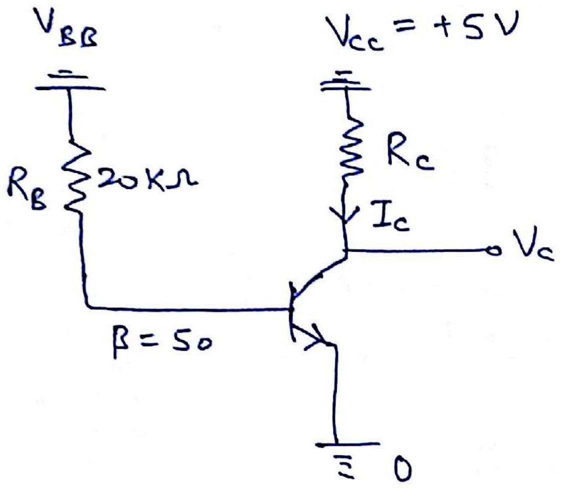
SOLUTION ASSIGNMENT- II

Sol 1. (a)



Active region:

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

$$= \frac{5-1}{1K} = 4mA$$

$$I_B = \frac{I_c}{\beta} = \frac{4}{50} = 0.08mA$$

$$V_{BB} = 0.7 + \frac{20 \times 4}{50} = +2.3V$$

(b) Edge of saturation: $V_c = 0.3V$

$$I_c = \frac{5-0.3}{1} = 4.7mA$$

$$I_B = \frac{I_c}{\beta} = \frac{4.7}{50} = 0.094mA$$

$$V_{BB} = 0.094 \times 20 + 0.7 = 2.58V$$

(c) Deep Saturation: $V_c = 0.2V$, $\beta_f = 10$

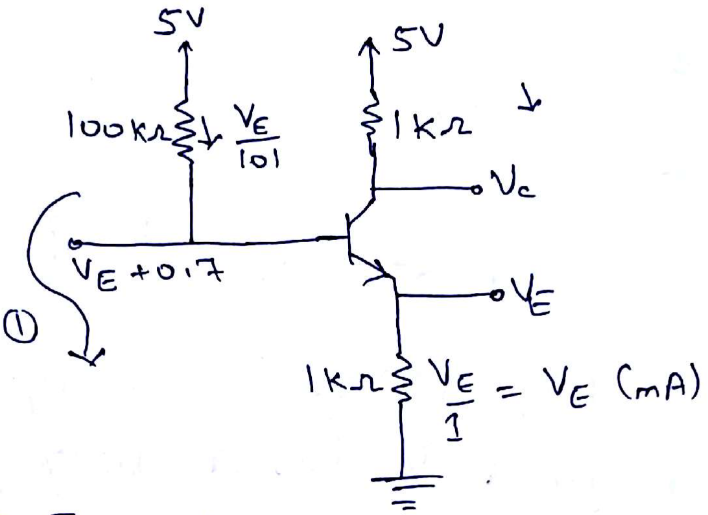
$$I_c = \frac{5-0.2}{1} = 4.8mA$$

$$I_B = \frac{I_c}{\beta_{forced}} = \frac{4.8}{10} = 0.48mA$$

$$V_{BB} = 0.48 \times 20 + 0.7 = +10.3V$$

Sol. 2 : $\beta = 100$.

(a) $R_B = 100\,k\Omega$. $\because R_B$ is large, assume active mode.



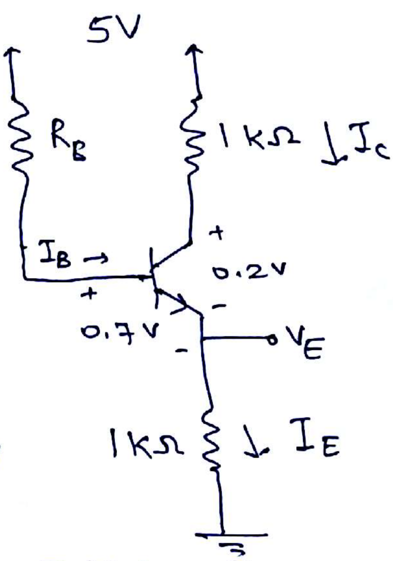
$\cancel{\frac{100}{100}}$ $\quad \frac{100}{101} I_E = \frac{100}{101} V_E \,(mA)$

Loop (1) : $\quad 5 - \frac{V_E}{101} \times 100 - 0.7 - V_E \times 1 = 0 \quad \Rightarrow V_E = 2.16\,V$

$V_B = V_E + 0.7 = 2.86\,V$

$V_c = 5 - 1 \times \frac{100}{101} V_E = 2.86\,V \quad \Rightarrow$ The BJT is in active mode as we assumed.

(b) $R_B = 10\,k\Omega$, assume saturation.



