Part - B

1) given (cascode)

$\beta = (120)$ $V_A = \infty$.

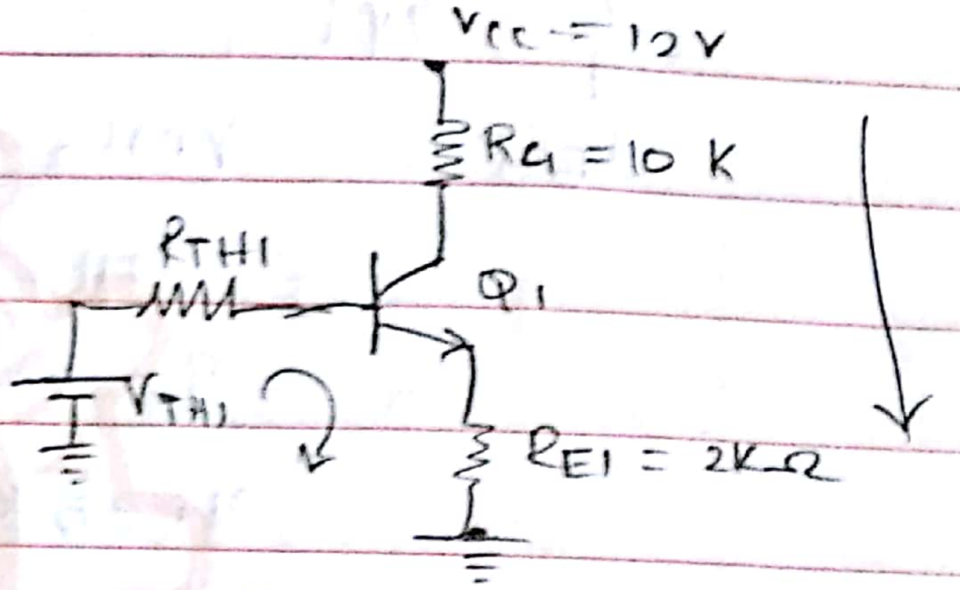
i) $r_{o1} = \frac{V_A}{I_{CQ}} = \infty$

$r_{o2} = \frac{V_A}{I_{CQ}} = \infty$.

of O.C capacitors

↓

DC Analysis.



$V_{TH1} = \frac{12 \times 12.7K}{12.7K + 67.3K}$

$V_{TH1} = 1.905\ V$

$R_{TH1} = 10.68\ K\Omega$ ⇒ $(R_1 || R_2)$

i/p KVL,

$V_{TH1} = I_{B1}R_{TH1} + V_{BE1} + I_{B1}(1+\beta)R_{E1}$

$I_{B1} = \frac{V_{TH1} - V_{BE1}}{R_{TH1} + (1+\beta)R_{E1}} = \frac{1.905 - 0.7}{10.68K + (121)(2K)}$

