Solⁿ ①

Let the BJT operates in saturatⁿ region.

Then $V_{CE_{sat}} = 0.2V$.

$$\therefore I_C = \frac{V_{CC} - 0.2}{R_C}$$

$$= \frac{4.8}{1.5} mA = 3.2 mA$$

$$\& \quad I_B = \frac{V_{BB} - V_{BE_{sat}}}{R_B}$$

[Don't apply $I_B = \frac{I_C}{\beta}$ in saturatⁿ region]

$$= \frac{6 - 0.8}{270}$$

$$= 21.5 \mu A.$$

$$\therefore \beta I_B = 2.58 mA.$$

For BJT to work in saturatⁿ region

$$I_C < \beta I_B$$

So our assumption is incorrect & transistor is in Active region.

Again solve for active region consideratⁿ

$$I_B = \frac{6 - 0.7}{270}$$

$$= \underline{\underline{19.6 \mu A}}.$$

$$I_C = \beta I_B$$

$$= \cancel{1.96 mA}.$$

$$= \underline{\underline{2.35 mA}}$$

& $V_{CE} = 6 - I_C R_C$
(active)

$= 2.46V.$

When $R_C = 3k\Omega$.

then, $I_{C_{sat}} = \frac{4.8}{3}$

$= 1.6 mA.$

& $I_{B_{sat}} = 21.5 \mu A$

$\beta I_{B_{sat}} = 2.58 mA.$

$\because \beta I_B > I_C$

$\therefore$ BJT is in saturatn region.

& $V_{CE} = 0.2 V.$

—x—x—

Soln. (2)

$$\begin{cases} V_{OH} = 5V \\ V_{OL} = 0.2V \end{cases} \quad \begin{cases} V_{IL} = ? \\ V_{IH} = ? \end{cases}$$

$$\begin{cases} NM_H = V_{OH} - V_{IH} \\ NM_L = V_{IL} - V_{OL} \end{cases}$$

Considering negligible current through base, find V_B (apply KVL).

i.e. $V_B = \frac{(V_{in} \times 50) + (-5 \times 20)}{50 + 20}$

$\Rightarrow V_B = \frac{50V_{in} - 100}{70}$ — (1)

V_{IL} is the maximum i/p voltage which will be considered as a low i/p. [logic 0].

$\therefore$ V_{IL} should be calculated at the verge of BJT gets ON.

i.e. $V_{BE} \leq 0.5V$.

$\Rightarrow \frac{50 V_{in} - 100}{70} \leq 0.5$

$\Rightarrow V_{in} \leq 2.7V$

$\therefore \boxed{V_{IL} = 2.7V}$

V_{IH} is the minimum i/p voltage which is to be considered as ~~active~~ high i/p [logic 1].
i.e. Transistor should just enter the saturatn. region.

i.e. $I_C \leq \beta I_B$ — ②.

Now, $\cancel{5 - 2 I_C}$

$$I_B = \left[\frac{V_{in} - V_B}{20}\right] - \left[\frac{V_B + 5}{50}\right]$$

$$= \frac{V_{in} - 0.8}{20} - \frac{5.8}{50} \quad [V_{BE_{sat}} = 0.8V]$$

By ②,

$$\frac{5 - 0.2}{2} \leq \frac{V_{in} - 0.8}{20} - \frac{5.8}{50}$$

$$\Rightarrow V_{in} \geq 3.6V$$

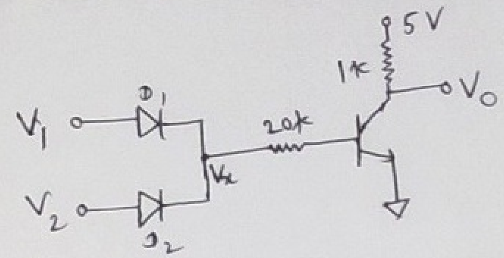
$$\therefore \boxed{V_{IH} = 3.6V}$$

$\therefore NM_L = 2.7 - 0.2$ & $NM_H = 5 - 3.6$

$\Rightarrow \boxed{NM_L = 2.5V}$ $\Rightarrow \boxed{NM_H = 1.4V}$

— x — x —

Q. 3



V_1	V_2	V_o
0	0	1
0	1	0
1	0	0
1	1	0

(a) $h_{FE\,min}$ (β) for proper operatⁿ.

