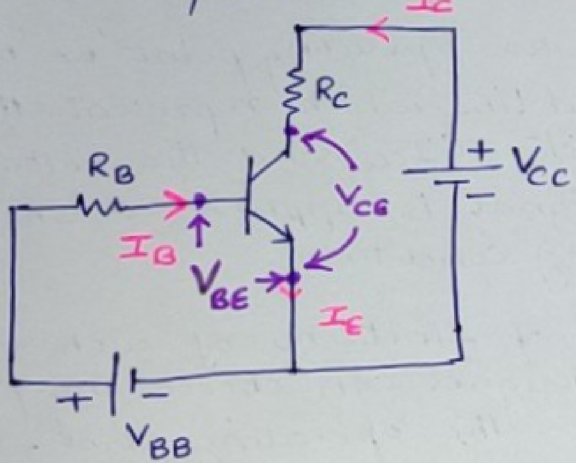
UNIT 2

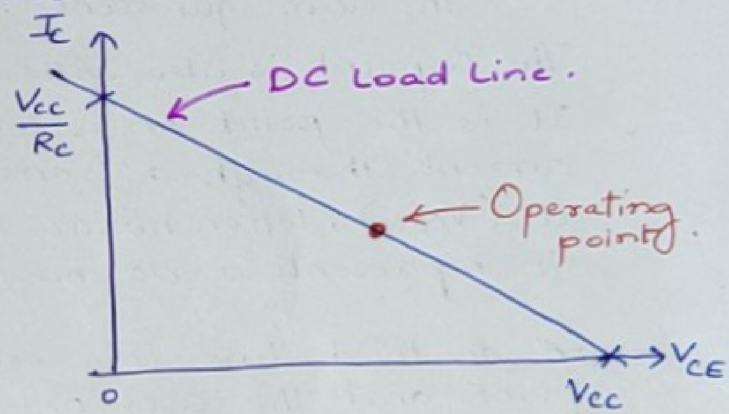
DC Load Line:

It is the line drawn on the o/p characteristic of the transistor. DC load line is used for analyzing the performance of an amplifier.

It is a graph of Collector current (I_c) and Collector-Emitter voltage (V_{CE}) for a given value of R_c and V_{cc}.
It is a graphical representation of all the possible operating points for the given circuit with the given DC biasing.

Q How to plot a DC load line?





Step 1:- Apply KVL at o/p section.

$$V_{cc} - I_c R_c - V_{CE} = 0$$

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

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

$$I_c = -\frac{1}{R_c} V_{CE} + \frac{V_{cc}}{R_c} \quad \text{--- (1)}$$

Equation for the slope of straight line.

$$y = mx + c. \quad \text{--- (2)}$$

Compare eqn 1 & 2

$y = I_c$ & $c = \frac{V_{cc}}{R_c}$ } constant (fixed)

$m = -\frac{1}{R_c}$

$x = V_{CE}$

Step 2 :- $I_C = 0$ in eq 1.

$$\therefore \quad 0 = -\frac{1}{R_C} V_{CE} + \frac{V_{CC}}{R_C}.$$

$$\frac{V_{CE}}{R_C} = \frac{V_{CC}}{R_C}$$

$$\boxed{V_{CE} = V_{CC}}$$

Step 3 :- $V_{CE} = 0$ in eq 1.

$$\boxed{I_C = \frac{V_{CC}}{R_C}.}$$

Q - Point (Quiescent point or Operating point) :-

The term quiescent means quite, still or inactive.
The Q point is also called as 'operating point' or 'bias point'.
It is the point on a load line which represents the dc current through a transistor (I_{CQ}) and the voltage across it (V_{CEQ}), when no ac signal is applied. In short it represents a dc biasing conditions.

- A dc load line is a set of finite no. of such operating points and the user or designer can choose any point on the dc load line as the operating point.

The position of operating point on the load line dependents on the application of transistor.

If the transistor is being used for 'amplification' purpose then the Q point should be at the center of load line.

FACTORS AFFECTING STABILITY OF Q - POINT.

i.) When I/P signal is applied, the O/P signal should not move the transistor either to saturation or to cut - off. However, this unwanted shift might occur due to various reasons outlined below.

a.) Change in the Temperature

b.) Change in the value of β.

What is the Requirement of Biasing Circuit?

The requirements of biasing circuit are

1.) Establish the Q-point in the centre of the active region of the characteristics, so that on applying the I/P signal the instantaneous Q point does not move either to the saturation region or to the cut-off region, even at the extreme values of the I/P signal.

2.) Stablize the collector current (I_c) against temperature variations.

3.) Make the Q point independent of the transistor parameters so that it does not shift when the transistor is replaced by another of the same type in the circuit.

