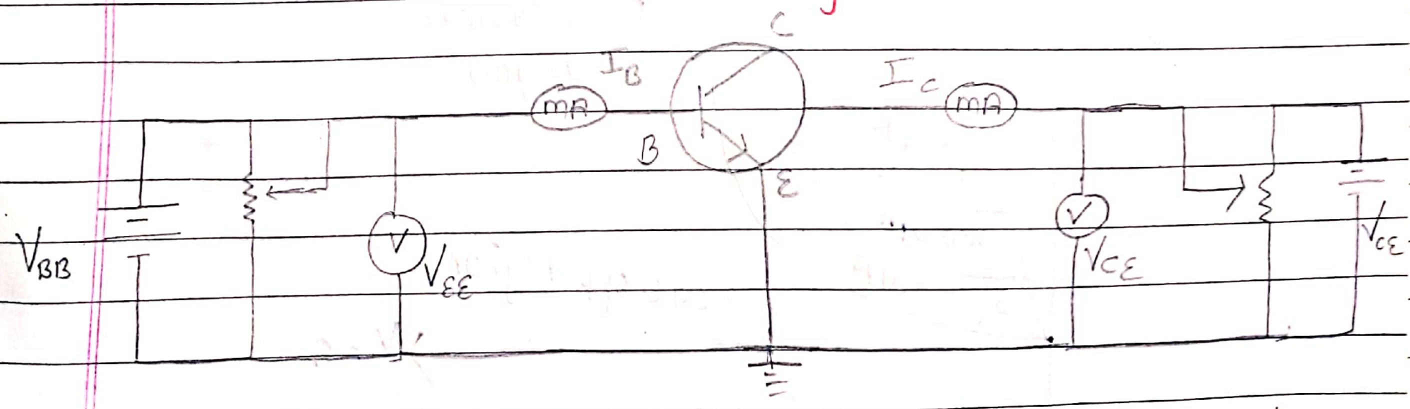
It is the graph bet^n I_c and I_E when V_{CB} is held constant



$$\text{Slope of line} = \frac{\Delta I_c}{\Delta I_E} = \alpha$$

Imp

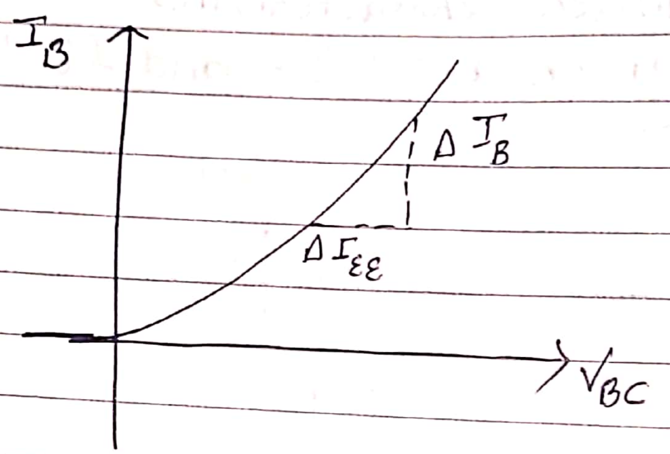
Common emitter configuration



The circuit diagram for common emitter configuration is as shown in fig:

i) Input characteristics

It is the graph plotted betⁿ I_B and V_{BC} when V_{CE} is kept constant.

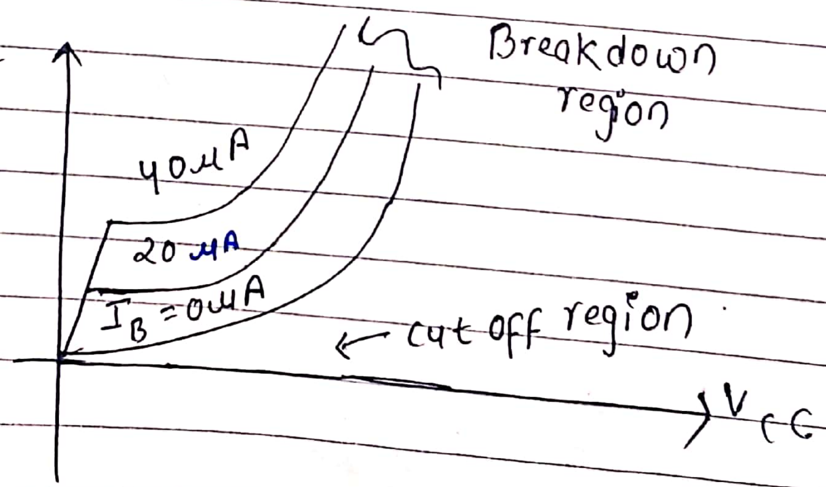


$$\text{slope of curve} = \frac{\Delta I_B}{\Delta V_{BE}}$$

The reciporcal of slope gives the input resistance.

