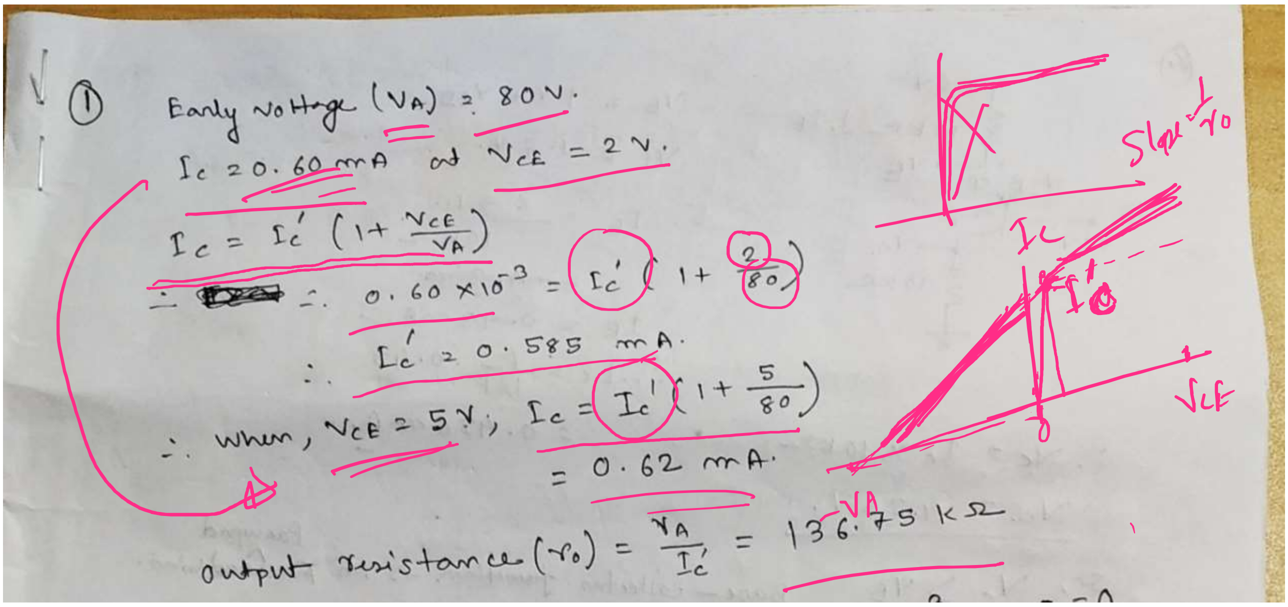
16 September 2021 06:45

Lec-15

TUTORIAL CLASS

1. A BJT has an Early voltage of 80 V. The collector current is $I_C = 0.60$ mA at a collector–emitter voltage of $V_{CE} = 2$ V. (a) Determine the collector current at $V_{CE} = 5$ V. (b) What is the output resistance?


① Early voltage $(V_A) = 80$ V.

$I_c = 0.60$ mA at $V_{CE} = 2$ V.

$I_c = I_c'\left(1 + \frac{V_{CE}}{V_A}\right)$

$\therefore\ 0.60 \times 10^{-3} = I_c'\left(1 + \frac{2}{80}\right)$

$\therefore\ I_c' = 0.585$ mA.

$\therefore$ when, $V_{CE} = 5$ V, $I_c = I_c'\left(1 + \frac{5}{80}\right)$

$= 0.62$ mA.