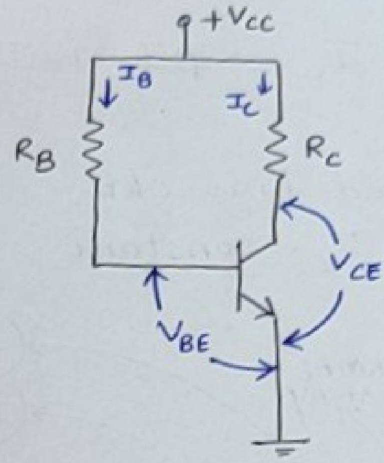
Biasing Circuits.

To avoid shift of Q-point, bias stablization is necessary. Various biasing circuits can be used for this purpose.

1.) Fixed bias.
2.) Collector to base bias.
3.) Fixed bias with emitter resistor.
4.) Voltage divider bias.
5.) Emitter bias.

FIXED BIAS :- (BASE BIASING).

Simplest biasing ckt.



Step 1:- I_B.

Analysis of fixed bias.

Apply KVL at I/P side.

$$V_{CC} - I_B R_B - V_{BE} = 0$$

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

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

$V_{BE} = 0.7V$ Si
$V_{BE} = 0.3V$ Ge. very small so neglect

$$\therefore I_B = \frac{V_{CC}}{R_B}$$

This eqn is for base current corresponding to Q point.

V_{CC} - constant
R_B - constant } (fixed) → hence fixed bias ckt.

Step 2:- I_C.

$$I_C = \beta I_B + I_{CEO}$$ But $I_{CEO} << \beta I_C$.

$$I_{CQ} = \beta_{dc} I_B$$

Step 3:- V_{CE} or V_{CEQ}.

Apply KVL at O/P side.

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

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

THERMAL RUNAWAY :-

① With $\uparrow^{se}$ in temperature, the leakage current ~~I_{CB}~~ I_{CBO} $\uparrow^{ses}$. $I_c = I_{c(majority)} + I_{c(minority)}$

② This $\uparrow^{se}$ in I_{CBO}, $\uparrow^{ses}$ I_{CEO}

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

③ As I_{CEO} $\uparrow^{ses}$, this leads to $\uparrow^{se}$ in I_C.

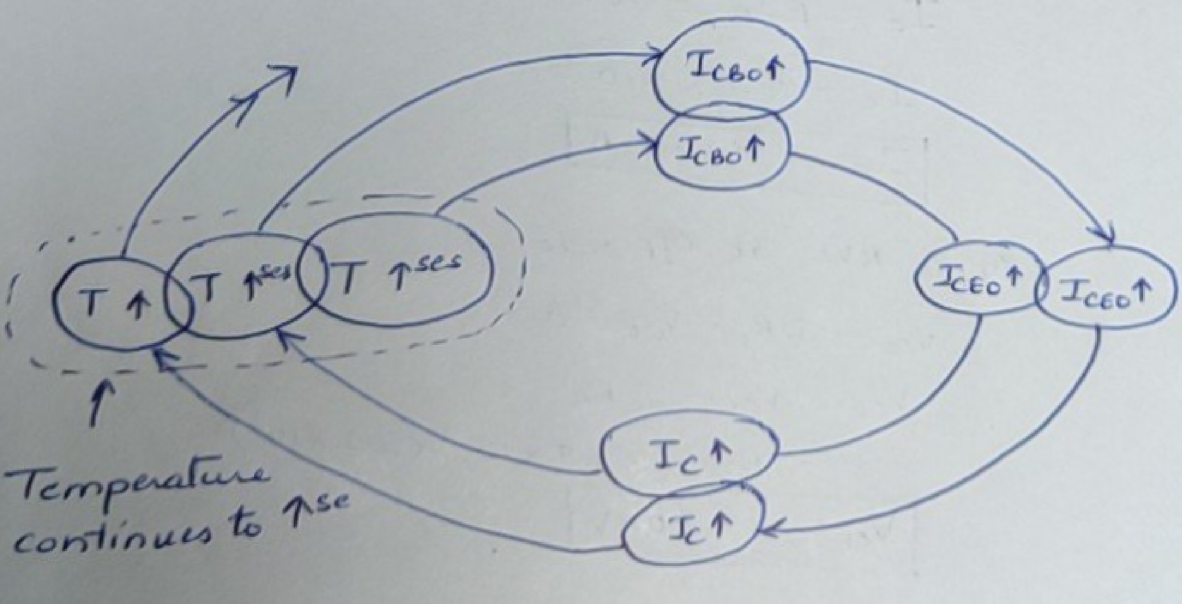
$$\because \quad I_C = I_{c(majority)} + I_{c(minority)}.$$

$$I_C = \beta I_B + I_{CEO}.$$

④. The further $\uparrow^{se}$ in I_C leads to more amount of power producing heat at the collector region and more minority carriers $\uparrow^{ses}$ as they are thermally generated.