$\boxed{I_{B1} = 4.768\ \mu A}$

$I_{C1} = \beta I_{B1} = 120 \times 4.768\ \mu$

$\boxed{I_{C1} = 0.572\ mA}$

$g_{m1} = \frac{I_{CQ1}}{V_T} = \frac{0.572\ m}{26\ m}$

$\boxed{g_{m1} = 0.022}$ A/V

$r_{\pi1} = \frac{\beta V_T}{I_{CQ1}} = \frac{120 \times 26\ m}{0.572\ m}$

$\boxed{r_{\pi1} = 5.454}$ $K\Omega$

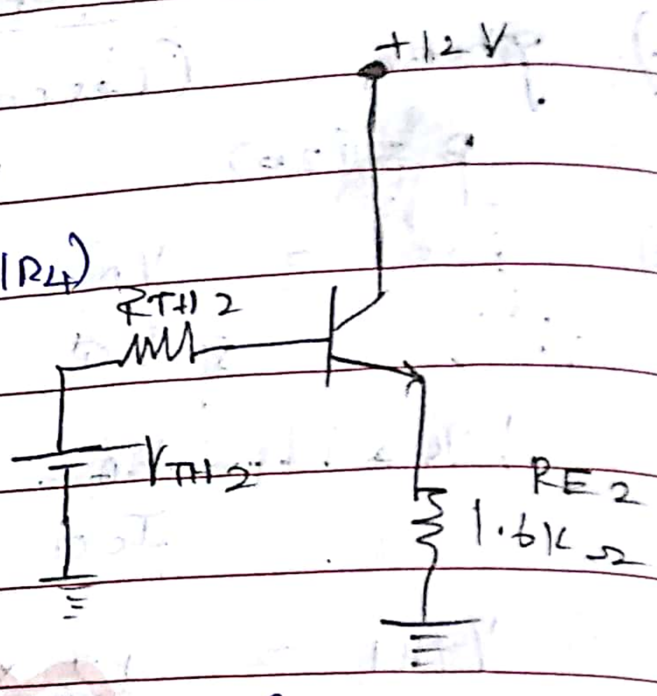
DC Analysis

$V_{TH2} = \frac{12 \times 45 K}{(45+15) K}$

$\boxed{V_{TH2} = 9V}$

$R_{TH2} = 45K \parallel 15K \Rightarrow (R_3 \parallel R_4)$

$\boxed{R_{TH2} = 11.25\ k\Omega}$



i/p KVL,

$I_{B2} = \frac{V_{TH2} - V_{BE2}}{R_{TH2} + (1+\beta) R_{E2}}$

$= \frac{9 - 0.7}{11.25K + (121)(1.6) K}$

(O.C capacitors

$I_{B2} = 0.0405\ mA$

$I_{C2} = \beta I_{B2} = 120 \times 0.0405\ mA$

$\boxed{I_{C2} = 4.86\ mA}$

$g_{m2} = \frac{I_{CQ2}}{V_T} = \frac{4.86\ m}{26\ m}$

$\boxed{g_{m2} = 0.1869}$ A/V

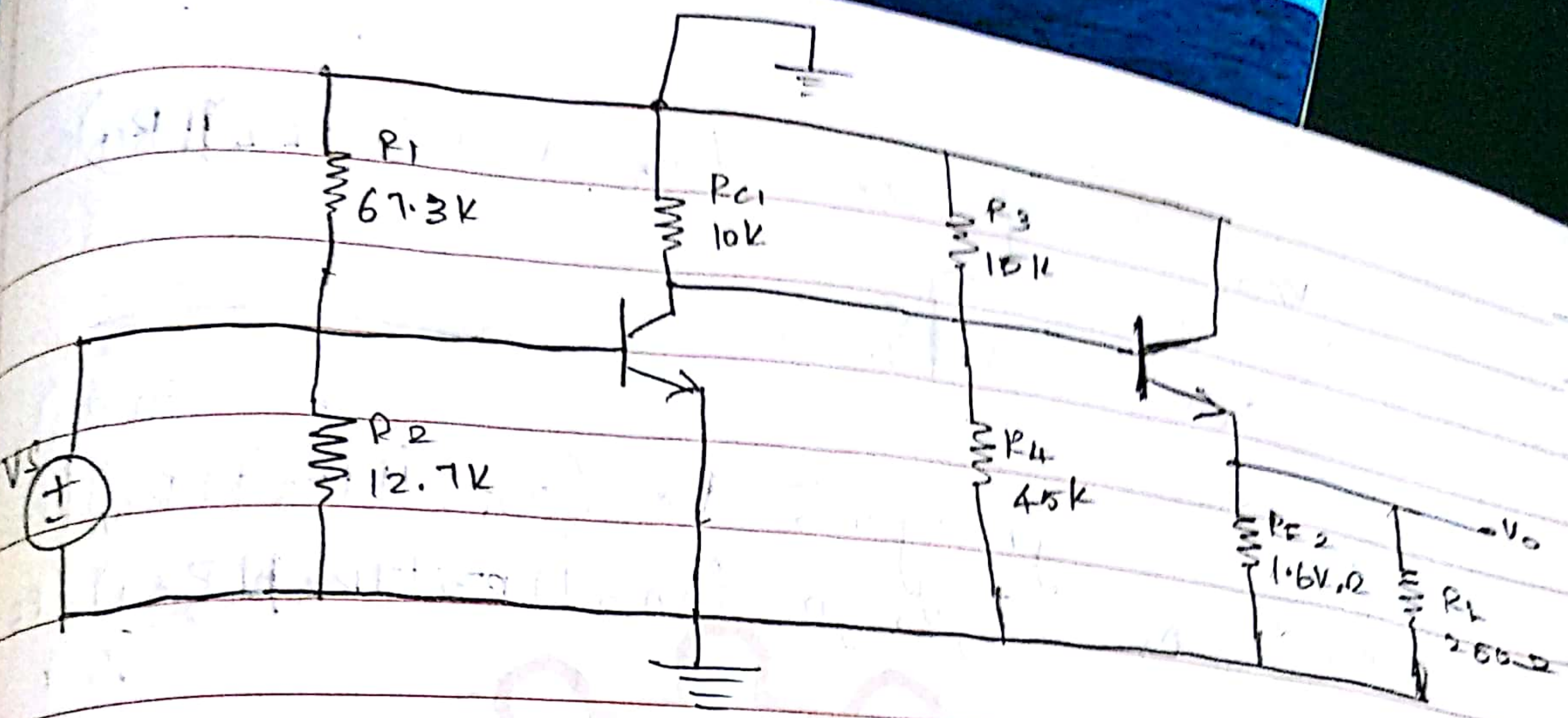
$r_{\pi 2} = \frac{\beta V_T}{I_{CQ2}} = \frac{120 \times 26\ m}{4.86\ m.}$

