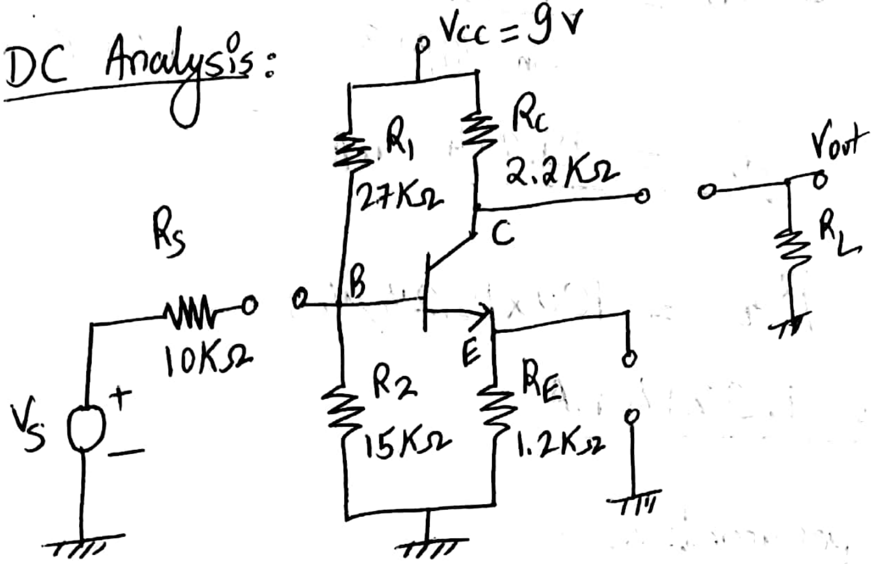
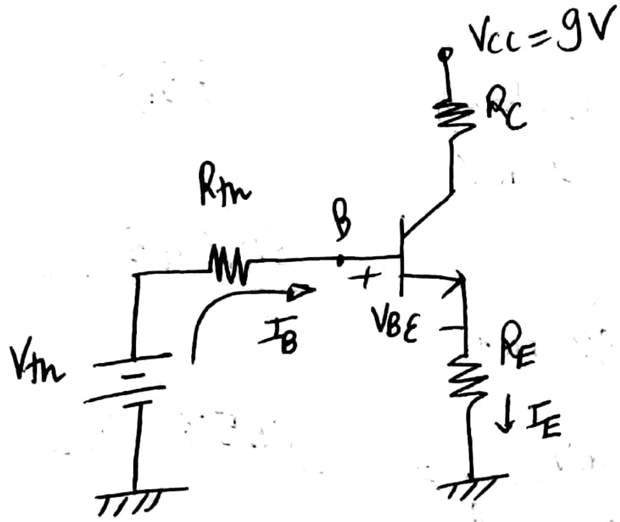
Q1. Given: $\beta = 100$, $V_A = 100V$

1. <u>DC Analysis</u>:



In dc analysis, we consider all capacitors to be open-ckt (Since $X_c \approx$ v. high)

ie



Assuming $\underline{V_{BE} = 0.7V}$ & applying thevenin's equivalent at the Base terminal.

ckt(a)

$\rightarrow V_{th} = \frac{R_2}{R_1+R_2} \times V_{cc} = \frac{15K}{27K+15K} \times 9 = \underline{3.214\ V}$ — 1m

$\rightarrow R_{th} = R_1 \,||\, R_2 = 27K\Omega \,||\, 15K\Omega = \underline{9.643\ K\Omega}$ --- 1m

KVL to B-E loop of ckt(a) gives,

$$V_{th} - I_B R_{th} - V_{BE} - I_E R_E = 0$$

Scanned by CamScanner

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

ie $I_B = \dfrac{V_{th} - V_{BE}}{R_{th} + (1+\beta) R_E} = \dfrac{3.214 - 0.7}{9.643K + 101 \times 1.2K}$