$I_B = \frac{5 - (V_E + 0.7)}{R_B}$

$I_c = \frac{5 - (V_E + 0.2)}{1}$

$I_E = \frac{V_E}{1} = I_B + I_c$

$\therefore V_E = \frac{4.3 - V_E}{10} + 4.8 - V_E \Rightarrow V_E = 2.49\,V$

Now, $V_c = 2.49 + 0.2 = 2.69\,V$; $V_B = V_E + 0.7 = 3.19\,V$

Check: $I_c = \frac{5 - 2.69}{1} = 2.31\,mA$; $I_B = \frac{5 - 3.19}{10} = 0.181\,mA$

$\frac{I_c}{I_B} = \frac{2.31}{181} = 12.76 < 100 \Rightarrow$ We are in saturation, as assumed.

Sol. 2: (c) $R_B = 1\,k\Omega$ - expect saturation, use circuit as in part (b).

$$I_B = \frac{5-(V_E+0.7)}{R_B} = \frac{4.3-V_E}{1}$$

$$I_c = \frac{5-(V_E+0.2)}{1} = \frac{4.8-V_E}{1}$$

$$I_E = I_B + I_c = V_E$$

$$4.3 - V_E + 4.8 - V_E = V_E \quad \Rightarrow \quad V_E = 3V$$

$$V_B = 3.7V$$

$$V_c = 3.2V$$

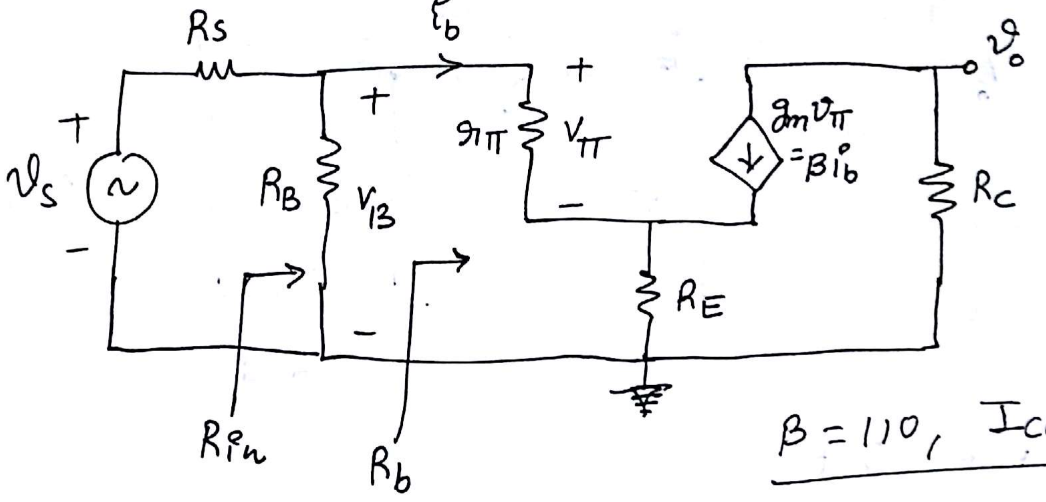
CHECK: $I_B = 4.3 - 3 = 1.3\ mA$

$I_c = 4.8 - 3 = 1.8\ mA$

$$\frac{I_c}{I_B} = \frac{1.8}{1.3} = 1.4 < 100$$

$\therefore$ Saturation, as assumed.

Solution 3



$\beta = 110, \quad I_{CQ} = 4.108\,mA$

R_{in}:-

$$R_{in} = R_B \parallel R_b = \frac{R_B R_b}{R_B + R_b} \quad \text{--- (1)}$$

where, $$R_b = \frac{V_B}{i_b} = \frac{i_b r_\pi + R_E(i_b + \beta i_b)}{i_b}$$

$$\Rightarrow R_b = r_\pi + R_E(1+\beta)$$

$g_m v_\pi$
$= g_m(r_\pi i_b)$
$= (g_m r_\pi) i_b$
$= \beta i_b$

Voltage gain:- (A_v)

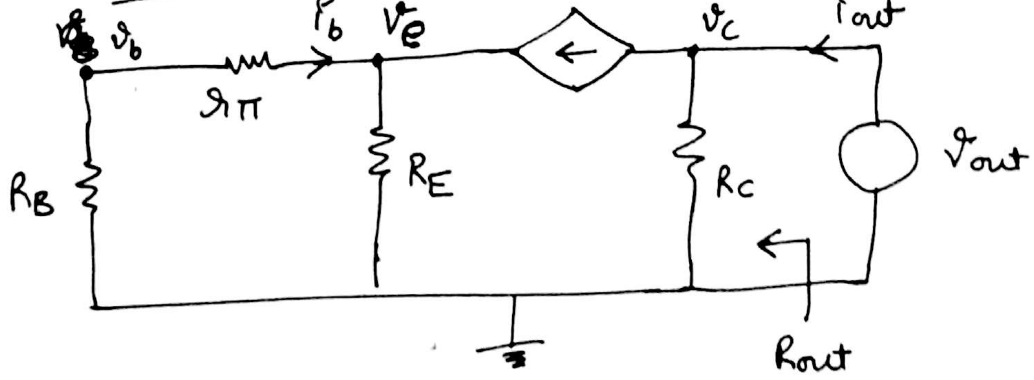
$$A_v = \frac{v_o}{v_B} \qquad (v_s = v_B, \text{ since } R_s = 0)$$