When $V_1 = V_2 =$ logic 0, both D_1 & D_2 are off.

$\therefore$ $V_o = 5V$. [No dependency on β].

When any one of V_1 & V_2 is logic 1 (5V):-

$V_x = 5 - 0.7 = 4.3V$.

For proper operatⁿ BJT in this case should be in saturatⁿ i.e. $V_o =$ logic 0 (0.2V)

i.e. $i_B \geq \frac{i_c}{\beta}$

$$\Rightarrow \beta \geq \frac{4.8}{\left(\frac{4.3-0.8}{20}\right)}$$

$$\Rightarrow \boxed{\beta \geq 27.42}$$

$$\therefore \boxed{\beta_{min} \approx 28}$$

(b) **V_{IL}**

$V_x < 0.5V$

$\Rightarrow V_i - 0.7 < 0.5$

$\Rightarrow V_i \cancel{<} 1.2V$

$\therefore \boxed{V_{IL} = 1.2V}$

V_{IH} (with $\beta = 100$)

$\beta \geq \frac{i_c}{i_B}$

$$\Rightarrow 100 \geq \frac{4.8}{\left(\frac{V_i - 0.7 - 0.8}{20}\right)}$$

$\Rightarrow \boxed{V_i \geq 2.46V}$

i.e. $V_{IH} = 2.46V$

Also, $V_{OL} = 0.2V$ & $V_{OH} = 5V$

$\therefore \boxed{NM_L = 1V, \quad NM_H = 2.54V}$

Sol 4 Given $h_{fe} = 100$ $R_1 = R_2 = 400\,k\Omega$

$R_E = R_S = 1\,k\Omega$

$R_L = 9\,k\Omega$

$V_{CC} = 20V$ $I_{CQ} = 3.09\,mA$

$$\therefore r_e = \frac{0.026}{3.09\times10^{-3}} = 8.414\,\Omega \qquad r_e = \frac{0.026}{I_{CQ}}$$

$$R_T = R_E \| R_L = \frac{1\times9}{1+9} = 0.9\,k\Omega$$

$$r_\pi = \beta r_e$$
$$= 100\,(8.414)\,\Omega$$
$$= 841.4\,\Omega$$

$$A_v = \frac{h_{fe} R_T}{[h_{fe} R_T + r_\pi]} = \frac{(100)(900)}{(100)(900) + 841.4}$$
$$\approx 0.9907 \text{ (Ans)}$$

$$R_b = r_\pi + h_{fe} R_T$$
$$= (100)(900) + 841.4\,\Omega$$
$$= 90.841\,k\Omega$$

$$R_p = R_1 \| R_2 = \frac{400\times400}{400+400} = 200\,k\Omega$$

$$\therefore R_{in} = R_b \| R_p = \frac{90.841\times200}{290.841}\,k\Omega$$
$$= 62.467\,k\Omega \text{ (Ans.)}$$

$$A_i = h_{fe}\cdot\frac{R_E}{R_E + R_L} = (100)\cdot\frac{1}{(1+9)} = 10 \text{ (Ans)}$$

$$R_o = R_E \,||\, R'$$

$$R' = \frac{r_\pi + R}{h_{fe}} \qquad R = R_S \,||\, R_P = \frac{1 \times 200}{200+1}\ k\Omega = 0.995\ k\Omega$$

$$R' = \frac{.841 + 0.995}{100} = 0.01836\ k\Omega = 18.36\ \Omega$$

$$\therefore R_o = R_E \,||\, R' = \frac{18.36 \times 1000}{1018.36} = 18.029\ \Omega \text{ (Ans)}$$