$\boxed{r_{\pi 2} = 0.642\ k\Omega}$

(b) overall gain, $A_v = \frac{v_o}{v_s}$

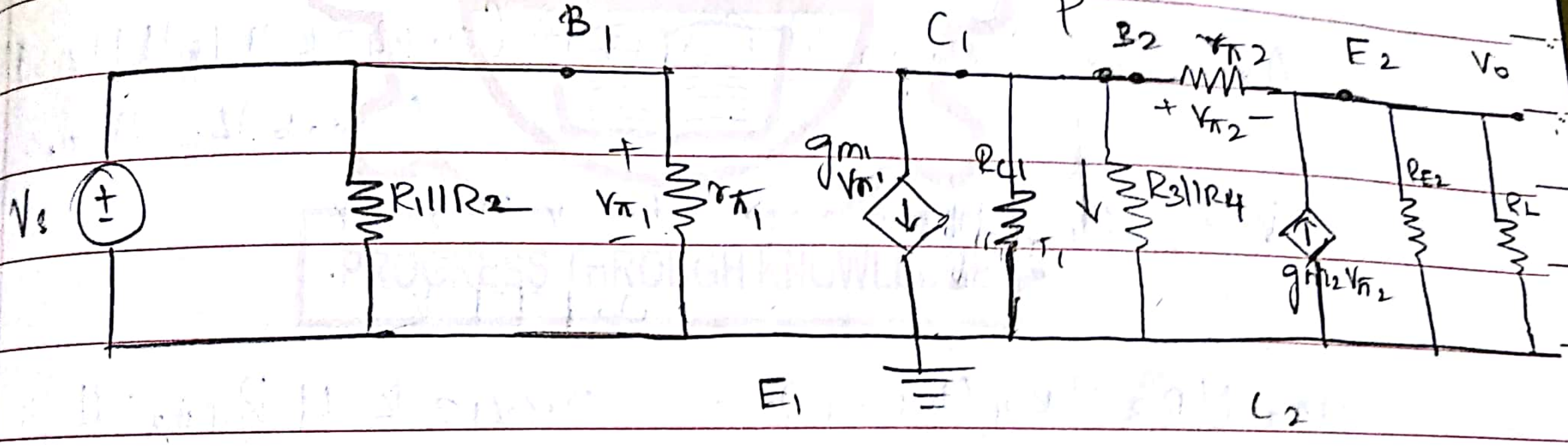
small signal analysis,

S.C all capacitors and dc sources,



⇓

hybrid pi model $\qquad r_{o1} = r_{o2} = \infty$



$$V_o = g_{m_2} V_{\pi 2} (R_{E2} \| R_L) \qquad \text{— (1)}$$

At P, KCl,

$$g_{m1} V_{\pi 1} + \frac{V_{\pi 2}}{r_{\pi 2}} + \frac{V_{\pi 2}}{R_3 \| R_4} + \frac{V_{\pi 2}}{R_{C1}} = 0$$

$$V_{\pi 1} = v_s$$

$$g_{m_1} v_s = -V_{\pi 2}\left(\frac{1}{r_{\pi 2}} + \frac{1}{R_3 \| R_4} + \frac{1}{R_{C1}}\right)$$

$$V_{\pi 2} = \frac{-g_{m_1} V_s}{\left(\frac{1}{r_{\pi 2}} + \frac{1}{R_3 \| R_4} + \frac{1}{R_{C1}}\right)}$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_p = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

$\parallel R_{E1}$) ②

$v_{\pi 2} = -g_{m1} v_s \; (r_{\pi 2} \parallel R_3 \parallel R_4 \parallel R_{E1})$ ②

Sub ② in ①

$V_o = -g_{m1} g_{m2} V_s (r_{\pi 2} \parallel R_3 \parallel R_4 \parallel R_{C1}) (R_{E2} \parallel R_L)$