output resistance $(r_o) = \frac{V_A}{I_c'} = 136.75\ k\Omega$

2. In the following circuit (Fig. 1), find the I_B, V_E and V_C. Assume, $\beta = 100$ and $|V_{BE}| = 0.7$ V.

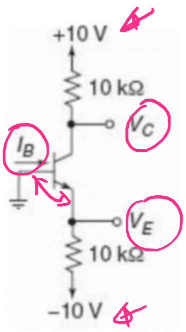


Fig. 1

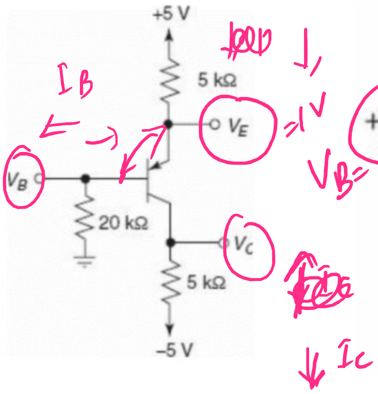


Fig. 2

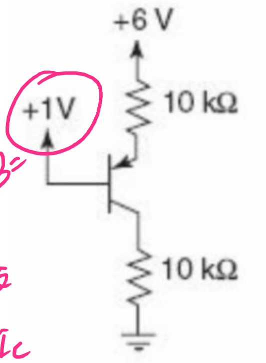


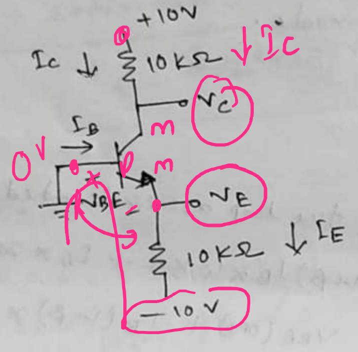
Fig. 3

$V_{EB} = 0.7$ V.

3. The circuit shown in Fig. 2 has $V_E = 1$ V. Find V_B, V_C, I_C, I_B, α and β. Assume, $|V_{BE}| = 0.7$ V.

4. Identify, whether the p-n-p transistor (shown in Fig. 3) is in active mode or in saturation mode. Assume, $\beta = 100$ and $|V_{BE}| = 0.7$ V.

(2)



$V_{BE} + I_E \cdot 10\times10^3 - 10 = 0.$

$\therefore 0.7 + I_E \cdot 10^4 = 10$

$\therefore I_E = \frac{9.3}{10^4} = 0.93$ mA.

$I_B = \frac{I_E}{(\beta+1)}$; $I_E = I_C + I_B$, $I_E = \beta I_B + I_B$, $I_E = (\beta+1) I_B$.

$\therefore = \frac{0.93 \text{ mA}}{101}$

$I_B = 9.2\ \mu A.$

$V_E = (-)\,0.7$ V.

$\therefore I_C = 0.921$ mA.

$\therefore V_C = 10 - I_C \times 10\text{ k}\Omega$

$= 10 - 0.921 \text{ mA} \times 10\text{ k}\Omega$

$V_C = 0.79$ V.

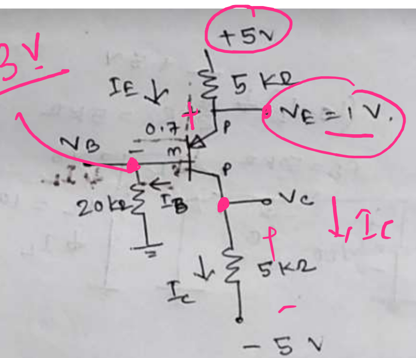
(3)

$V_E = 1$ V

$V_{EB} = 0.7$ V.

$\therefore V_B = 1 - 0.7 = 0.3$ V

0.3V



pnp

$\therefore I_B = \frac{0.3}{20\text{k}\Omega} = 0.015$ mA.

$\therefore I_E = \frac{5-1}{5\text{k}\Omega} = 0.80$ mA.

$\therefore I_C = 0.80 - 0.015 = 0.785$ mA.

$I_C + I_B = I_E$

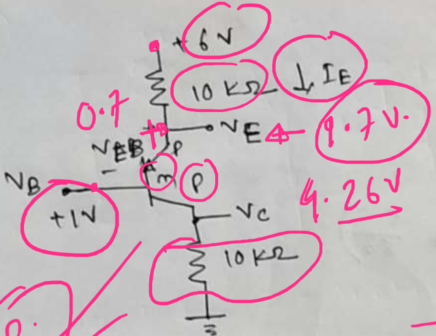
$\therefore V_C = -5 + I_C \cdot 5\text{k}\Omega = -1.075$ V.