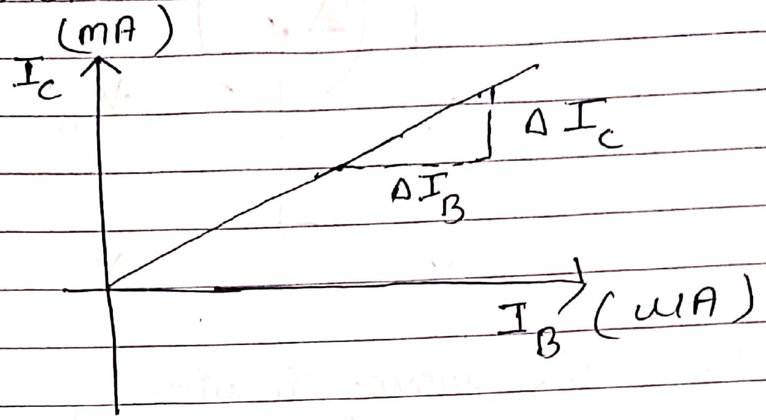
ii) Output characteristics

It is the graph plotted betⁿ I_C and V_{CE} when I_B is kept constant.



iii) Current Transfer characteristics

It is the graph betn I_C and I_B when V_{CE} is constant.

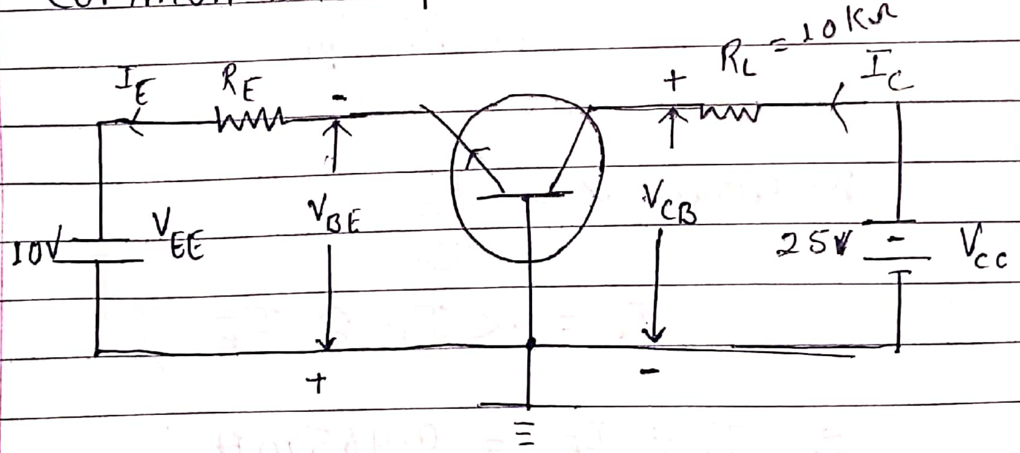


The slope of line $= \frac{\Delta I_C}{\Delta I_B} = \beta$

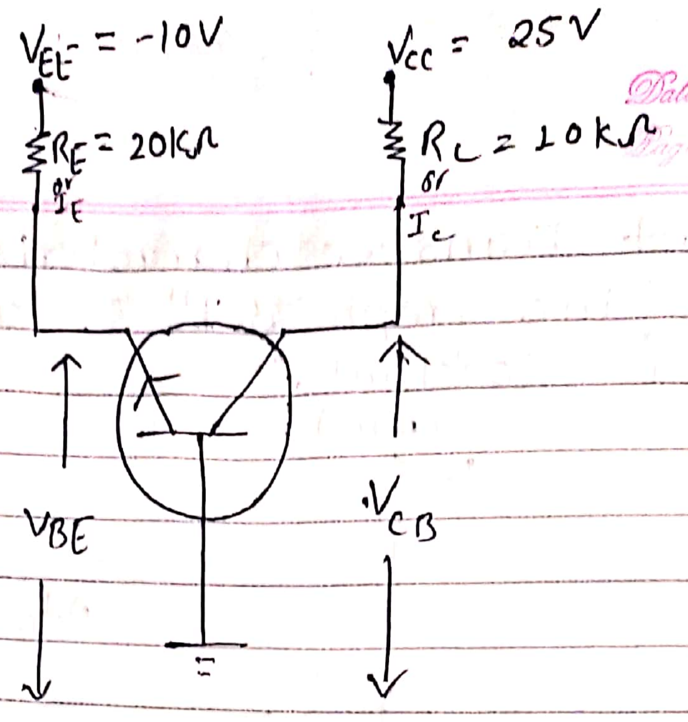
Thus, β of transistor is given by slope of the line.