$\frac{V_o}{V_s} = A_v = -g_{m1} g_{m2} (r_{\pi 2} \parallel R_3 \parallel R_4 \parallel R_{C1}) (R_{E2} \parallel R_L)$

$\therefore$ gain, $A_v = -g_{m1} g_{m2} (r_{\pi 2} \parallel R_3 \parallel R_4 \parallel R_{C1})(R_{E2} \parallel R_L)$

Substituting

$A_v = -(0.022)(0.187)(0.642K \parallel 15K \parallel 45K \parallel 10K)$
$(1.6K \parallel 0.2K)$

$R_{E2} \parallel R_L \Rightarrow 1.6K \parallel 0.2K$
$= 0.177 K$

$(r_{\pi 2} \parallel R_3 \parallel R_4 \parallel R_{C1}) = 0.642K \parallel R_{TH2} \parallel 10K$
$= 0.642K \parallel 11.25K \parallel 10K$
$= 0.572 K$

Now, $A_v = -(0.022)(0.187)(0.177)(0.572) \times 10^6$

$\boxed{A_v = 416.5}$

c) swing in o/p voltage,

$i_{C2} = 4.66 \; mA$

$0 = V_{ce2} + (R_{E2} \parallel R_L) i_{C2}$

$$i_{c2} = \frac{-1}{R_{E2} \| R_L} v_{ce2}$$

$$\text{slope} = \frac{-1}{R_{E2} \| R_L} = \frac{-1}{1.6K \| 0.2K}$$

$$\text{slope} = \frac{-1}{0.177K}$$

$$i_{c2} = \frac{-1}{0.177K} v_{ce2}$$

$$|v_{ce2}|_{max} = 0.177K \times i_{c2}$$

$$= 0.177 \times 4.86$$

$$|v_{ce}|_{max} = 0.86 \text{ V}$$

$$2 \times V_{ce} = 1.72 \text{ V}$$

$\therefore$ Maximum output voltage swing is 1.72 V peak to peak.

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f) $CM = ?$ $A_V = ?$ $f_H = ?$

given. $K_p = 2 \text{ mA}/V^2$ $V_{Tp} = -2V$

$\lambda = 0.01 \text{ V}^{-1}$ $C_{gs} = 10pF$ $C_{gd} = 1pF$

DC analysis,

O.C Capacitance.

$V_g = 0V$. KVL $9 - V_S = I_D R_S$

$$\boxed{V_S = 9 - I_D R_S}$$

$V_{sg} = V_s - V_g$ —— (1)

$V_{sg} = 9 - I_D R_s$

$I_D = K_p (V_{sg} + V_{TP})^2$ (sub (1))