Forward Active

$\alpha = \frac{I_C}{I_E} = 0.981$

$\beta = \frac{I_C}{I_B} = \frac{0.785}{0.015} = 52.33$

(4)



$V_E = 1\text{V} + V_{EB}$

$V_E = 1.7$ V.

$\therefore I_E = \frac{6 - 1.7}{10\text{k}\Omega}$

~~4.3 m~~

$I_E = 0.43$ mA.

$\therefore I_C = \frac{\beta}{1+\beta} \cdot 0.43$

$= 0.426$ mA.

F.B.

$\therefore V_C = I_C \times 10\text{k}\Omega$

$V_C = 4.26$ V.

Forward ~~Forward~~ bias.

$V_C = 4.26$ V.

So, $V_C > V_B$, Base – collector junction (B – C) is in Forward bias.

So, BJT is in saturation mode.

5. In the circuit shown in Fig. 4, find V_C. Assume, $\beta = 75$ and $|V_{BE}| = 0.7$ V.

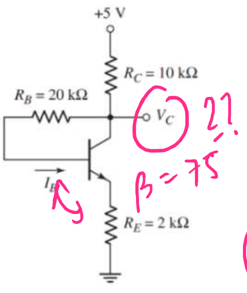


Fig. 4

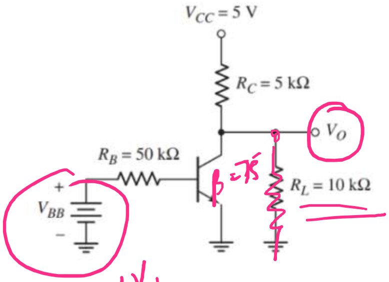


Fig. 5

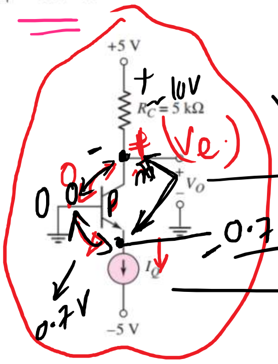


Fig. 6

$V_{CE} = 0.2$ V.

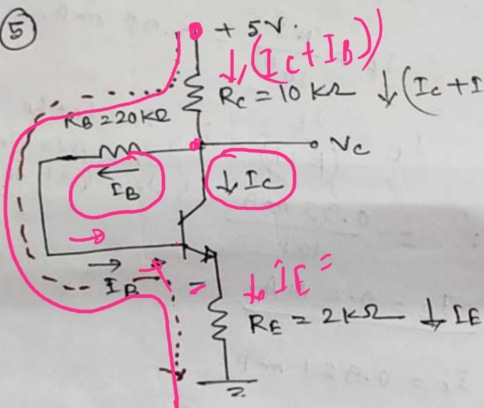
$V_0 =$

2 mA

6. (a) The common emitter current gain of the transistor in Fig. 5 is $\beta = 75$. Determine V_0 for: (i) $V_{BB} = 0$, (ii) $V_{BB} = 1$ V, and (iii) $V_{BB} = 2$ V.

7. The transistor shown in Fig. 6 has $\beta = 100$. Determine V_O for (i) $I_Q = 0.1$ mA, (ii) $I_Q = 0.5$ mA, and (iii) $I_Q = 2$ mA.

(5)



$\downarrow (I_C + I_B) = I_E$

$I_C + I_B = \beta I_B + I_B$

Along the loop as indicated in fig.