Different ways of drawing transistor circuit

1) Common Base formula



This circuit also can be drawn as,



From the above circuit,

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

$$I_E = \cancel{V_{EE}} \frac{V_{EE} - V_{BE}}{R_E \cancel{+ V_{BE}}}$$

$$I_E = \frac{(10 - 0.7)}{20 \times 10^3}$$

$$I_E = 0.465 \text{ mA}$$

Note:

~~If~~ V_{BE} is not given, it can be neglected since,

$$V_{EE} >> V_{BE}$$

We know, $\alpha = \frac{I_c}{I_E}$

$$I_c = \alpha I_E \approx I_E$$

$$\Rightarrow I_c = I_E = 0.465 \text{ mA}$$

Now,

In collector part

Note:
$\left[V_{BE} = \begin{array}{l} 0.3\,V \text{ For Ge} \\ 0.7\,V \text{ For Si} \end{array} \right.$

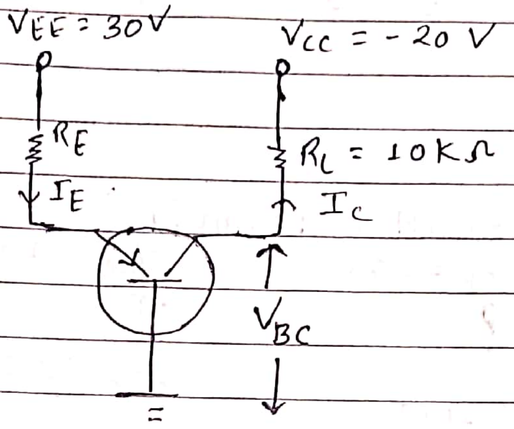
$$V_{CC} = I_C R_L + V_{CB}$$

$$\therefore V_{CB} = \cancel{I_C R_L - V_{CE}}\ V_{CC} - I_C R_L$$

$$= \cancel{0.465 \times 10^{-3} \times 10^{3} - 25}\ 25 - 0.465 \times 10^{-3} \times 10^{3}$$

$$= 24.53\ V$$

Q)



Find value of R_E if $V_{BC} = 10\,V$ & $V_{EB} = 0.7\,V$

Soln:

Here,

From the above circuit,

$$V_{CC} = I_C R_L + V_{BC}$$

$$I_C = \cancel{V_{EC}}\ \frac{V_{CC} - V_{BC}}{R_L}$$

$$I_C = \frac{20 - 10}{10 \times 10^3}$$

$$I_C = \frac{\cancel{10}}{\cancel{1000}} \quad \frac{10}{10 \times 1000}$$

$$I_C = 0.001$$

Now,

$$I_C = I_E$$

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

$$R_E = \frac{V_{EE} - V_{EB}}{I_E}$$

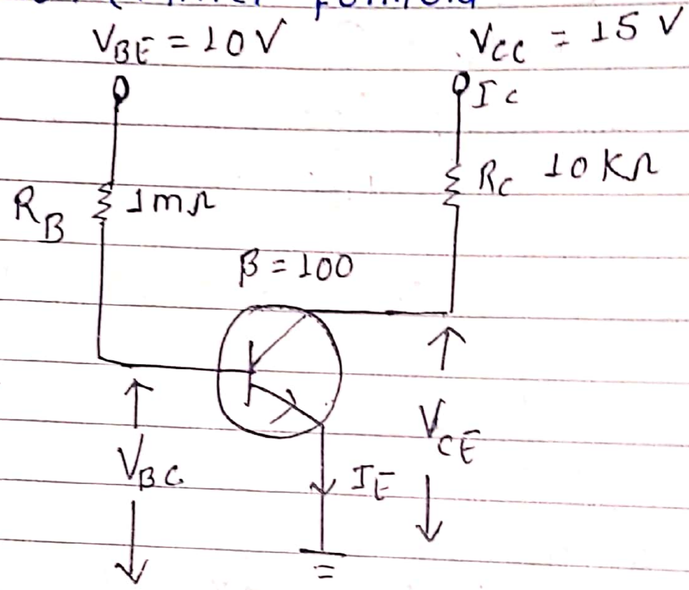
$$= \frac{30 - 0.7}{0.001}$$

$$= \frac{29.30}{0.001}$$

$$= 29{,}300\ V$$

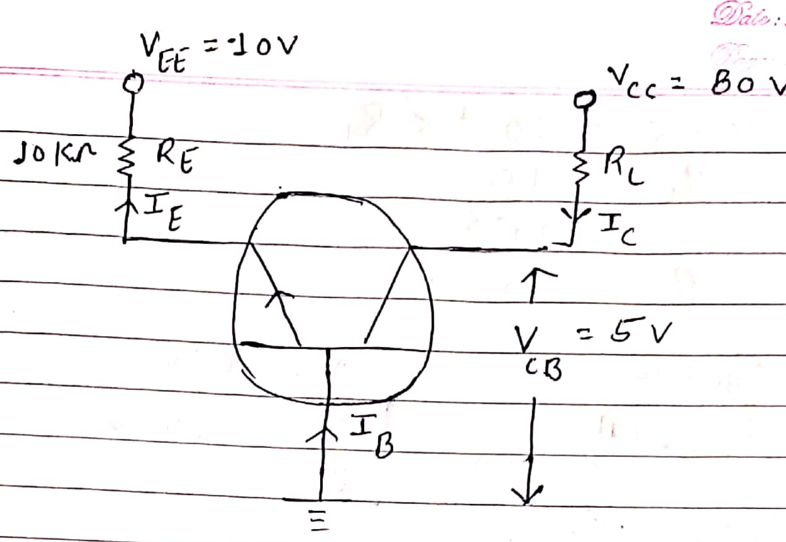
2) Common emitter formula

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

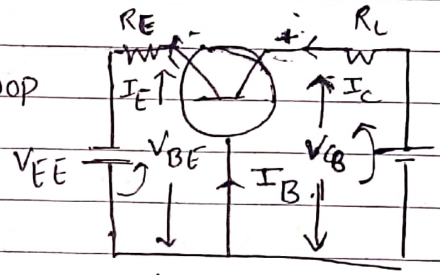


Find I_B, I_C and V_{CE}

Q)



Find the value of R_L



Using Kirchoff's law, In left loop

$\Sigma E = \Sigma IR$

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

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

$V_{BE} << V_{EE}$, So, it can be neglected.

$V_{EE} = I_E R_E$

$I_E = \frac{V_{EE}}{R_E}$

$= \frac{10}{10 \times 10^3}$

$= 10^{-3} A$

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

$I_C = \alpha . I_E \approx I_E$

$I_C = 10^{-3} A$

Using Kirchoff's law, In Right loop

$\Sigma E = \Sigma IR$

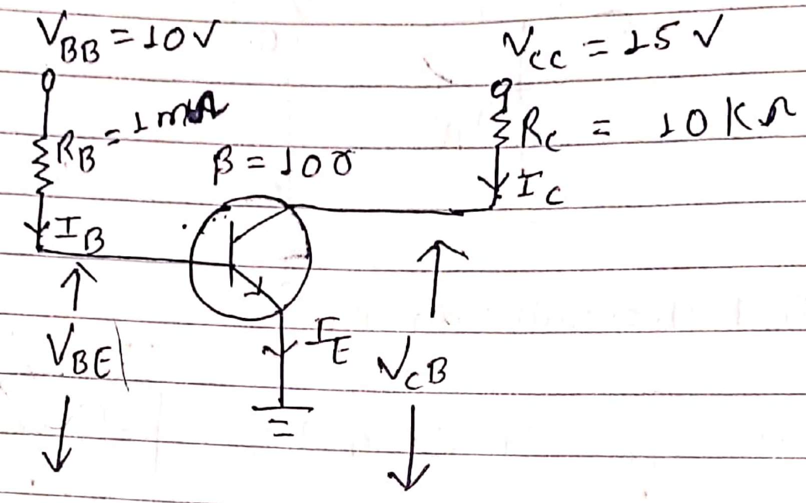
$V_{CC} - V_{CB} = I_C R_L$

$$20-5 = 10^{-1} \times R_L$$

$$R_L = \frac{15}{10^{-3}}$$

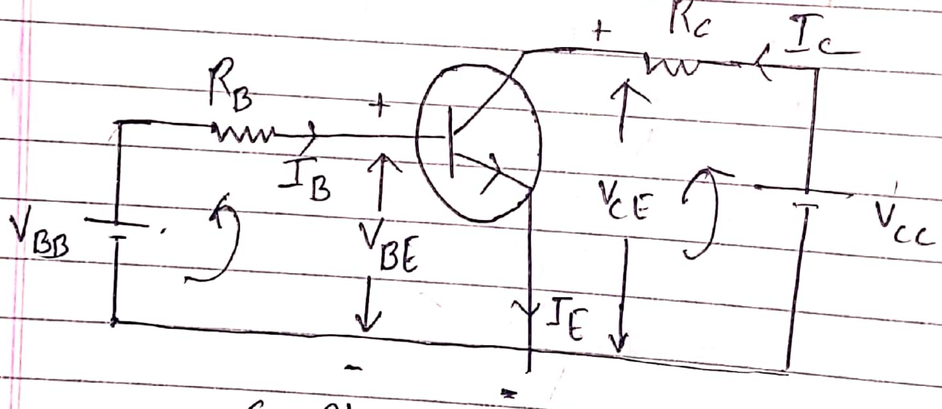
$$R_L = 15\ k\Omega$$

Q)



$$V_{BE} = 0.7V$$

Find V_{CB}, I_B, I_c, I_E



Soln:

~~From the abov~~

Using Kirchoff's law in left loop

$$V_{BE} - V_{BB} = -I_B R_B$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_B = \frac{10 - 0.7}{1 \times 10^{-6}}$$

Dc load line

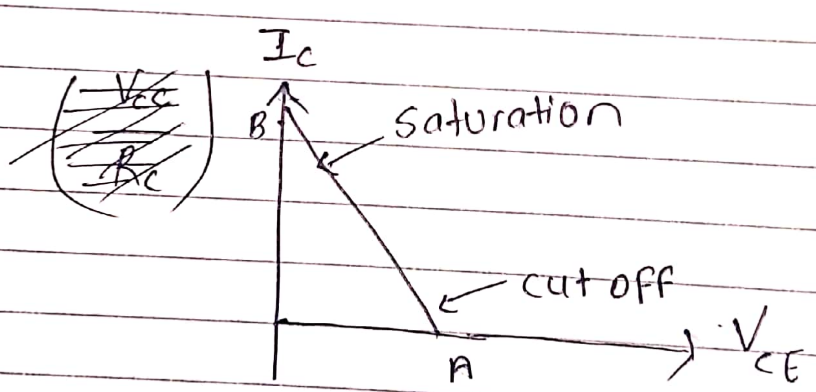
It is the straight line Joining the cut-off and Saturation point.

We know that the voltage eqn in common ~~emitter~~ base configuration is $V_{cc} = I_c$

$$I_c = \frac{V_{cc}}{R_c} - \frac{V_{CE}}{R_c}$$

When, $I_c = 0$; $V_{CE} = V_{cc}$ which Corresponds to cut off point.

When $I_c = 0$; $I_c = \frac{V_{cc}}{R_{C(B)}}$ which correspond to saturation point.



Avobe graph represents the relation betn V_{CE} and I_c. A straight line AB in above figure is the Dc load line.

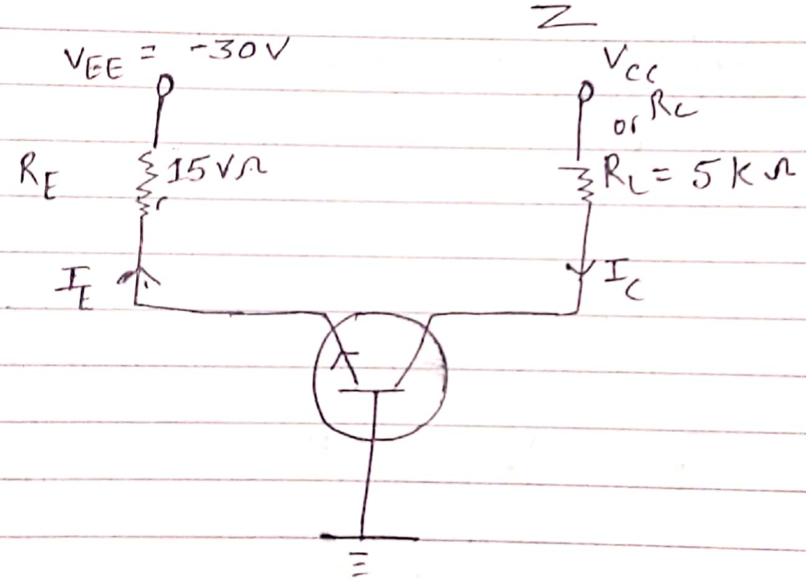
The points ~~lie~~ lying betn saturation & cut off points are the operating points and this is the (Along line AB) is the active region.

Quiescent point (Q-point)

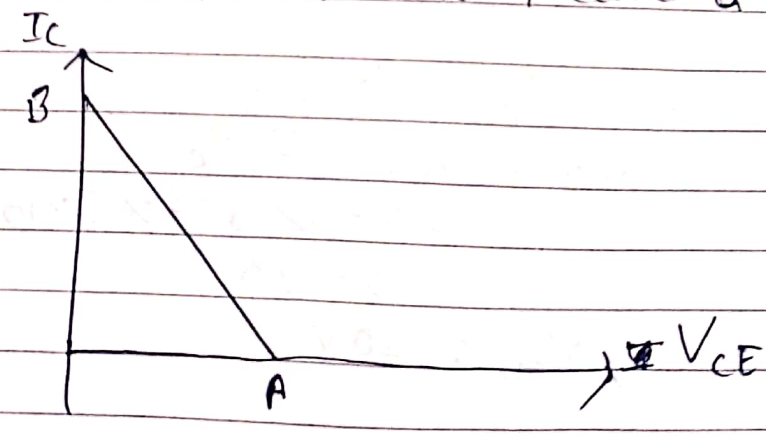
It is the point on the DC load line which represents values of I_C and V_{CE} when no ~~p~~ input signal is applied. It is also known as DC operating point or working point. The best position for this point is mid-way between ~~cut~~ cut-off and saturation point.

i.e. $V_{CE} = \frac{V_{CC}}{2}$

Q.