$I_D = 2m(9 - I_D R_S - 2)^2$

$I_D = 2m(7 - 1.2K I_D)^2$

$I_D = 2m(49 + 1.44K^2 I_D^2 - 16.8K I_D)$

$I_D = 98m + 2.88K I_D^2 - 33.6 I_D$

$2.88K I_D^2 - 34.6 I_D + 98m = 0.$

$I_D = 7.4m$

$\boxed{I_D = 4.5\ mA}$ ✓

$V_{sg} = 9 - 4.5(1.2)$

$\boxed{V_{sg} = 3.6\ V}$

$V_{ds} > V_{sg} + V_{TP}$

o/p ~~at~~ KVL,

$18 = I_D R_S + V_{DS} + I_D R_D$

$V_{DS} = 18 - I_D(R_S + R_D)$

$V_{DS} = 18 - 4.5m(2.2)$

$\boxed{V_{DS} = 8.1\ V}$

$8.1 > 2.6$ ✓

$g_m = 2\sqrt{K_p I_D} = 2\sqrt{2m \times 4.5}$

$\boxed{g_m = 6m}$

Miller capacitance,

$C_M = C_{gd}(1 + g_m(R_D \| R_L))$

$C_M = 1pF(1 + 6m(1K))$

$$\boxed{C_M = 7\,pF}$$

3 dB upper frequency

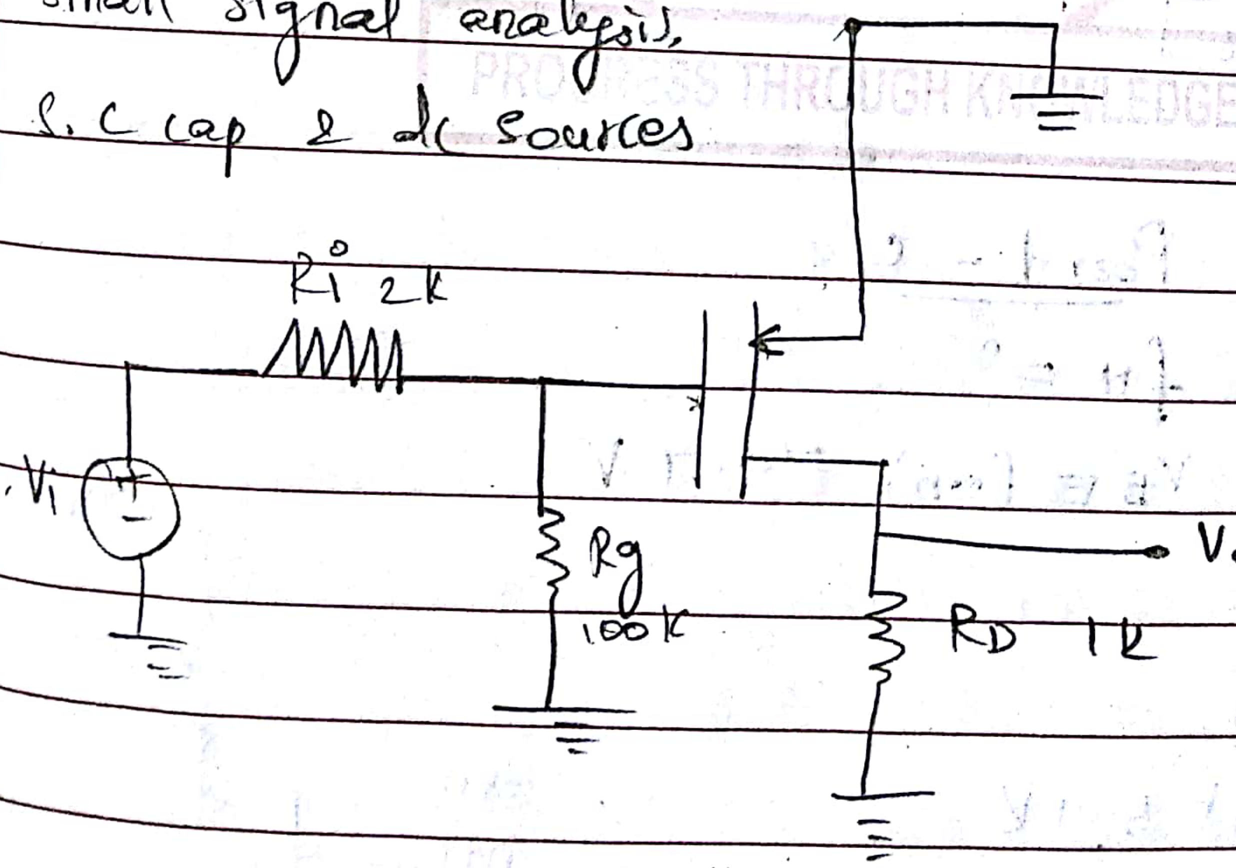
$$f_H = \frac{1}{2\pi R_{eq} C_{eq}}$$

$$f_H = \frac{1}{2\pi (R_g \| R_{si}) (C_{gs} + C_M)}$$

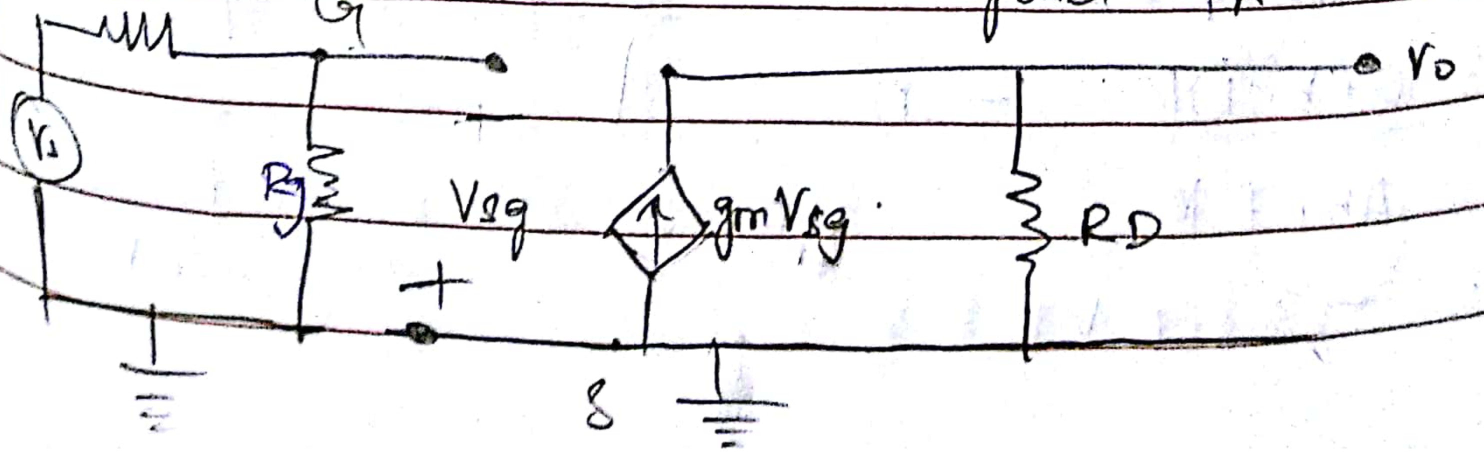
$$f_H = \frac{1}{2\pi (2k \| 100k)(10pF + 7pF)} = \frac{1}{2\pi (1.96)(17)\times 10^{-9}}$$