$\underline{I_B = 19.214\ \mu A}$

ie $I_C = \beta I_B = 100 \times 19.214\ \mu A$

$\underline{I_{CQ} = 1.9214\ mA}$ ---- 2m

2. Small-signal parameters: -

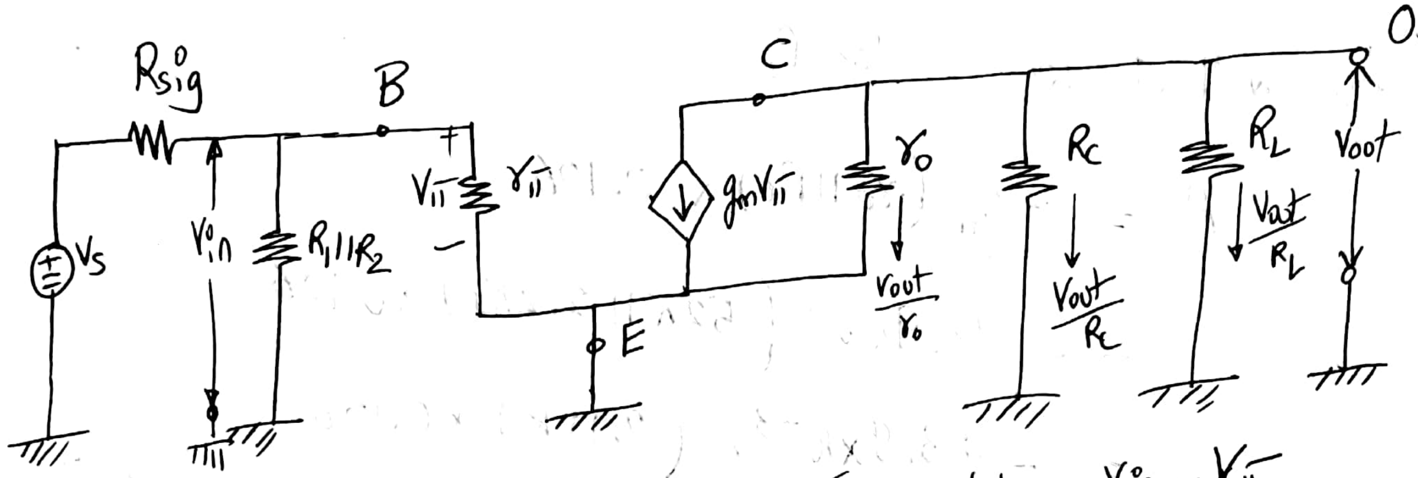
a) $g_m = \dfrac{I_{CQ}}{V_T} = \dfrac{1.9214\ mA}{26 mV} = \underline{73.9}\ \dfrac{mA}{V}$ -- 1m

b) $r_o = \dfrac{V_A}{I_{CQ}} = \dfrac{100}{1.9214 mA} = \underline{52.045}\ K\Omega$ --- 1m

c) $r_\pi = \dfrac{V_T}{I_{BQ}} = \dfrac{26 mV}{19.214\ \mu A} = \underline{1.353}\ K\Omega$ --- 1m

3. Small-signal AC analysis: -

Next, we draw small-sig equivalent.
Consider, constant sources & capacitors to be short-ckt
& replace BJT by its hybrid-π model.



From ckt, $V_{in} = V_\pi$

KCL at node C,

$$g_m V_\pi + \frac{V_{out}}{r_o} + \frac{V_{out}}{R_C} + \frac{V_{out}}{R_L} = 0$$

$$g_m V_{in} = -V_{out}\left(\frac{1}{r_o} + \frac{1}{R_C} + \frac{1}{R_L}\right)$$

ie $$\frac{V_{out}}{V_{in}} = -g_m (r_o || R_C || R_L)$$

Now, $$A_v = \frac{V_{out}}{V_s} = \frac{V_{out}}{V_{in}} \times \frac{V_{in}}{V_s} = -g_m (r_o || R_C || R_L) \times \frac{V_{in}}{V_s}$$