⑤ With further $\uparrow^{se}$ in temperature, the thermally generated minority carriers $\uparrow^{se}$ and the whole cycle is repeated.

⑥ This leads to a situation called 'THERMAL RUNAWAY'.



NOTE:- $T\uparrow \rightarrow I_{CBO}\uparrow \rightarrow I_{CEO}\uparrow \rightarrow I_C\uparrow$

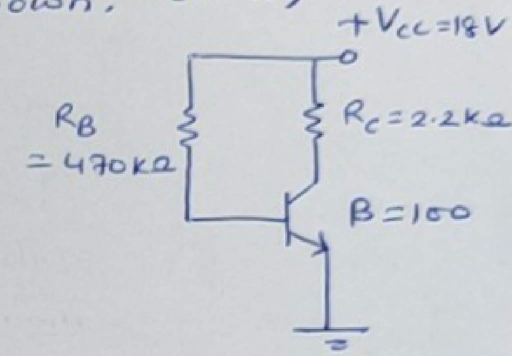
ADVANTAGES OF FIXED BIAS CIRCUIT :-

1. Simple ckt and less components.
2. Good flexibility as Q point can be set at any point in the region by just adjusting the value of R_B.

DISADVANTAGES OF FIXED BIAS CIRCUIT :-

1. Very poor thermal stability $(S = 1 + \beta)$.
2. With change in β due to changes in temperature the operating point keeps on shifting its position.

Q. Find I_B, I_c & V_{CE} for the ckt shown. (15-16) ← 6mks.



soln Apply KVL at I/p side,

$$V_{CC} - I_B R_B - V_{BE} = 0$$

$$V_{CC} - V_{BE} = I_B R_B.$$

$$I_B = \frac{V_{CC}}{R_B} - \frac{V_{BE}}{R_B}.$$

$$= \frac{18 - 0.7}{470 \times 10^3} = 36.8 \times 10^{-6}.$$

$$\boxed{I_B = 36.8\ \mu A}$$

$$I_c = \beta I_B = 100 \times 36.8 \times 10^{-6}.$$

$$I_c = 3.68 \times 10^{-3}.$$

$$\boxed{I_c = 3.68 mA}$$

Apply KVL at O/p side.

$$V_{CC} - I_c R_C - V_{CE} = 0.$$

$$V_{CE} = V_{CC} - I_c R_c$$

$$= 18 - (3.68 \times 10^{-3} \times 2.2 \times 10^3)$$

$$\boxed{V_{CE} = 9.904V}$$

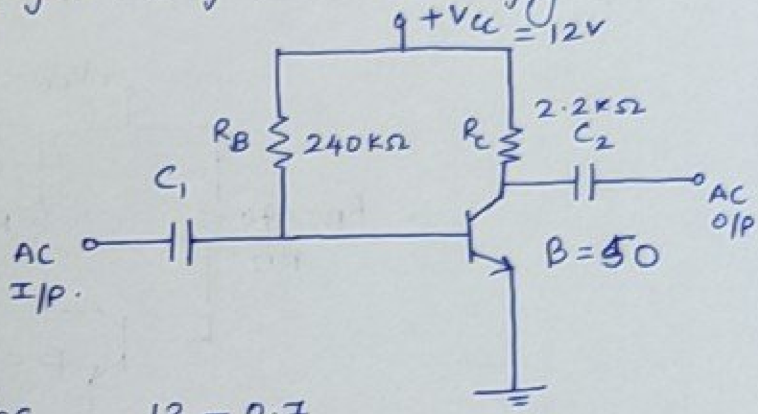
Q: Determine the following for the fixed bias configuration

a.) I_{BQ} & I_{CQ}

b.) V_{CEQ}

c.) V_B & V_C.

d.) V_{BC}.