$$\boxed{f_H = 4.77\ MHz}$$

Small signal analysis,
S.C cap & dc sources



⇓ Hybrid π model



$\cancel{V_o = -g_m V_{gs} R_D}$

$$V_o = +g_m V_{sg} R_D$$

$$-V_{sg} = \frac{V_s \; R_g}{R_g + R_{si}}$$

$$\therefore V_o = -g_m V_s R_D \frac{R_g}{R_g + R_{si}}$$

$$A_v = \frac{V_o}{V_s} = -g_m R_D \frac{R_g}{R_g + R_{si}}$$

$$\therefore A_v = -6m \times 1K \frac{100K}{102K}$$

$$= -6 \times \frac{100}{102}$$

$$\boxed{A_v = -5.88}$$

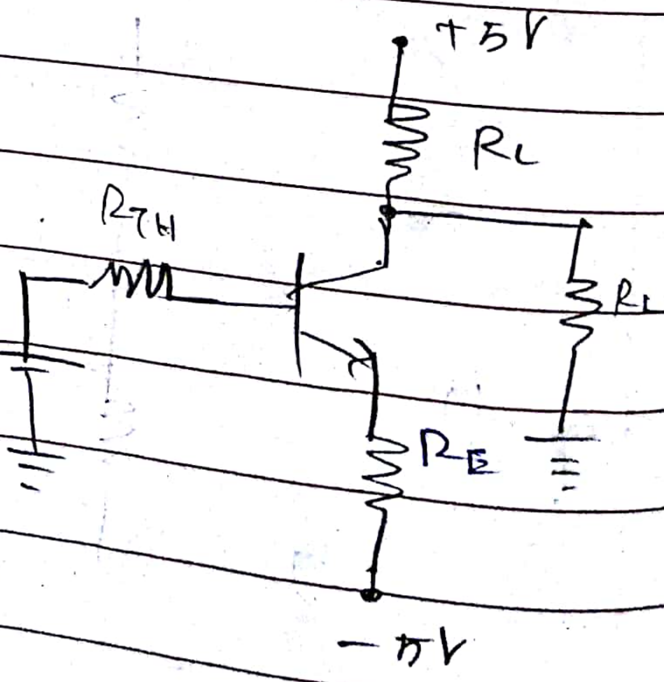
Part - C

9) $A_v = ?$ $f_H = ?$

$\beta = 100$ $V_{BE(on)} = 0.7V$

$V_A = \infty$.