$$\frac{V_{in}}{V_s} = \frac{R_1 || R_2 || r_\pi}{R_1 || R_2 || r_\pi + R_{sig}}$$ --- by V.D.R

$$= \frac{27K || 15K || 1.353K}{(27K || 15K || 1.353K) + 10K\Omega} = 0.106$$

$$A_v = -g_m (r_o || R_L || R_C) \times 0.106$$

$$= -73.9 \times 10^{-3} (52K || 2.2K || 2K) \times 0.106$$

$$= -73.9 \times 10^{-3} (1.027K) \times 0.106$$

$\boxed{A_v = -8.04}$ with load resistor R_L --- 3m

A_v without load resistor R_L

$$A_v = -g_m(r_o \| R_C) \times 0.106$$

$$= -73.9\times10^{-3}\,(52K \| 2.2K\Omega) \times 0.106$$

$$= -73.9\times10^{-3} \times (2.11K) \times 0.106$$

$$\boxed{A_v = -16.528}$$ without R_L ----- 2m

→ $R_i = R_1 \| R_2 \| r_\pi = 27K\Omega \| 15K\Omega \| 1.353K\Omega$

$$= 9.643K \| 1.353K\Omega$$

$$\boxed{R_i = 1.1865\ K\Omega}$$ ------- 2m

→ R_i including source resistance $= R_i + R_{sig} = 1.1865K + 10K\Omega$

$$= 11.865\ K\Omega$$

→ $R_o = r_o \| R_C \| R_L$

$$= (52K \| 2.2K \| 2K)$$

$$= (2.11K \| 2K)$$

$$\boxed{R_o = 1.027\ K\Omega}$$ ------ 1m

OR

Q1. Given: $\beta = 100$, $V_{BE(on)} = 0.7V$, $V_A = \infty$, $V_{CC} = 5V$

$I_{CQ} = 0.5mA$, $V_{CEQ} = 2.5V$, $A_v = -8$

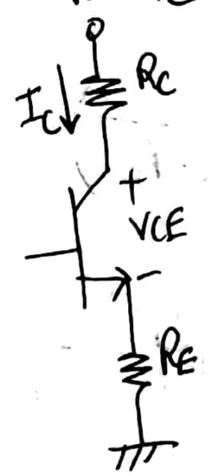
Soln:- Consider voltage gain A_v to be $\left(\frac{V_o}{V_{in}}\right)$ which excludes source resistance R_S

Since, the given configuration is with R_E unbypassed, gain formula is

$$A_v = -\frac{R_C}{\frac{1}{g_m} + R_E} \qquad \because \frac{1}{g_m} << R_E$$

$$A_v \approx -\frac{R_C}{R_E}$$

ie $-8 \approx -\frac{R_C}{R_E}$ ie $\boxed{R_C = 8R_E}$ — (i)



KVL to CE loop, gives $\qquad I_C \approx I_E$

$$V_{CC} - I_C R_C - V_{CE} - I_C R_E = 0$$

ie $I_C(R_C + R_E) = V_{CC} - V_{CE}$

$$R_C + R_E = \frac{(5 - 2.5)}{0.5mA} = 5000$$

ie $8R_E + R_E = 5000$ (From i)

$$R_E \approx 555.55\Omega$$

Selecting L.S.V of R_E, (Low side value)

Select $\boxed{R_E = 510\Omega\,(\text{std}), \frac{1}{4}W}$ --- (5m)

From (i), $R_C = 8R_E = 8 \times 510 \approx 4.08\,K\Omega$

Select $\boxed{R_C = 4.2\,K\Omega\,(\text{std}), \frac{1}{4}W}$ --- (2m)

H.S.V

→ Calculation of R_1 & R_2 :-

For bias-stable circuit

$R_{th} \approx 0.1(1+\beta)R_E$

$\approx 0.1 \times 101 \times 510$

$\boxed{R_{th} \approx 5.15\,K\Omega}$ --- (1m)