Draw the DC load line and locate Q-point



For point B

$$(I_c)_{sat} = \frac{V_{cc}}{R_c}$$

$$= \frac{20}{5\times10^3}$$

$$= 4\times10^{-3} A$$

$$I_c = 4mA$$

For point A

$V_{CE} = V_{CC} = 20V$ (cut off)

To find Q-point

$$I_E = \frac{V_{EE}}{R_E}$$

$$= \frac{30}{15\times10^3}$$

$$I_E = 2mA$$

$\{ V_{EE} = I_E R_E + \cancel{V_B}$

$$I_C \propto I_E \approx I_E = 2mA$$

$$\therefore \boxed{I_C = 2mA}$$

Then,

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

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

$$= 20 - 2\times10^{-3}\times5\times10^3$$

$$= 20-10$$

$$V_{CB} = 10V$$

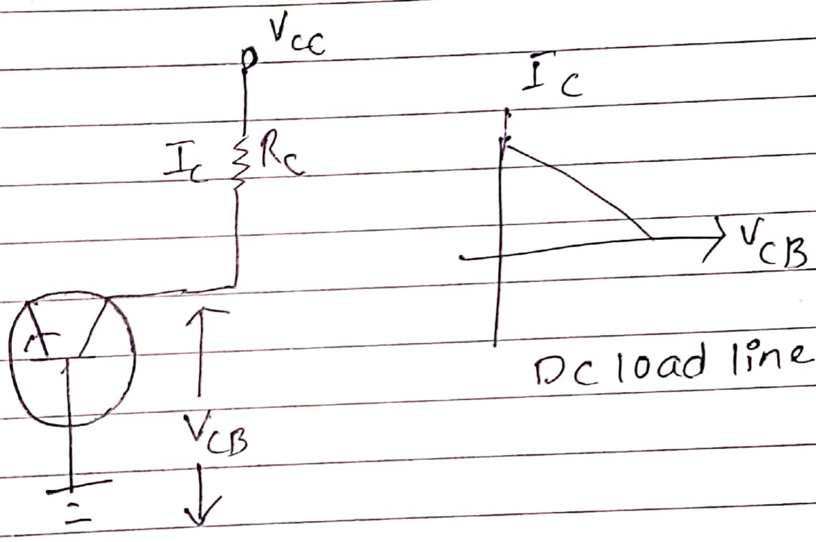
In generate, for Q-point

$$\left(\frac{V_{CC}}{2}, \frac{I_C}{2}\right)$$

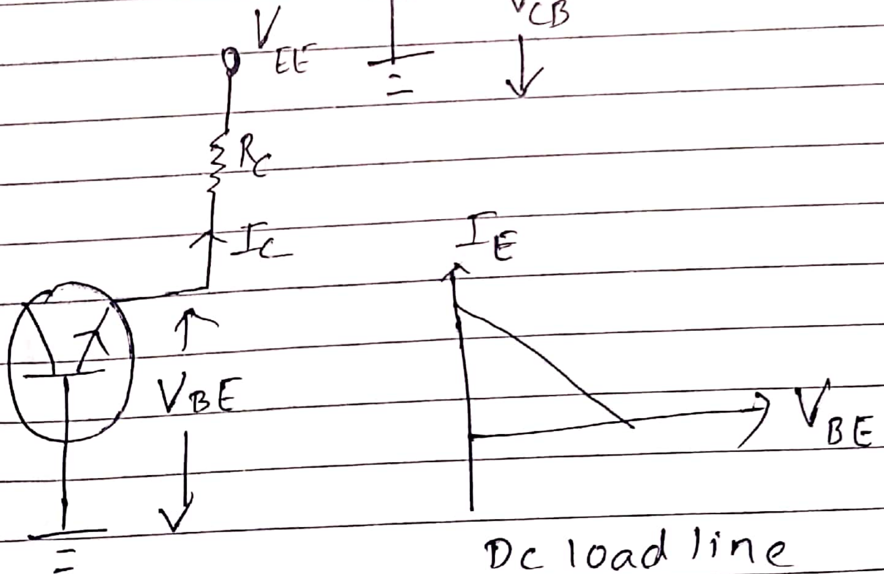
$$\left(\frac{20}{2}, \frac{4mA}{2}\right)$$