DC analysis,



$R_{TH} = 40K \| 5.7K$

$R_{TH} = 4.99 K\Omega$

$$V_{TH} = \frac{10(5.7)K}{45.7K} - 5$$

$V_{TH} = -3.89 V$

$V_{TH} = I_B R_{TH} + V_{BE} + (1+\beta) R_E I_B - 5$

$-3.89 + 5 - 0.7 = I_B (R_{TH} + (1+\beta) R_E)$

$$\frac{0.41}{4.99k + (101)(0.5k)} = I_{BQ}$$

$I_{BQ} = 7.38\ \mu A$

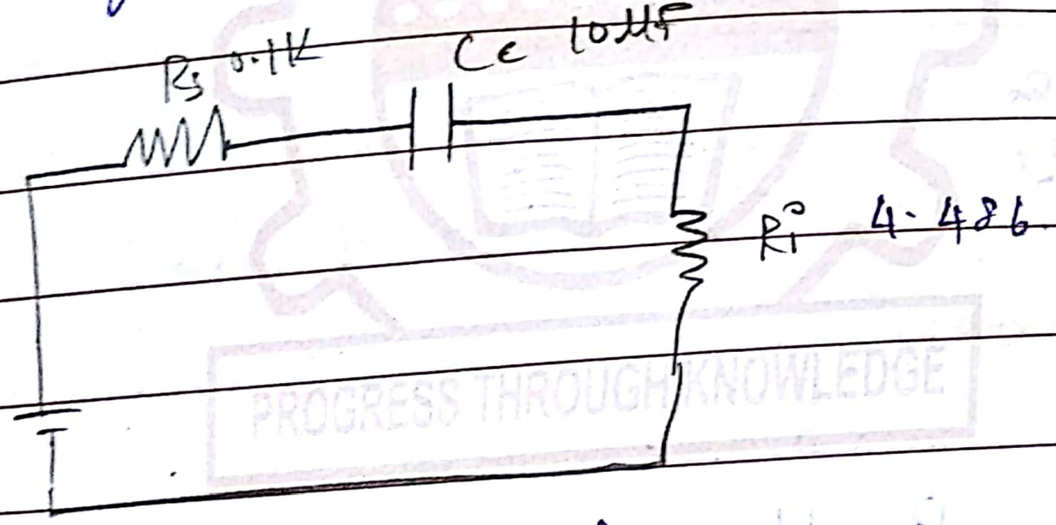
$\boxed{I_{CQ} = 0.738\ mA}$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{0.738}{26}$$

$$r_\pi = \frac{V_T \times \beta}{I_{CQ}}$$

$\boxed{g_m = 0.0284}$

$\boxed{r_\pi = 3.523\ k\Omega}$



$R_i = R_1 \parallel R_2 \parallel R_{ib}$

$R_{ib} = r_\pi + (1+\beta) R_E$

$R_{ib} = 3.523\ k + (101)(0.5k)$

$R_{ib} = 54.023\ k\Omega$

$R_i = R_{TH} \parallel R_{ib}$

$= 4.99K \parallel 54.023\ k$

$\boxed{R_i = 4.486\ k\Omega}$

Series capacitance ckt.