Soln:-

$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12 - 0.7}{240 \times 10^3}$$

$$= 47.08 \times 10^{-6}$$

$$I_{BQ} = 47.08\ \mu A.$$

$$I_{CQ} = \beta I_{BQ}.$$

$$= 50 \times 47.08 \times 10^{-6}.$$

$$= 2.354 \times 10^{-3}$$

$$I_{CQ} = 2.354\ mA.$$

$$V_{CEQ} = V_{CC} - I_C R_C.$$

$$= 12 - 2.354 \times 10^{-3} \times 2.2 \times 10^3.$$

$$= \cancel{12 - 6.8}\ 6.8212\ V.$$

$$V_B = V_{BE} + V_E.$$

$$= 0.7 + 0$$

$$= 0.7V.$$

$$V_C = V_{CE} + V_E.$$

$$= 6.8212 + 0.$$

$$V_C = 6.8212V.$$

$$V_{BC} = V_B - V_C.$$

$$= 0.7 - 6.8212$$

$$= -6.1212V.$$

Q Design a fixed circuit using a Si npn x^{r} which has $\beta_{dc} = 150$. The dc biasing point is at $V_{CE} = 5V$ and $I_c = 5mA$. Supply vtg is 10V.

Soln.

n-p-n

$\beta = 150$.

$V_{CE} = 5V$

$I_c = 5mA$.

$V_{cc} = 10V$

$$I_B = \frac{I_c}{\beta} = \frac{5\times10^{-3}}{150} = 33.33\,\mu A.$$

$$V_{cc} - V_{BE} = I_B R_B.$$

$$R_B = \frac{V_{cc} - V_{BE}}{I_B} = \frac{10 - 0.7}{33.33\times10^{-6}}.$$

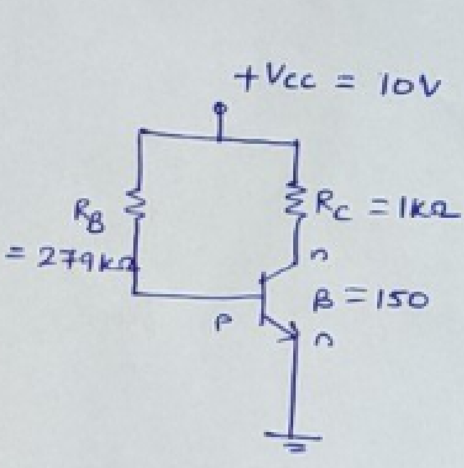
$$R_B = 279.02\,K\Omega$$

$$V_{cc} - V_{cE} = I_c R_c.$$

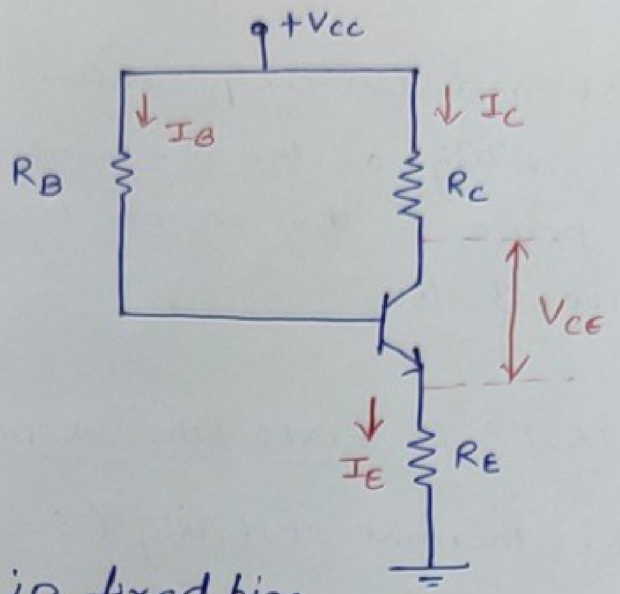
$$R_c = \frac{V_{cc} - V_{cE}}{I_c}.$$

$$= \frac{10 - 5}{5\times10^{-3}}$$

$$R_c = 1K\Omega$$



MODIFIED FIXED BIAS CIRCUIT (EMITTER BIAS)



R_E is added in fixed bias ckt. The emitter resistor improves the bias point stability.

Stablization of Q point.

1.) If I_C ↑ses due to either ↑se in temperature or change in β due to replacement of transistor then Ike I_E will ↑se.

2.) Due to ↑se in I_E, voltage drop across R_B. i.e; V_E ↑ses.

3.) ∴ V_{BE} will decrease. This will reduce the value of I_B and Therefore the ↑sed I_C will reduce. Thus stablization of Q point takes place.

Analysis:-

Step 1:- I_{BQ}

Apply KVL to base ckt.

$$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0.$$

$$I_B R_B = V_{CC} - V_{BE} - I_E R_E.$$

$$R_B I_B = V_{CC} - V_{BE} - (I_B + I_C) R_E.$$

$$= V_{CC} - V_{BE} - (\beta I_B + I_B) R_E.$$

$$= V_{CC} - V_{BE} - (1+\beta) I_B R_E$$

$$R_B I_B + (1+\beta) I_B R_E = V_{CC} - V_{BE}.$$

$$I_B [R_B + (1+\beta) R_E] = V_{CC} - V_{BE}.$$

$$\boxed{I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_E}}$$

Step 2:- I_{CQ}.

$$I_{CQ} = \beta I_{BQ}.$$

$$I_{CQ} = \beta \left[\frac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_E} \right]$$

$$\boxed{I_{CQ} = \frac{\beta (V_{CC} - V_{BE})}{R_B + (1+\beta) R_E}}.$$

Step 3:- V_{CEQ}.