Q-point = (10V, 2mA)

Note:



Dc load line

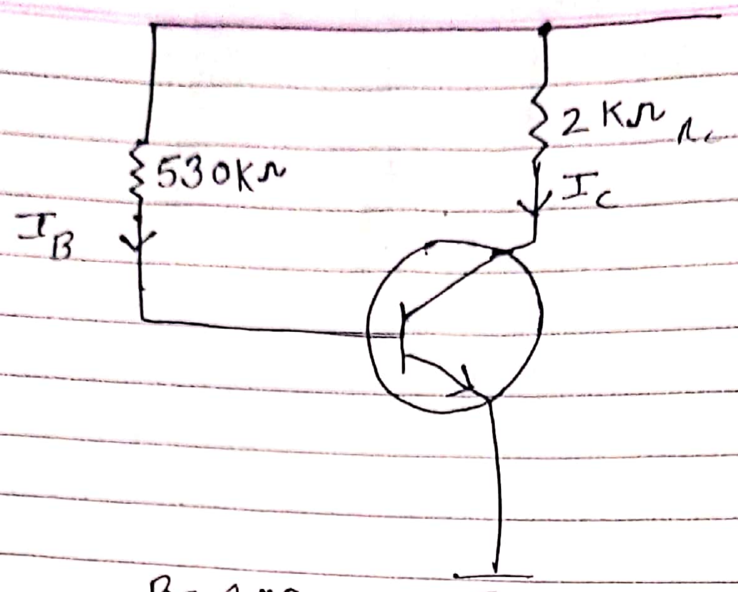


Dc load line

V_{BB} :

$V_{cc} = 6V$

Q)



$\beta = 100$

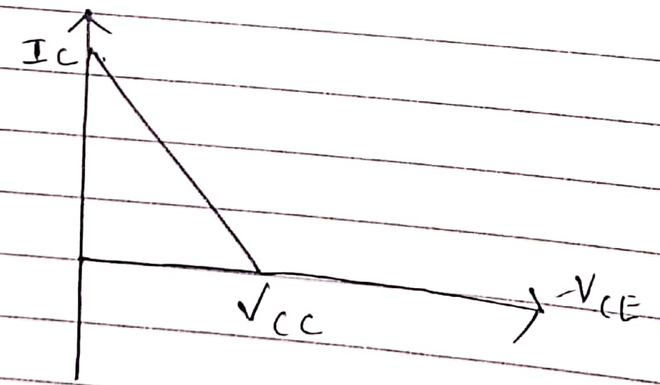
$(V_{BE} = 0.7V)$

Draw Dc load line and determine operating point.

Soln:

Here,

~~Draw the Dc load line and~~



For point B

(I_c) ~~saturation~~ $= \frac{V_{cc}}{R_c}$

$=$

$$V_{cc} = I_C + R_C + V_{CE}$$

When, $I_C = 0$

$$V_{CE} = V_{cc} = 6V.$$

When,

$$V_{CE} = 0$$

$$V_{cc} = I_C R_C$$

$$I_C = \frac{V_{cc}}{R_C}$$

$$= \frac{63}{2\times10^3}$$

$$= 3\,K\Omega$$

At point A.