$5 = (1+\beta) I_B \times 10\text{ k}\Omega + I_B \times 20\text{ k}\Omega$

$+ V_{BE(ON)} + I_B (1+\beta) \times 2\text{ k}\Omega$

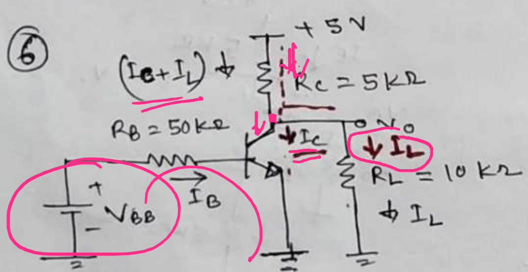
$\therefore I_B = 4.61\ \mu A.$

$\therefore I_C = \beta \times I_B = 0.346$ mA.

$V_C = 5 - 10\text{ k}\Omega \times (I_C + I_B)$

$= 1.5$ V.

(6)



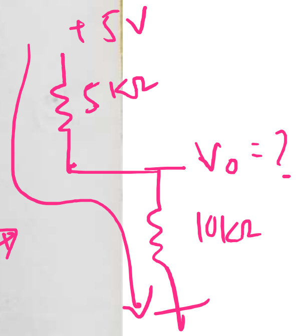
(a) When, $V_{BB} = 0$.

Cut – off.

$I_B = 0$, $I_C \simeq 0$.

$\therefore V_0 = \frac{10}{10+5} \times 5$ V.

$V_0 = 3.33$ V. (1)



(b) When, $V_{BB} = 1$ V., $I_B = \frac{V_{BB} - V_{BE(ON)}}{R_B} = \frac{1 - 0.7}{50\text{ k}\Omega} = 6\ \mu A.$

$\therefore I_C = \beta I_B = 75 \times 6\ \mu A = 0.45$ mA. (assuming BJT in active mode)

KCL in the marked ~~loop~~ node, → Current through 5k = ...

$\frac{5 - V_0}{\ldots} = I_C + \frac{V_0}{\ldots}$

(assuming BJT in active mode)

KCL in the marked ~~loop~~, mode, $\rightarrow$ Current through 5k = $I_c + I_L$

$$\frac{5-V_0}{5} = I_c + \frac{V_0}{10}$$

$\therefore V_0 = 1.83\,V.$, so, BJT is in active mode as assumed.

(c) When, $V_{BB} = 2V.$

$$I_B = \frac{2-0.7}{50} = 26\,\mu A.$$

$\therefore I_c = \beta I_B = 1.95\,mA.$ (if in active mode).

$$\frac{5-V_0}{5k} = I_c + \frac{V_0}{10k}$$

$\therefore 1 - 0.2V_0 = 1.95 + V_0 \times 0.1$

$\therefore -0.95 = 0.3\,V_0.$

$\therefore V_0 < 0.$ (BJT not in active mode, so it is in saturation).

In saturation,

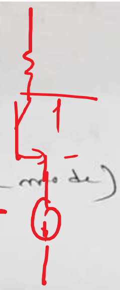
$V_{CE} = 0.2\,V = V_0.$

(7) $\beta = 100$ given,

if $I_B = I_E = 0.1\,mA.$

$\therefore I_c = \frac{\beta}{1+\beta} \cdot I_E = 0.099\,mA$

$\therefore V_0 = 5 - I_c \cdot R_c = 4.50\,V.$ (i)



(Active mode)

if $I_B = I_E = 0.5\,mA.$ (Active mode)

$\therefore I_c = \frac{\beta}{1+\beta} I_E = 0.495\,mA.$

$\therefore V_0 = 5 - I_c R_c = 2.52\,V.$ --- (ii)

if $I_B = I_E = 2\,mA$, then BJT is in saturation.

$\therefore V_{CE} = 0.2\,V.$; $V_{BE(sat)} = V_{BE(ON)}$ (assuming)

$\therefore V_{CB} + V_{BE(ON)} = 0.2\,V.$

$\therefore V_{CB} = (0.2 - 0.7)V.$

$= -0.5\,V.$ --- (iii)

8. In the common-base (CB) circuit shown in Fig. 7, assume the transistor gain $\alpha = 0.9920$. Determine I_E,

8. In the common-base (CB) circuit shown in Fig. 7, assume the transistor gain $\alpha = 0.9920$. Determine I_E, I_C, and V_{BC}.