☐ Input impedance $Z_{in} = R_P \,||\, (r_\pi + h_{fe} R_T)$

Output impedance $Z_0 = R_E \,||\, \left(\frac{r_\pi + R_S || R_P}{h_{fe}}\right)$

$$A_v = \frac{h_{fe} R_T}{h_{fe} R_T + r_\pi}$$

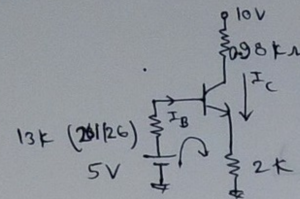
Now input impedance can be made higher by increasing h_{fe} and R_T.

Again output impedance can be decreased by increasing h_{fe}.

∴ Higher input impedance and low output impedance means high value of h_{fe} and high value of R_T and at that condition $A_v \simeq 1$

∴ It works as unity gain amplifier

Soln. 5 DC equivalent ckt. can be drawn as follows :-



By KVL in base emitter loop:-

$$5 = 13 I_B + 0.7 + 2(I_B + I_C)$$

$$\Rightarrow 15 I_B + 2 I_C = +4.3 \quad \text{—(1)}$$

By KVL in C-E loop:-

$$10 = 0.98 I_C + 2(I_B + I_C) + V_{CE}$$

$$\Rightarrow 2.98 I_C + 2 I_B + V_{CE} = 10 \quad \text{—(2)}$$

also, $I_C = \beta I_B$

$\Rightarrow I_C = 100 I_B$

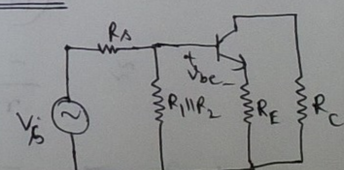
$\therefore$ By (1), $\frac{15}{100} I_C + 2 I_C = +4.3$

$\Rightarrow \boxed{I_C = 2\,mA}$

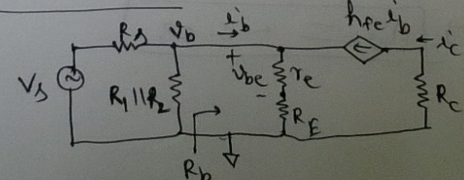
(i) $\because g_m = \frac{I_C}{V_T} = \frac{2}{26} = \underline{\underline{76.9\, m℧}}$

(ii) $\because r_e = \frac{1}{g_m} = \underline{\underline{13\,\Omega.}}$

A.C. equivalent circuit:-



Small signal A.C. model:-



$$R_b = \frac{v_b}{i_b}$$

$$R_b = \frac{v_b}{i_b}.$$

$$= \frac{(i_b + i_c)(r_e + R_E)}{i_b}$$

$$= \frac{i_b(1+h_{fe})(r_e + R_E)}{i_b}$$

$$\Rightarrow R_b = (1+h_{fe})(r_e + R_E) = 203.313\,k\Omega$$

(iii) $\because R_{in} = R_b \,||\, (R_1 || R_2)$

$$= (203.313 \,||\, 13)\,k\Omega$$

$$\Rightarrow \boxed{R_{in} = 12.3\,k\Omega}$$

(iv) $\because A_v = \frac{v_c}{v_b}$

$$= \frac{-R_c \cdot h_{fe} \cancel{i_b}}{\cancel{i_b}(1+h_{fe})(r_e + R_E)}$$

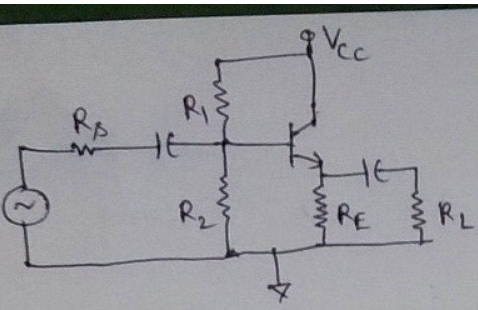
$$= \frac{-R_c h_{fe}}{(1+h_{fe})(r_e + R_E)}$$

