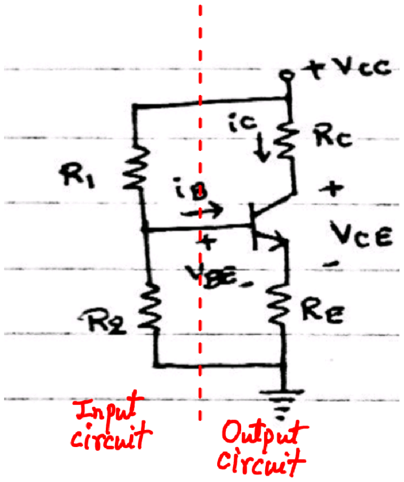
Tutorial 11 Solution

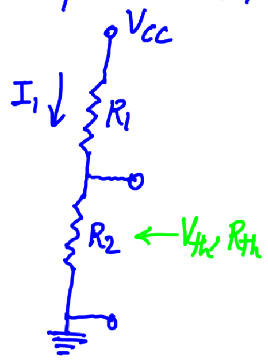
Q.1



Given : $h_{FE}=100\ (\beta)$; $R_1=R_2=26k\Omega$; $V_{CC}=10V$

Find R_C and R_E such that $I_{CQ}=2mA$; $V_{CEQ}=4V$ and BJT is biased in active region

For input circuit, finding Thevenin's equivalent circuit



For V_{th}, applying KVL in the circuit

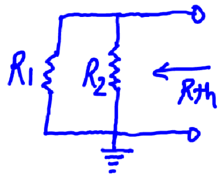
$$V_{CC}-I_1R_1-I_1R_2=0$$

$$\therefore I_1=\frac{V_{CC}}{R_1+R_2}$$

$\boxed{\because R_1=R_2}$

$$\therefore V_{th}=I_1R_2=\frac{V_{CC}\cdot R_2}{R_1+R_2}=\frac{V_{CC}}{2}=5V$$

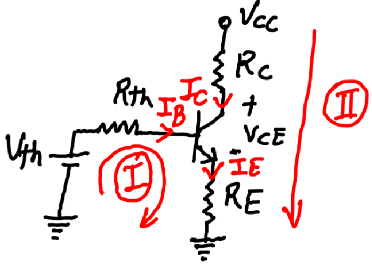
For R_{th}, grounding voltage source



$$\therefore R_{th}=R_1 // R_2=\frac{R_1R_2}{R_1+R_2}=\frac{R_1^2}{2R}$$

$$\therefore R_{th}=0.5R_1=13k\Omega$$

∴ The equivalent circuit becomes



$\because I_{CQ}=2mA$ and $h_{FE}=100$

$$\therefore I_B=\frac{I_{CQ}}{h_{FE}}=20\mu A$$

For loop (I), Applying KVL

$$V_{th}-I_BR_{th}-V_{BE}-I_ER_E=0$$

$\because V_{BE}=0.8eV$ and $I_E=(\beta+1)I_B$

$$\therefore V_{th}-I_B(R_{th}+(\beta+1)R_E)-0.8=0$$

$$\therefore R_E=\frac{\left[\frac{V_{th}-0.8}{I_B}-R_{th}\right]}{(\beta+1)}=\frac{\frac{5-0.8}{20\times10^{-6}}-13k\Omega}{101}$$

$$\therefore R_E\approx1950.5\Omega\approx1.9505k\Omega$$

For loop (II), Applying KVL

$$V_{CC}-I_CR_C-V_{CE}-I_ER_E=0$$

$$\because I_E=\frac{\beta+1}{\beta}I_C=1.01I_C$$

$$\therefore 10-2\times10^{-3}R_C-4-1.01\times2\times10^{-3}\times1950.5=0$$

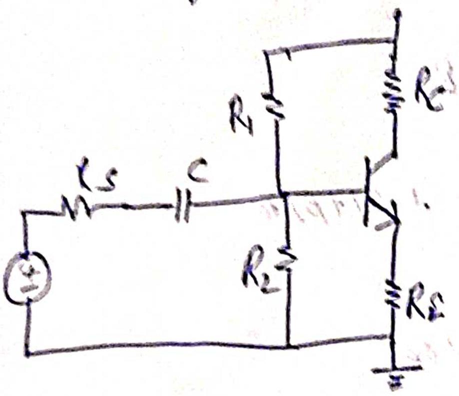
$$\therefore 2\times10^{-3}R_C=10-4-3.94=2.06$$