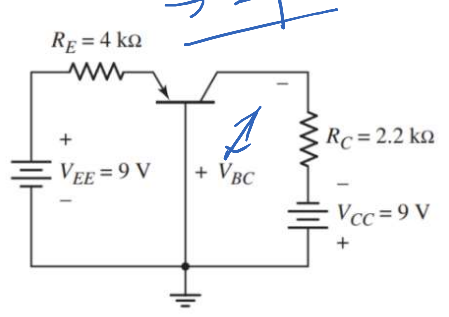


Fig. 7

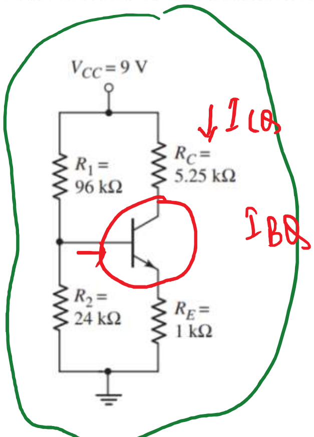


Fig. 8

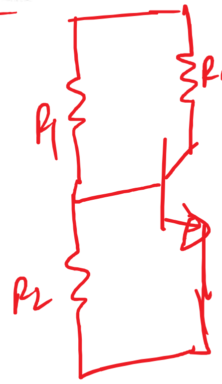
ΔI_{CQ}

$\Delta I_{CQ} \rightarrow$ 7.77 % change

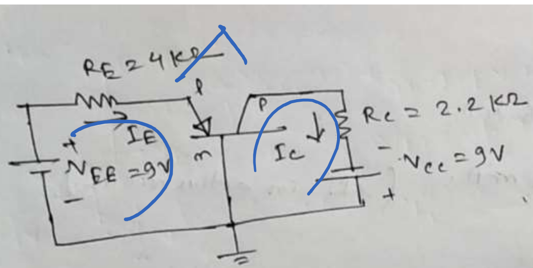
I_{BQ}, I_{CQ}, V_{CEQ} $\beta = 80$

$\beta = 120$ 50 % change

9. Consider the circuit shown in Fig. 8. (a) Determine I_{BQ}, I_{CQ}, and V_{CEQ} for $\beta = 80$. (b) What is the percent change in I_{CQ} and V_{CEQ} if β is changed to $\beta = 120$? Now, comment on the change in I_{CQ} and V_{CEQ} compared to the change in β.



⑧



$\alpha = 0.9920$.

$|V_{BE(ON)}| = 0.7$ V.

$\therefore$ i/p loop, $9 = I_E . R_E + V_{EB\_ON}$

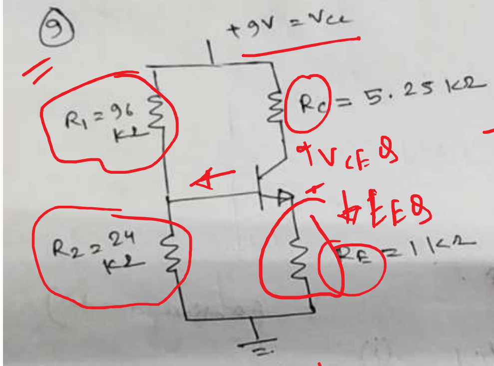
$\therefore I_E = \dfrac{9 - 0.7}{4\ k\Omega} = 2.075$ mA.

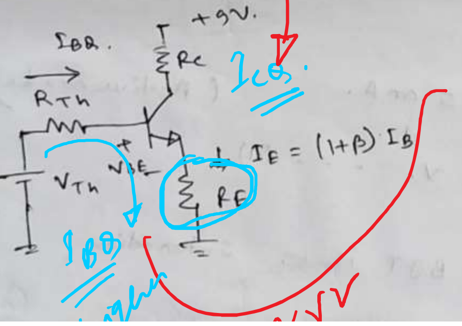
$\therefore I_C = \alpha I_E = 2.06$ mA.