$\therefore \tau_s = (R_s + R_p) C_s$

Here, $T_s = (R_s + R_i)\, C_c$

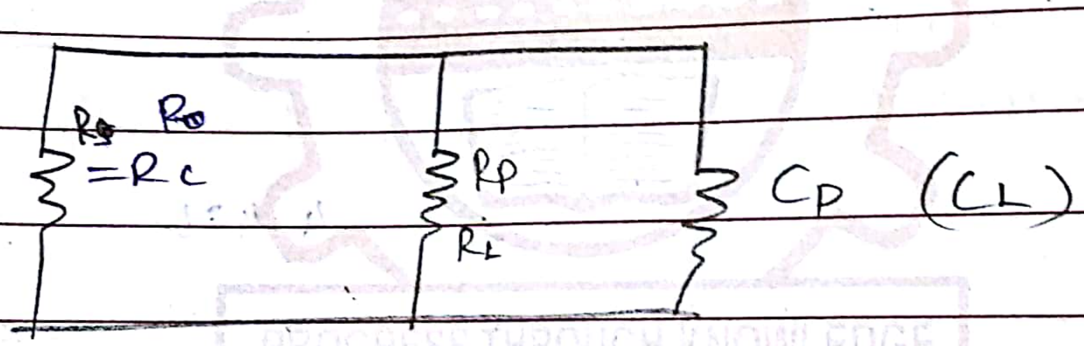
$= (0.1k + 4.486k)\, 10\mu$

$T_s = 4.586 \times 10 \;ms$

$\boxed{T_s = 45.86\; ms}$

$f_L = \dfrac{1}{2\pi T_s} = \dfrac{1000}{2\pi \times 45.86}$

$\boxed{f_L = 3.47\; Hz}$



$R_o = R_c \,||\, r_o$

$R_o = R_c$

$T_p = (R_o \,||\, R_p)\, C_p$

here, $T_p = (R_c \,||\, R_L)\, C_L$

$= (5k \,||\, 10k)\, 15p$

$= 3.33 \times 15 \times 10^{-9}$

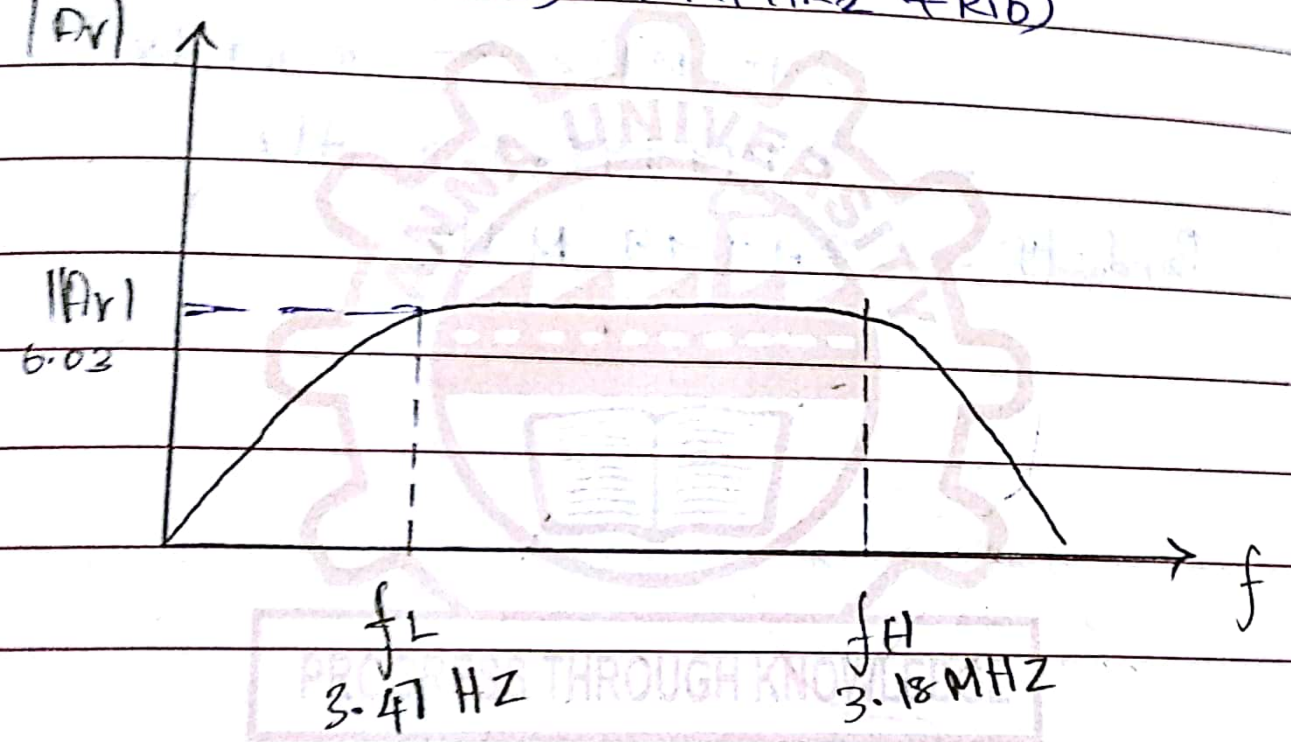
$T_p = 50 \times 10^{-9}\; s$

$f_H = \dfrac{1}{2\pi T_p} = \dfrac{10^9}{2\pi \times 50}$ (49.99) (Approx)

$\boxed{f_H = 3.18\; MHz}$

(For maximum gain,
s.c coupling capacitor
o.c load capacitor)

$$A_v = \frac{-g_m (R_C \| R_L) (R_1 \| R_2 \| r_\pi)}{(R_i + R_s)(R_1 \| R_2 + R_{ib})}$$



Given, CE amplifier with R_E

$$\therefore A_v = \frac{-\beta (R_C \| R_L)}{r_\pi + (1+\beta) R_E} \left(\frac{R_i}{R_i + R_s} \right)$$

$R_i = 4.486\,k\Omega$ $r_\pi = 3.523\,k\Omega$

$$\therefore |A_v| = \frac{\beta (R_C \| R_L)}{r_\pi + (1+\beta) R_E} \left(\frac{R_i}{R_i + R_s} \right) = \frac{100\,(5 \| 10)k}{(3.523k)}$$

$$= \frac{100 \times 3.33\,k}{54.023\,k} \left(\frac{4.486\,k}{(4.486\,k + 0.1)\,k} \right)$$

$|A_v| = 6.03$

$\therefore$ mid band gain = 6.03

Bandwidth = $f_H - f_L$

= 3.18 MHz − 3.47 Hz

= 3179996.53 Hz

Bandwidth = 3.1799 MHz

5

42/50