OR let Stability factor $S = 10$

$$S = \frac{1+\beta}{1+\beta\left(\frac{R_E}{R_{th}+R_E}\right)}$$

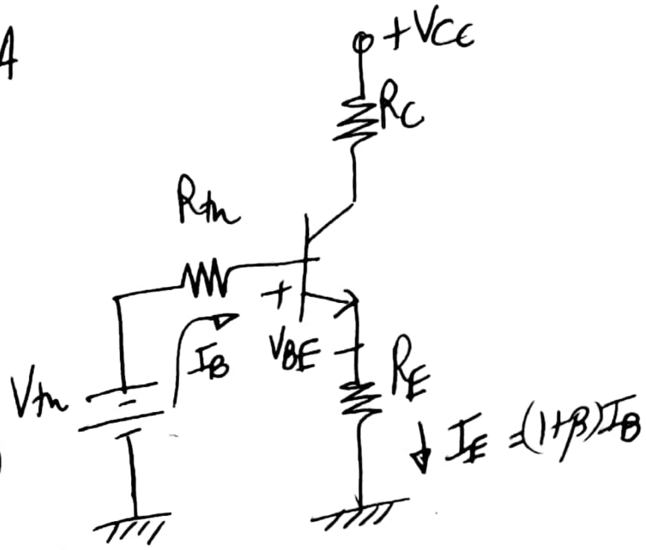
$$10 = \frac{1+100}{1+100\left(\frac{510}{R_{th}+510}\right)}$$

ie $\boxed{R_{th} \approx 5.094\,K\Omega}$

. Both techniques for finding R_{th} yields almost similar results.

Consider $R_{th} \approx 5.15\,K\Omega$ & moving ahead with calculations.

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{0.5mA}{100} = 5\mu A$$



KVL to B-E loop gives,

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

ie $V_{th} = V_{BE} + I_B \left(R_{th} + (1+\beta) R_E\right)$

$$= 0.7 + 5\mu A\left(5.15K + 101 \times 510\right)$$

$\boxed{V_{th} = 0.9833}$ ----- (2m)

$\because R_{th} = \frac{R_1 R_2}{R_1 + R_2}$

Also, $V_{th} = \frac{R_2}{R_1+R_2} \times V_{CC} = \frac{R_{th}}{R_1} V_{CC}$

ie $\frac{V_{th}}{V_{CC}} = \frac{R_{th}}{R_1} \Rightarrow R_1 = \frac{5.15K \times 5}{0.9833} = 26.187\,K\Omega$

Select $\boxed{R_1 = 27\,K\Omega, \tfrac{1}{4}W}$ ----- (3m)

H.S.V

Now; $\frac{V_{th}}{V_{CC}} = \frac{R_2}{R_1+R_2}$ ie $\frac{0.9833}{5} = \frac{R_2}{27K + R_2}$

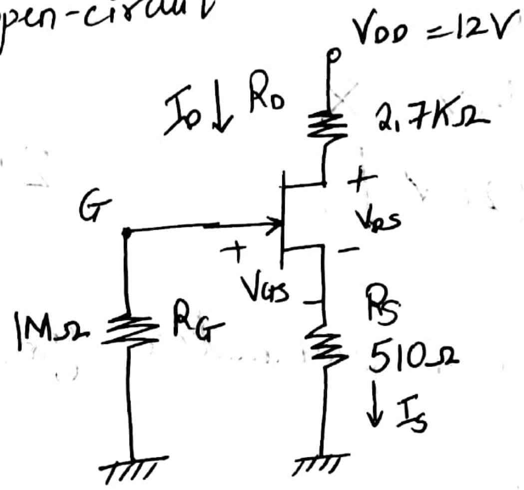
ie $R_2 = 6.6\,K\Omega$

Select $\boxed{R_2 = 6.2\,K\Omega (std), \tfrac{1}{4}W}$ ---- (2m)