$\therefore$ o/p loop, $V_{BC} + I_C R_C = V_{CC}$

$\therefore V_{BC} = V_{CC} - I_C R_C = 4.47$ V.

⑨





$\boxed{\beta = 80}$

$R_{Th} = 96 \parallel 24$

$R_{Th} = \dfrac{96 \times 24}{96 + 24} = 19.2\ k\Omega$

$\therefore V_{Th} = 9 \times \dfrac{24}{96 + 24}$

$= 1.8$ V.

$V_{Th} = I_{BQ} . R_{Th} + V_{BE} + I_E R_E$

$\therefore V_{Th} = I_{BQ} . R_{Th} + V_{BE} + (1+\beta) I_{BQ} R_E$

$\therefore I_{BQ} = \dfrac{V_{Th} - V_{BE}}{R_{Th} + (1+\beta) R_E}$

$= \dfrac{1.8 - 0.7}{\ldots + (1+80)\, 1\ K}$

$I_E = (1+\beta) I_{BQ}$

I_{BQ} higher

$$= \frac{1.8 - 0.7}{19.2K + (1+80)\,1K}$$

$\beta = 80$

$$I_{BQ} = 10.97\ \mu A$$

$$\therefore I_{CQ} = \beta I_{BQ} = 0.878\ mA$$

$$\therefore I_{EQ} = (\beta+1) I_{BQ} = 0.888\ mA$$

$$\therefore V_{CEQ} = V_{CC} - I_{CQ} \cdot R_C - I_{EQ} \cdot R_E = 3.50V$$

if, $\beta = 120$,

$$I_{CQ} = \beta \times \frac{V_{Th} - V_{BE}}{R_{Th} + (1+\beta) R_E}$$

$$\therefore I_{BQ} = \frac{V_{Th} - V_{BE}}{R_{Th} + (1+\beta) R_E} = \frac{1.8 - 0.7}{19.2K + (1+120)\,1K} = 7.84\ \mu A$$

$$\therefore I_{CQ} = I_{BQ} \cdot \beta = 120 \times 7.84\ \mu A = 0.941\ mA$$

$V_{CEQ} = ??$

$$\therefore \text{change in } I_{CQ} = \frac{0.941 - 0.878}{0.878} \times 100\% = 7.17\%\quad \text{Ans}$$

$$\text{" " } \beta = \frac{120 - 80}{80} = 50\%$$

Observation: In voltage divider biasing, along with R_E though β changes by 50%, the I_{CQ} changes only by 7.17%. So, the circuit is quite stable in terms of change in β.

Now Find V_{CEQ} when $\beta = 120$

Change in $V_{CEQ} = -11.\%$ Ans

10. The dc load line and Q-point of the circuit in Fig. 9(a) are shown in Fig. 9(b). For the transistor, $\beta = 120$. Find R_E, R_1, and R_2 such that the circuit is bias stable in terms of change in β.