$$\approx \frac{-R_c}{r_e + R_E}$$

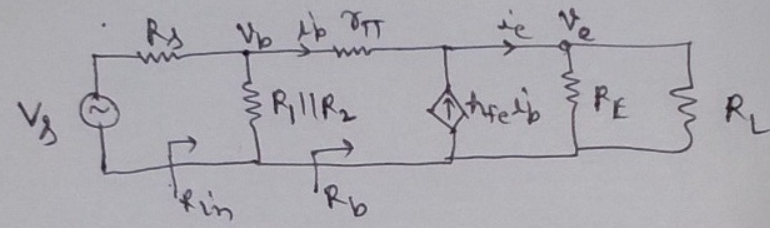
$$\therefore A_v \approx \cancel{-2000} \;\; \frac{-980}{2013}$$

$$\Rightarrow \boxed{A_v = -0.48}$$

Soln Q. 6



Ac equivalent ckt:-



(a) $\frac{v_e}{v_b} = ?$

$\because v_e = i_e \cdot (R_E \| R_L)$

$\Rightarrow v_e = i_b (1+h_{fe})(R_E \| R_L)$ — (1)

$\because v_b = v_e + r_\pi i_b$

$= i_b[(1+h_{fe})(R_E \| R_L) + r_\pi]$

$$\therefore A_v = \frac{v_e}{v_b} = \frac{(1+h_{fe})(R_E \| R_L)}{(1+h_{fe})(R_E \| R_L) + r_\pi}$$

$$\approx \frac{R_E \| R_L}{R_E \| R_L + \frac{r_\pi}{h_{fe}}}$$

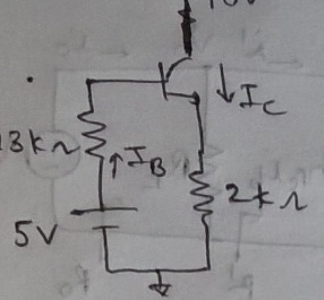
$$= \frac{R_E \| R_L}{R_E \| R_L + r_e} \quad \text{— (2)}$$

&

Finding r_e:-

$$r_e = \frac{1}{g_m} = \frac{V_T}{I_c}$$

D.C equivalent ckt:-



$$5 = 13 I_B + 0.7 + 2(I_B + I_C)$$

$$\& \quad I_C = 100 I_B$$

$$\therefore 5 = 0.13 I_c + 0.7 + 2 \times 1.13 I_c$$

$$\Rightarrow I_c = 1.8\ mA$$

$$\therefore \boxed{r_e = 14.4\,\Omega}$$

$$\therefore \frac{v_e}{v_b} = \frac{1000}{1014.4} = \underline{\underline{0.98}}$$

(b) $R_{in} = ?$

$$R_{in} = (R_1 \| R_2) \| R_b$$

$$\& \quad R_b = \frac{v_b}{i_b}$$

$(r_e \cdot h_{fe})$

$$= (1 + h_{fe})(R_E \| R_L) + r_\pi$$

$$= 101 \times 1k + 1.44k$$

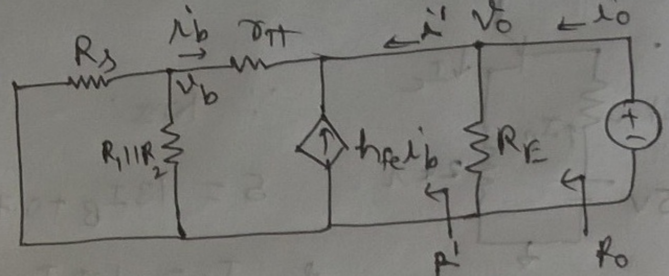
$$= 102.44k$$

$$\therefore R_{in} = 13 \| 102.44$$

$$= 11.53\,k\Omega$$

(c) $R_o = ?$

ckt for finding R_o



$$i_b = -v_b / (R_s \| R_1 \| R_2) \quad \text{—} (1)$$

$$R_o = R_E \| R' \quad \text{—} (2)$$

$$\& \; R' = \frac{v_o}{i'} \quad \text{—} (3).$$

By KCL, $i' + i_b + h_{fe} i_b = 0$

$$\Rightarrow i' = -(1+h_{fe}) i_b$$

$$= -(1+h_{fe}) v_b (R_s \| R_1 \| R_2)$$

[By eq (1)]