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

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

$$= V_{CC} - I_C R_C - (I_C - I_B) R_E.$$

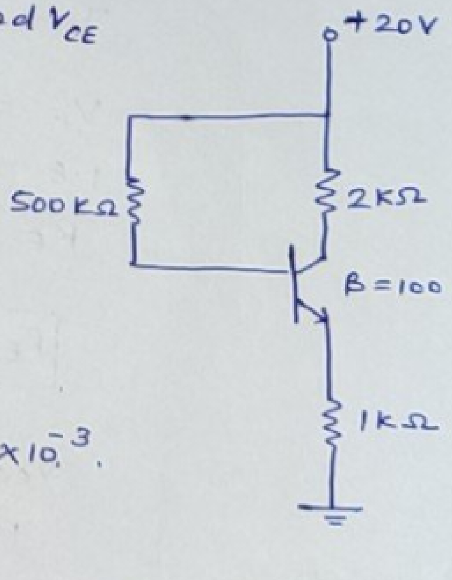
$$= V_{CC} - I_C R_C - I_C R_E + I_B R_E.$$

$$= V_{CC} - I_C (R_C + R_E) + I_B R_E.$$

$$V_{CC} \gg I_B R_E$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E).$$

Q. For the emitter bias, find I_B, I_C, V_C, V_E and V_{CE}



Soln:- $I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_E} = \frac{20 - 0.7}{500 \times 10^3 + (1+100) \times 1000}$

$\boxed{I_B = 32.11\ \mu A}$

$I_C = \beta I_B = 100 \times 32.11 \times 10^{-6}.$

$\boxed{I_C = 3.2113\ mA}$

$I_E = I_B + I_C = 32.11 \times 10^{-6} + 3.2113 \times 10^{-3}.$

$\boxed{I_E = 3.2431\ mA}$

$V_C = V_{CC} - I_C R_C = 20 - (3.2113 \times 10^{-3} \times 2 \times 10^3)$

$= \cancel{20 - (3} \ 13.58 V$

$V_E = I_E R_E = 3.2431 \times 10^{-3} \times 1000$

$$\boxed{V_E = 3.2431\ V.}$$

$V_{CE} = V_C - V_E.$

$= 13.58 - 3.2431$

$$\boxed{V_{CE} = 10.337V}$$

Q. Design the emitter bias ckt to satisfy the following

$V_{CC} = 18V$

$I_{CQ} = 2mA.$

$V_{CEQ} = 9V$

$\beta = 100.$

soln:-

$I_{BQ} = \frac{I_C}{\beta} = \frac{2 \times 10^{-3}}{100} = \frac{2 \times 10^{-3}}{10^2} = 20\mu A.$

For good Q point stability.