$$= \frac{-R_C \beta i_b}{i_b r_\pi + R_E(i_b + \beta i_b)}$$

$$\boxed{A_v = \frac{-R_C \beta}{r_\pi + R_E(1+\beta)}} \quad \text{--- (2)}$$

R_{out} :-

Eq. CKT



$$R_{out} = v_{out} / i_{out}$$

$$i_b = -\frac{v_b}{R_B}, \quad \text{Nodal @ } v_e$$

$$\Rightarrow i_b + \beta i_b = \frac{v_e}{R_E} = \frac{v_b - i_b r_\pi}{R_E}$$

$$\Rightarrow i_b(1+\beta) = \frac{-i_b R_B - i_b r_\pi}{R_E} = \frac{-i_B(R_B + r_\pi)}{R_E}$$

Since, $1+\beta \neq \dfrac{R_B + r_\pi}{R_E}$

$\therefore$ Only possible solution is $i_b = 0$

$$\Rightarrow i_b = 0 \text{ (A)}$$

$$\therefore i_{out} = \frac{v_{out}}{R_C} + \beta i_b = \frac{v_{out}}{R_C} \quad \left(\text{By Nodal @ } v_c,\ v_c = v_{out}\right)$$

$$\Rightarrow R_{out} = \frac{v_{out}}{i_{out}} = R_C = 2.4\ k\Omega$$

Calculating values.

$$g_m = \frac{I_{CQ}}{0.026} = \frac{4.108 \times 10^{-3}}{26 \times 10^{-3}} = 0.158 \ A/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{110}{0.158} = 696.20 \ \Omega$$

Substituting all the values in (1) and (2)

$$R_b = (110+1)10^3 + 696.20 = 111.6962 \ K\Omega$$

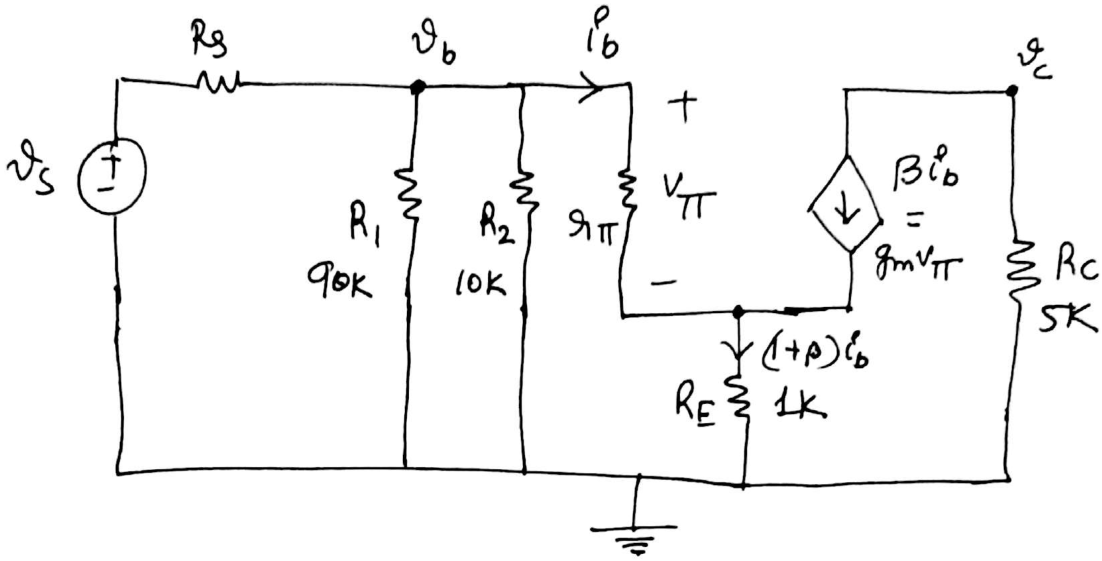
$$\therefore R_{in} = 94.645 \ K\Omega$$

and $A_V = -2.36$

and $R_{out} = 2.4 \ K\Omega$

Solution 4

Small Signal Model $\quad \beta = 100$, $I_{CQ} = 1.18\,mA$



Since $R_S = 0\,\Omega$

$v_b = v_s \Rightarrow A_v = \dfrac{v_c}{v_b}$ ——— ①

$$v_c = -\beta i_b R_C$$

$$v_b = r_\pi i_b + R_E(1+\beta) i_b = i_b\{r_\pi + R_E(1+\beta)\}$$

$$\therefore \boxed{A_v = \frac{v_c}{v_b} = \frac{-\beta R_C}{r_\pi + R_E(1+\beta)}} \quad \text{——— ②}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{1.18\,mA}{26\,mV} = 45.4\,mA/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{45.4\,mA/V} = 2.2\,K\Omega$$

Substituting Values in ②, we get

$$A_v = \frac{-500}{103.3} = -4.84$$