$$\& \; v_o = v_b - i_b r_\pi$$

$$\Rightarrow v_o = v_b + v_b r_\pi / (\underbrace{R_s \| R_1 \| R_2}_{R_X})$$

$$v_o = v_b \left[1 + \frac{r_\pi}{R_X} \right] \quad \text{—} (4)$$

By (1) & (4),

$$i_b = \frac{-v_o R_X}{R_X + r_\pi} \times \frac{1}{R_X}$$

$$\Rightarrow \boxed{i_b = \frac{-V_o}{R_x + r_\pi}}$$

$$\therefore\ i = -(1+h_{fe}) \cdot \left(\frac{-V_o}{R_x + r_\pi}\right)$$

$$\cancel{\therefore\ R} =$$

$$\therefore\ R' = \frac{R_x + r_\pi}{1 + h_{fe}} .$$

$\beta r_e = r_\pi$

Now, $r_\pi = 1.44\,k\Omega$

$h_{fe} = 100$

$R_x = 13\,k\Omega \,||\, 1\,k\Omega$

(Assume $R_s = 1\,k\Omega$)

$\Rightarrow R_x = 928.5\,\Omega .$

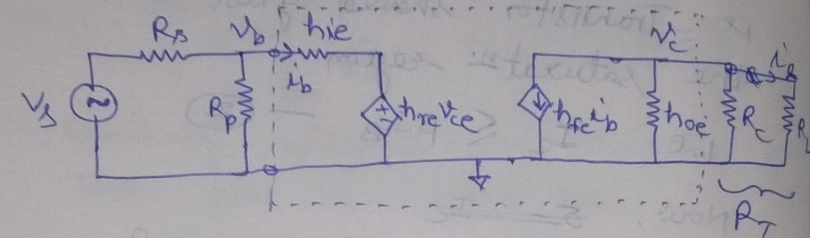
$\therefore\ R' = 23.20\,\Omega$

$\therefore\ R_o = R_E \,||\, R'$

$$\Rightarrow \boxed{R_o = 23.10\,\Omega}$$

— x — x —

Soln: (8) Ac equivalent becomes as shown below :-



$\because \; i_b = \dfrac{v_b - h_{re}v_{ce}}{h_{ie}}$

$\Rightarrow i_b = \dfrac{v_b - 10^{-4}v_c}{1.3k}$ —— (1)

$R_T = R_C \| R_L = 1\,k\Omega$.

$r_{oe} = 1/h_{oe} = 100\,k\Omega$

$\because \; v_c = -h_{fe}\, i_b \cdot (r_{oe} \| R_T)$

$= -100\, i_b \cdot (100k \| 1k)$

$= -99 \times 10^3\, i_b$

$\therefore \; v_c = -99 \times 10^3 \times \left[\dfrac{v_b - 10^{-4}v_c}{1300}\right]$ [By eqn (1)]

$\Rightarrow \boxed{\dfrac{v_c}{v_b} = -76.9}$

Without hre & hoe :-

$$i_b = \frac{v_b}{1.3k} \quad -(2)$$

& $$v_c = -h_{fe} \cdot i_b \cdot R_T$$

$$= -100\times10^3 i_b \quad -(3)$$

$\therefore$ By (2) & (3),

$$-100\times10^3 i_b = v_c$$

$$\Rightarrow -100\times10^3 \times \frac{v_b}{1300} = v_c$$

$$\Rightarrow \boxed{\frac{v_c}{v_b} = -76.9}$$

In this case answer is nearly same but calculation becomes easy.