$V_E = 0.1 V_{CC}.$

$= 0.1 \times 18$

$$\boxed{V_E = 1.8V}$$

$V_E = I_E R_E.$

$I_E = I_B + I_C = 20 \times 10^{-6} + 2 \times 10^{-3}.$

$I_E = 2.02mA.$

$V_E = I_E R_E$

$1.8 = 2.02 \times 10^{-3} \times R_E.$

$R_E = \frac{1.8}{2.02 \times 10^{-3}}.$

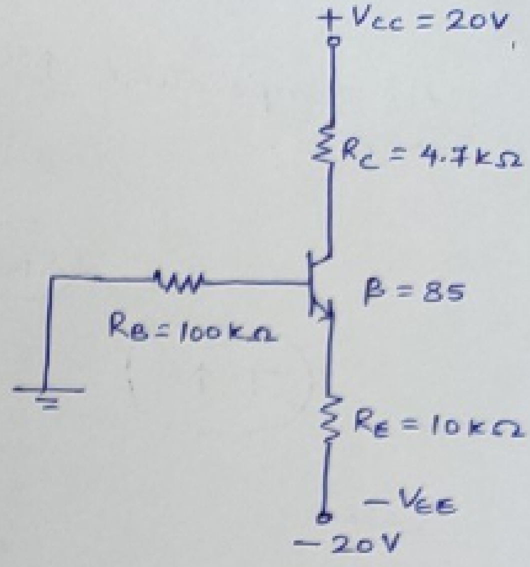
$$\boxed{R_E = 831\Omega}$$

$V_{CC} - I_B R_B - V_{BE} - V_E = 0.$

$18 - R_b 20 \times 10^{-6} - 0.7 - 1.8 = 0.$

$R_B = \frac{18 - 0.7 - 1.8}{20 \times 10^{-6}} = 775 k\Omega.$

Q. For the emitter bias ckt shown, find I_E, I_C, V_C and V_{CE} for $\beta = 85$ and $V_{BE} = 0.7V$



Soln:-

$$I_c \simeq I_E = \frac{V_{CC} - V_{BE}}{R_E + (R_B/\beta)}$$

$$I_E = \frac{20 - 0.7}{10\times10^3 + (100\times10^3/85)}$$

$$I_C = \boxed{I_E = 1.73 mA}$$

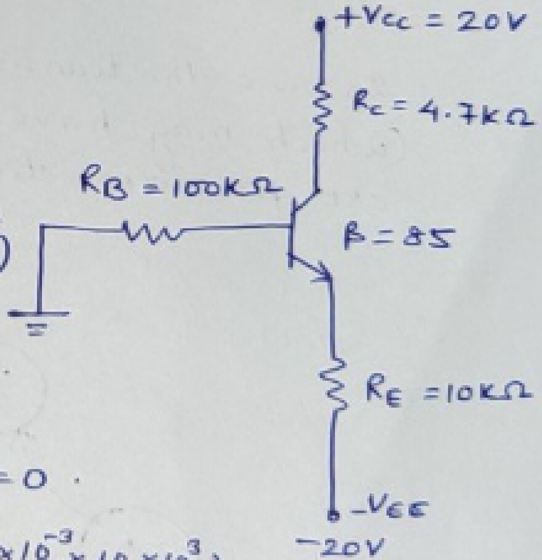
$$V_C = V_{CC} - I_C R_C = 20 - (1.73\times10^{-3} \times 4.7\times10^3) = 11.9V$$

$$V_E = -V_{EE} + I_E R_E = -20 + (1.73\times10^{-3} \times 10\times10^3)$$

$$\boxed{V_E = -2.7V}$$

$$V_{CE} = V_C - V_E = 11.9 - (-2.7) = 14.6V.$$

Q. Determine how much the Q-point in the fig change over a temperature range where β increases from 85 to 100 and V_{BE} ↓ses from 0.7V to 0.6V.



Soln:- For $\beta = 85$. & $V_{BE} = 0.7V$.

$$I_C = \frac{V_{CC} - V_{BE}}{R_E + \left(\frac{R_B}{\beta}\right)} = \frac{20 - 0.7}{10\times10^3 + \left(\frac{100\times10^3}{85}\right)}$$

$$I_E = \boxed{I_C = 1.73 mA}$$

$$V_{CC} - I_C R_C - V_{CE} - I_E R_E - (-V_{EE}) = 0.$$

$$20 - (1.73\times10^{-3} \times 4.7\times10^3) - V_{CE} - (1.73\times10^{-3} \times 10\times10^3) + 20 = 0$$

~~40 19.448 = Vce − 17.3 + 20~~.

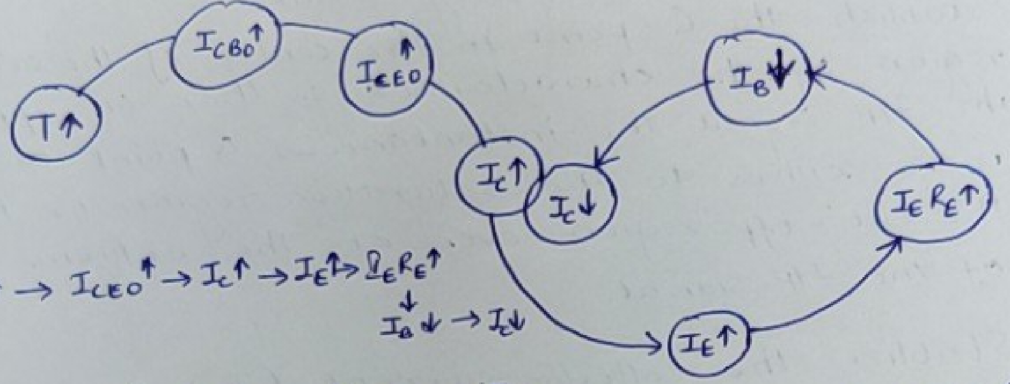
$$V_C = V_{CC} - I_C R_C = 20 - (1.73\times10^{-3} \times 4.7\times10^3) = 11.9V$$