$$V_{cc} = I_B R_B + V_{BE}$$

$$6 = I_B \times 530\times10^3 + 0.7$$

$$I_B = \frac{5.3}{\cancel{6}5.30\times10^3}$$

$$I_B = 10^{-5}$$

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

$$I_C = \beta \cdot I_B$$

$$= 100\times10^{-5}$$

$$= 10^{-3}$$

$$I_C = 1mA$$

Now,

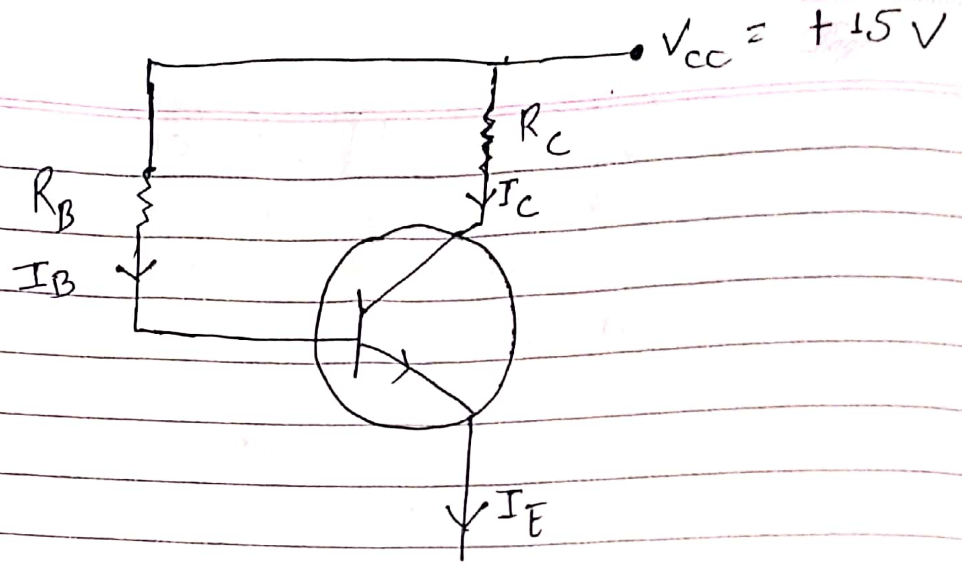
$$V_{cc} = I_C R_C + V_{CE}$$

$$V_{CE} = V_{cc} - I_C R_C$$

$$= \cancel{6\times} 6 - 1\times10^{-3} \times 2\times10^3$$

$$= 4V$$

Q)



The operating point is

$V_{CE} = 8V$

$I_C = 2mA$

$\beta = 100$

$V_{BE} = 0.6V$

Find R_B & R_C

Soln:

Here,

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

$R_C = \dfrac{V_{CC}}{I_C + V_{CE}}$

$= \dfrac{15-8}{2\times10^{-3} \cancel{+8}}$

$= \dfrac{7}{2\times10^{-3}}$

$= 3.5 \cancel{\times10^{-3}}$ V

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

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

$= \dfrac{2\times10^{-3}}{100}$

$= \cancel{0.2A}$ 2×10^{-5} A

$V_{cc} = I_B R_B + \cancel{I_{cq}} \cancel{V_{CE}}\ V_{BE}$

$\cancel{R_B} =$

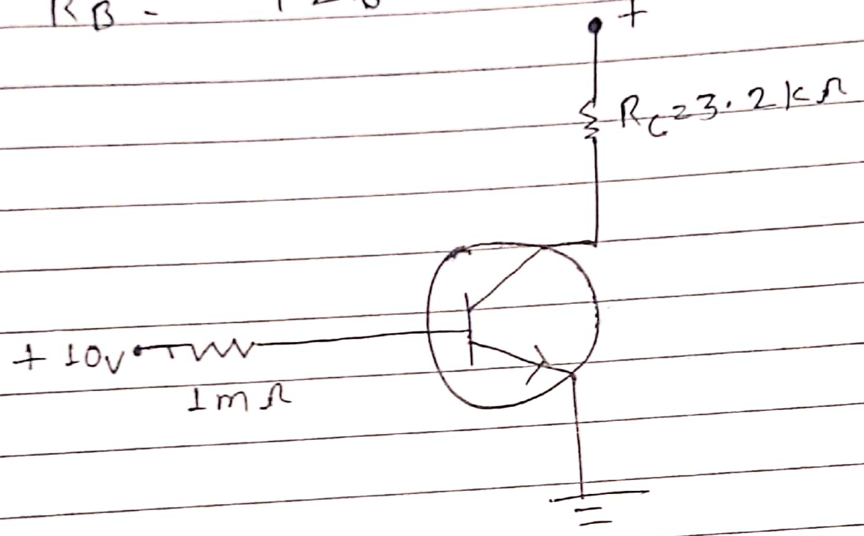
$15 = 0.2 \times R_B + 0.6$

$15 = 0.2 R_B + 0.6$

$R_B = \dfrac{15 - 0.6}{2 \times 10^{-5}}$

$R_B = 72 k\Omega$

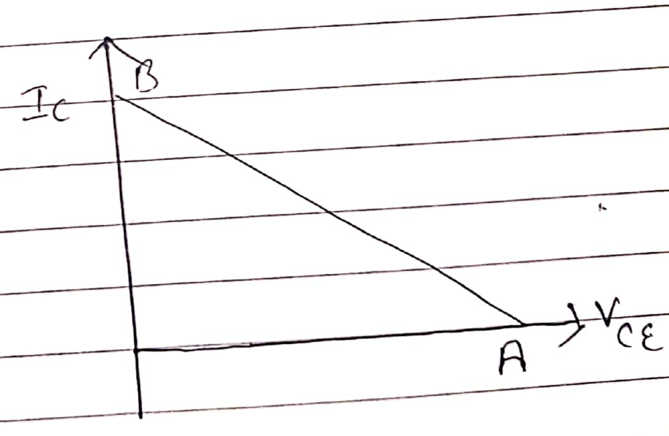
Q)



Draw DC load line

Soln:

Here,



At point B,

$(I_c) = \dfrac{V_{cc}}{R_C}$

$= \dfrac{10}{3.3 \times 10^3}$

$= 6.06 \times 10^{-3}$ A