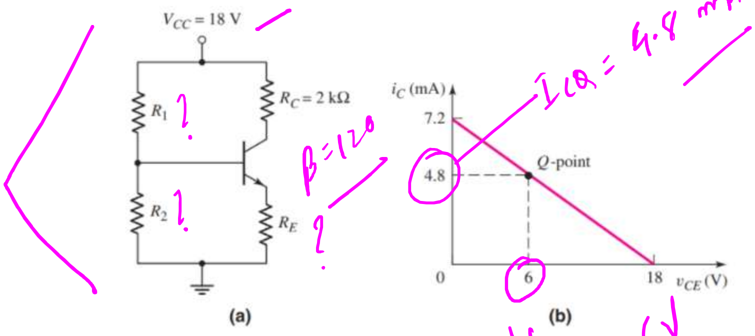
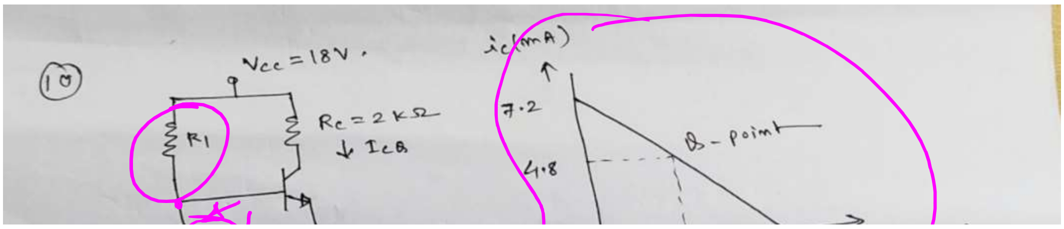
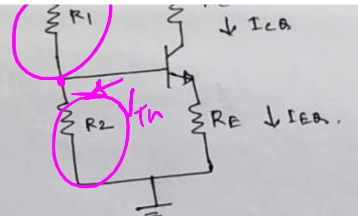
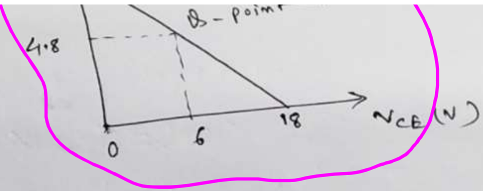


Fig. 9

I_{CQ}, V_{CEQ}







$I_{CQ} = 4.8$ mA from DC load line characteristics.

$\beta = 120 \quad \therefore \alpha = 0.9917 \quad \therefore I_{EQ} = \frac{I_{CQ}}{\alpha} = 4.84$ mA.

$V_{CEQ} = 6$ from DC load line characteristics.

$V_{CEQ} = 18 - I_{CQ} R_C - I_{EQ} \cdot R_E$

$\therefore 6 = 18 - 4.8 \times 2 - 4.84 \times R_E$.

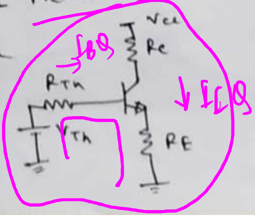
$\therefore R_E = 0.496$ kΩ $= 496$ Ω.

We know that for voltage devider biasing to make the circuit bias stable in terms of change in β,

$R_{Th} = 0.1 \times (1+\beta) R_E = 6$ kΩ [Please see class note].

where, R_{Th} is the Thevenin's equn. resistance at base terminal and

$R_{Th} = (R_1 \| R_2)$ and $V_{Th} = V_{CC} \cdot \frac{R_2}{R_1 + R_2}$



$R_{Th} = R_1 \| R_2$

$V_{Th} = \frac{R_2}{R_1 + R_2} \times V_{CC}$

$= \frac{1}{R_1} \times \frac{R_1 R_2}{R_1 + R_2} \times V_{CC}$

$V_{Th} = \frac{1}{R_1} \times R_{Th} \times V_{CC}$

$\therefore I_{BQ} = \frac{I_{CQ}}{\beta} = 0.040$ mA

$\therefore V_{Th} = I_{BQ} \cdot R_{Th} + V_{BE(ON)} + R_E \cdot I_E$

$= I_{BQ} \cdot R_{Th} + V_{BE(ON)} + R_E (1+\beta) I_{BQ}$.

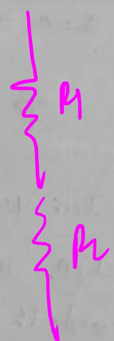
$V_{Th} = 0.04 \times R_{Th} + 0.7 + 0.496 \times 0.040 \times 121$

$V_{Th} = 3.34$ V.

$V_{Th} = R_{Th} \cdot \frac{1}{R_1} \cdot V_{CC}$; $\left[R_{Th} = \frac{R_1 R_2}{R_1 + R_2} \right]$

$3.34 = 6 \text{ K} \cdot \frac{1}{R_1} \cdot 18$ V.

$R_1 = 32.3$ kΩ



$R_{Th} = \frac{R_1 R_2}{R_1 + R_2} = 6$ K.

$R_2 = 7.37$ kΩ.