$$\therefore R_C=\frac{2.06}{2\times10^{-3}}\Omega=1.03k\Omega$$

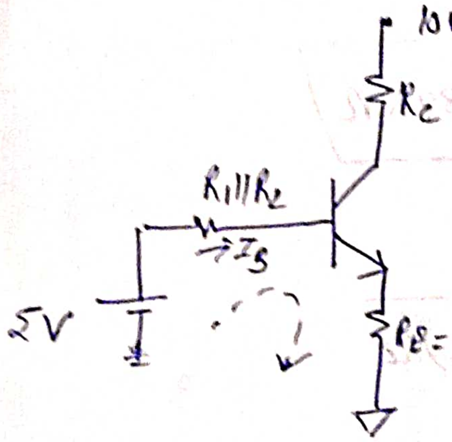
Q.2) Given · $h_{fe} = h_{FE} = 100$; $R_1 = R_2 = 26K\Omega$, $R_C = 980\Omega$

$R_E = 2K\Omega$ and $V_{CC} = 10V$

find (a) g_m (b) r_e (c) R_{in} (d) A_V



for DC analysis – capacitor is open –



$$V_{Th} = \frac{R_2 V_{cc}}{R_1 + R_2}$$

$$= \frac{10 \times 26}{52} = 5V$$

$R_{th} = R_1 \| R_2 = 13K\Omega$

(a) $g_m = \frac{I_C}{V_T}$

KVL at input –

$$5 - 13 I_B - 0.7 - 2(1 + h_{FE}) I_B = 0$$

$$4.3 = 13 I_B + 202 I_B$$

$$I_B = 0.02 \text{ mA}$$

$$I_C = \beta I_B = 2 mA$$

$$\boxed{g_m = \frac{2mA}{25mV} = 80mS}$$

(b) r_e (from T-model)

$$r_e = \frac{1}{g_m} = 12.5\,\Omega$$

(c) Input resistance with R_E

$$R_i = h_{ie} + (1+\beta)R_E + (1+\beta)r_e$$

$$R_i \approx (1+\beta)R_E + (1+\beta)r_e$$

$$= 101 \times 2K + 101 \times 12.5$$

$$R_i = 2.26225\,K\Omega$$

$$\boxed{R_i' = 2.625 \,//\, 12 \approx 2.89\,K\Omega}$$

(d-2)

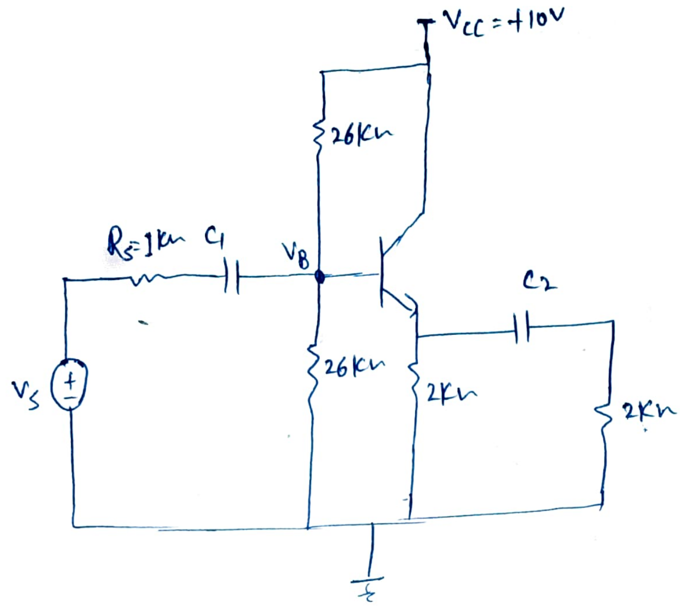
$$A_v = -\frac{h_{fe} \times load}{h_{ie} + (1+h_{fe})R_E}$$