$$V_E = I_E R_E - V_{EE} = (1.73\times10^{-3} \times 10\times10^3) - 20$$

$$= -2.7V$$

$$V_{CE} = V_C - V_E = 11.9 - (-2.7) = 14.6V$$

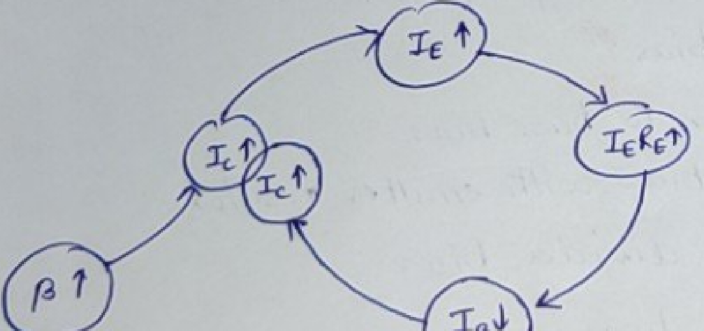
(1.) As the temperature tends to $\uparrow$se, the following sequence of events occurs



$T\uparrow \rightarrow I_{CBO}\uparrow \rightarrow I_{CEO}\uparrow \rightarrow I_C\uparrow \rightarrow I_E\uparrow \rightarrow I_E R_E\uparrow$
$\downarrow$
$I_B\downarrow \rightarrow I_C\downarrow$

Because of $\uparrow$se in temperature,
The leakage current I_{CBO} $\uparrow$ses, and hence I_{CEO} $\uparrow$ses $(I_{CEO} = (1+\beta)I_{CBO})$
This $\uparrow$ses the collector I_{CEO} $\uparrow$ses, I_C $\uparrow$ses, $I_C = \beta I_B + I_{CEO}$.
With $\uparrow$se in the collector current I_C, I_E $\uparrow$ses as $I_E = I_B + I_C$
Thus the voltage drop across the emitter resistor R_E $\uparrow$ses.
$\therefore$ $I_E R_E \uparrow$, further reduces I_B. and this leads to
the reduction in the collector current I_C.
Thus we see that I_C is not allowed to $\uparrow$se to the extent it would have been in the absence of R_E.

(2.) In case the transistor is replaced by another of the same type



(1.) β $\uparrow$ses, $\beta = \dfrac{I_C}{I_B}$, hence I_C $\uparrow$ses.

(2.) As I_C $\uparrow$ses, $I_C = I_B + I_E$ and I_B is very small hence, I_E $\uparrow$ses.

(3) Voltage drop across R_E $\uparrow$ses ($V_E = I_E R_E$ $\uparrow$ses)

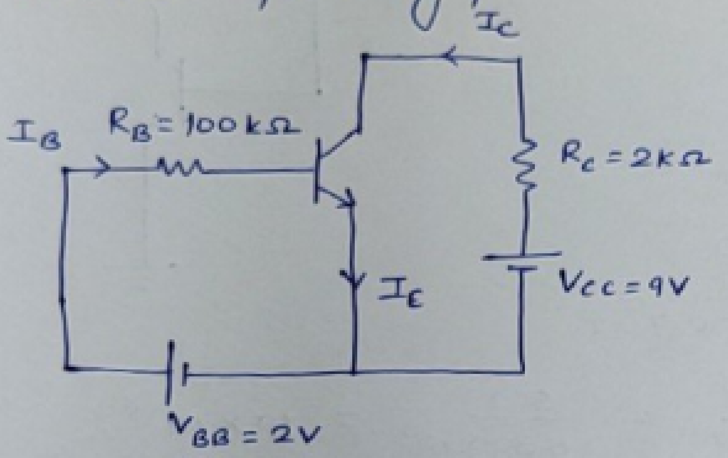
(4) Which $\downarrow$ses I_B, As $I_B = \dfrac{V_{CC} - V_{BE} - V_E}{R_B}$.

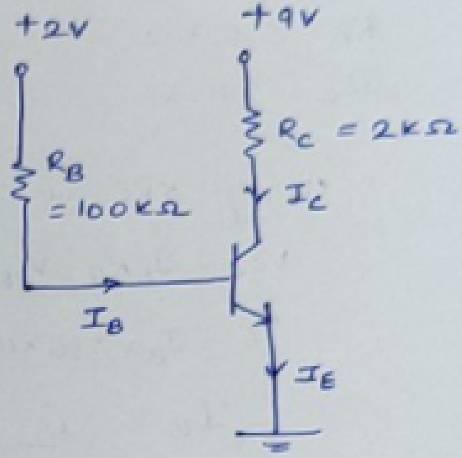
(5) As V_{CC} is constant and V_{CE} also, then with $\uparrow$se in V_E I_B $\downarrow$ses. This leads to $\downarrow$se in I_C.