$$\approx \frac{-h_{fe} \times R_C}{(1+h_e)R_E}$$

$$A_v \approx -\frac{R_C}{R_E} = -\frac{2K\Omega}{980\,\Omega}$$

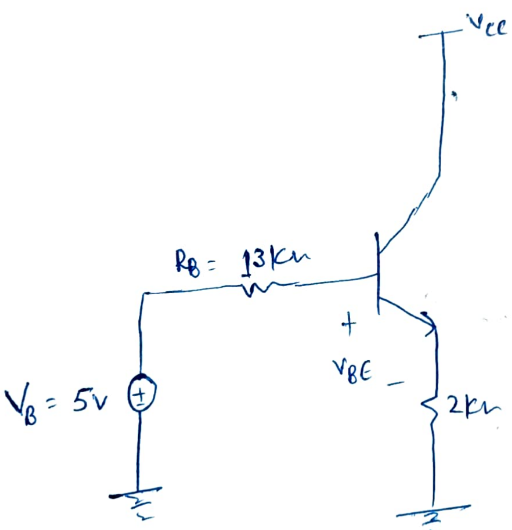
$$\boxed{A_v \approx -2}$$

⇒



⇒ DC Analysis :

Thevenin equivalent ckt : [Capacitors → O.C.]



$$\left[\begin{array}{l} V_B = \frac{10}{26K + 26K} \times 26K = 5V \\ R_B = R_1 \parallel R_2 = 26K \parallel 26K = 13K \end{array} \right]$$

By applying KVL @ i/p loop -

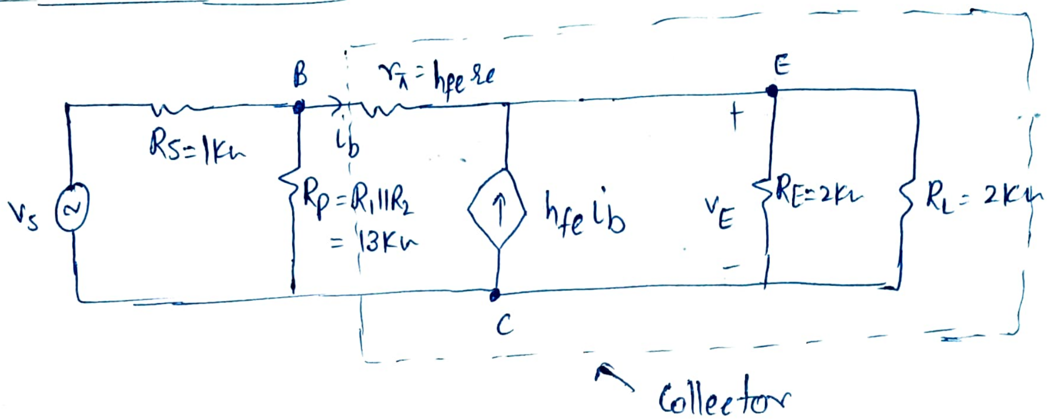
$$-5 + 13K \times I_B + V_{BE} + (I_C + I_B) \times 2K = 0$$

$$I_B = \frac{4.3}{215K}$$

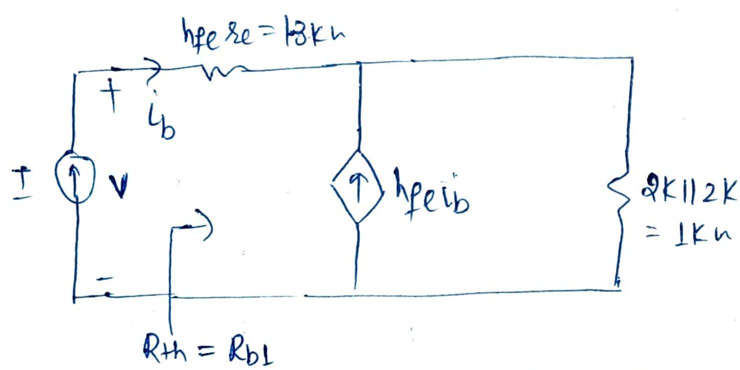
$$I_C = I_B \times h_{fe} = 100 \times \frac{4.3}{215K} = 2mA$$

$$r_e = \frac{\eta V_T}{I_c} \cong \frac{26\,mV}{2\,mA} \cong 13\,\Omega$$

⇒ Small Signal Model :-



→ input resistance :