Q. Figure shows biasing with base resistor method.

i) Determine the collector current I_C and collector emitter voltage V_{CE}. Neglect small base-emitter voltage. Given that $\beta = 50$.

ii) If R_B in this ckt is changed to $50K\Omega$, find the new operating point.





soln:- Apply KVL at I/P,

$$V_{BB} - I_B R_B - V_{BE} = 0.$$

$(\because V_{BE} = 0$ given$)$.

$$V_{BB} - I_B R_B = 0.$$

$$2 - I_B \times 100 \times 10^3 = 0$$

$$I_B = \frac{2}{100 \times 10^3} = 20\mu A //$$

$$I_C = \beta I_B = 50 \times 20 \times 10^{-6}.$$

$$I_C = 1 \times 10^{-3}$$

$$I_C = 1mA //.$$

Apply KVL at o/p,

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

$$9 - (1 \times 10^{-3} \times 2 \times 10^3) - V_{CE} = 0.$$

$$9 - 2 = V_{CE}$$

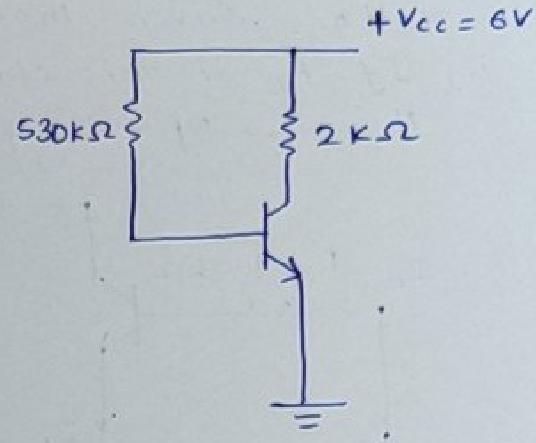
$$V_{CE} = 7V //.$$

When $R_B = 50K\Omega$. $I_B = \frac{2}{50 \times 10^3} = 40\mu A$.

$$I_C = \beta I_B = 50 \times 40 \times 10^{-6} = 2000\mu A. = 2mA$$

$$V_{CE} = V_{CC} - I_C R_C = 9 - (2 \times 10^{-3} \times 2 \times 10^3) = 5V$$

Q: Fig shows that a Si x^{or} with $\beta = 100$ is biased by base resistor method. Draw the dc load line and determine the operating point. What is the stability factor?



Soln: $V_{cc} = 6V$

$R_B = 530k\Omega$

$R_C = 2K\Omega$.

Apply KVL at I/P.

$V_{cc} - I_B R_B - V_{BE} = 0$.

$6 - I_B \times 530 \times 10^3 - 0.7 = 0$.

$I_B = \frac{6-0.7}{530 \times 10^3} = \frac{5.3}{530 \times 10^3} = 10 \times 10^{-6}$.

$= 10 \mu A$.

$I_C = \beta I_B$.

$= 100 \times 10 \times 10^{-6}$

$= 1 \times 10^{-3}$

$= 1 mA$.

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

$= 6 - (1 \times 10^{-3} \times 2 \times 10^3)$

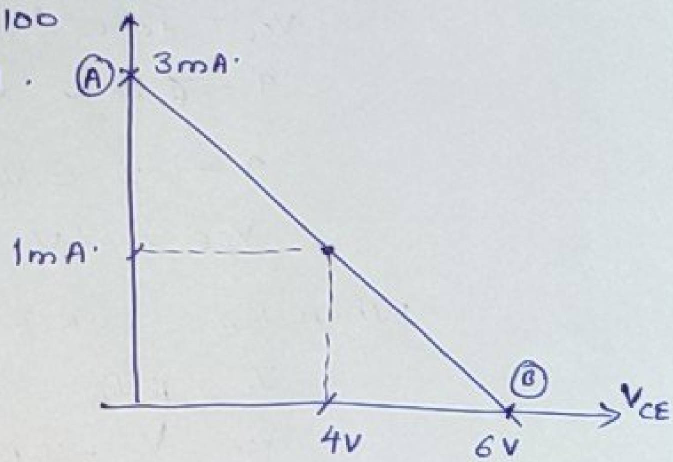
$= 6 - 2$

$= 4V$

stability factor $= 1 + \beta$.

$= 1 + 100$

$= 101$.



point A $= I_{c\,max} = \frac{V_{cc}}{R_c}$

$= \frac{6}{2 \times 10^3} = 3 \times 10^{-3}$

$= 3 mA$.

point B $= V_{CE\,max} = V_{cc} = 6V$.