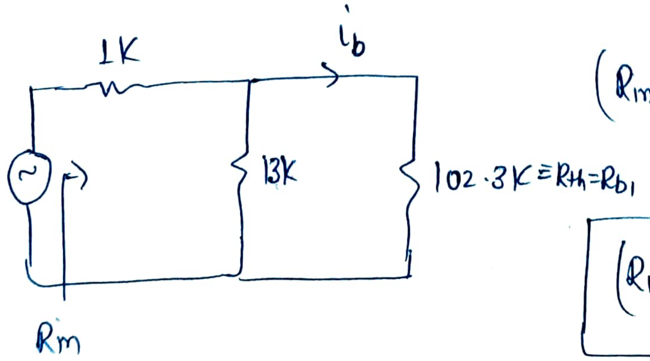


$$V = 1.3K \times i_B + 1K \times (1 + h_{fe})\, i_B$$

$$R_{th} = \frac{V}{i_b} = 1.3K + 101K \qquad [\, i_b = I \,]$$

$$R_{b1} = R_{th} = 102.3K$$

Now, Total i/p resistance from Source -



$$(R_{in})_{total} = 1K + (13K \,\|\, 102.3K)$$

$$= 1K + 11.53K$$

$$\boxed{(R_{in})_{total} \cong 12.5K}$$

⇒ Ac voltage gain - $A_v = \frac{V_e}{V_b} = ?$

$$V_e = (1+h_{fe})\, i_b \times (R_E \| R_L)$$

$$V_e = 101 \times 1K\; i_b$$

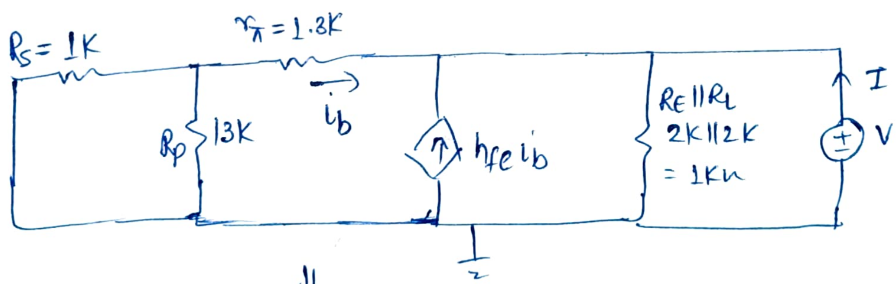
And $V_b = i_b \times R_{th} = i_b \times R_{b1}$

so, $$V_e = \frac{101 \times 1K \times V_b}{R_{th}}$$

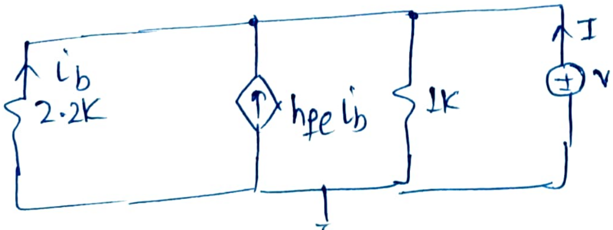
$$\frac{V_e}{V_b} = \frac{101K}{102.3K}$$

$$\boxed{\frac{V_e}{V_b} = 0.987 \cong 1}$$

⇒ Output resistance R_o :- [$V_s \to$ S.C.]



⇓



$$\frac{V}{2.2K} + \frac{V}{1K} = I + h_{fe}\, i_b \qquad \left[\; i_b = \frac{-V_o}{2.2K} \;\right]$$

$$\frac{(1+2.2)V}{2.2K} = \frac{2.2KI + h_{fe}(-V_o)}{2.2K}$$

So, $\boxed{\frac{V}{I} = \frac{22k}{103.2} = 22n = R_{out}}$