L.S.V

2a) To find g_m :

For DC Analysis , $f=0$, $X_C = \frac{1}{2\pi f C} = \infty$ ie Capacitors behaves as open-circuit



$I_{DSS} = 10mA$

$V_P = -6V$

Soln:- From the above ckt, we have

$$V_G = 0$$

$$V_S = I_S R_S = I_D R_S \quad \text{------} \quad (I_S = I_D)$$

$$\rightarrow V_{GS} = V_G - V_S = 0 - I_D R_S$$

$$V_{GS} = -I_D (510) \quad \text{—} \quad ①$$

Assuming JFET is working in saturation region,

$$\rightarrow I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 10mA\left(1 + \frac{V_{GS}}{6}\right)^2 \quad - ②$$

Put ② in ① , we have

$$\text{ie } V_{GS} = -5.1\left(1 + \frac{V_{GS}}{3} + \frac{V_{GS}^2}{36}\right)$$

$V_{GS} = -5.1 - 1.7V_{GS} - 0.1416\ V_{GS}^2$

ie $0.1416\ V_{GS}^2 + 2.7V_{GS} + 5.1 = 0$

$V_{GS} = -2.126V$ ✓ (we select this value, since $V_{GS} < V_P$)

OR

$V_{GS} = -16.94V$ ✗

$\therefore \boxed{V_{GS} = -2.126V}$ ---------- (3m)

→ Small-signal hybrid-π parameter (g_m):-

$$g_m = \frac{2I_{DSS}}{|V_P|}\left(1 - \frac{V_{GS}}{V_P}\right)$$

$$= \frac{2 \times 10mA}{6}\left(1 - \frac{(-2.126)}{(-6)}\right)$$

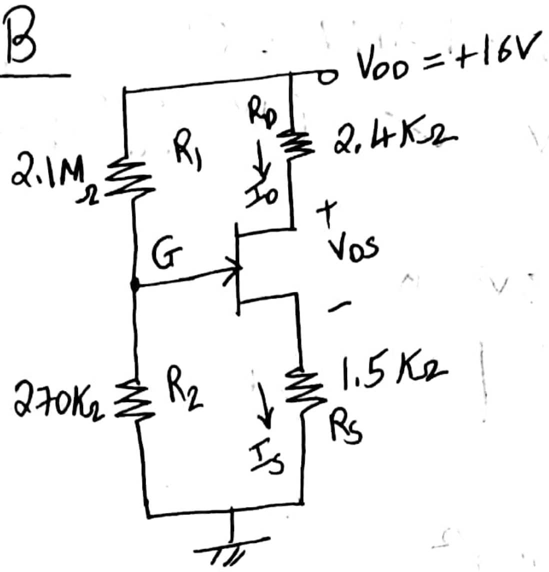
$$= 3.33mA\ (0.6456)$$

$$\boxed{g_m = 2.15\ \frac{mA}{V}}$$ ---------- (1m)

2b) JFET is a voltage-controlled device. (3m)

<u>Justification</u>

Circuit B



$I_{DSS} = 8mA$
$V_P = -4V$

i) Analytical method :-

Above circuit is voltage-divider bias

$V_G = \frac{R_2}{R_1+R_2} \times V_{DD} = \frac{270K}{2.1M + 270K} \times 16$

$\rightarrow \boxed{V_G = 1.823\ V}$ --- (1m) ; $V_S = I_D R_S$

$\rightarrow V_{GS} = V_G - I_D R_S = 1.823 - I_D(1.5K\Omega)$ — ①

Assuming transistor is working in saturation region,

$\rightarrow I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 8mA\left(1 + \frac{V_{GS}}{4}\right)^2$ — ②

Put ② in ①, we get

ie $V_{GS} = 1.823 - 12\left(1 + \frac{V_{GS}}{2} + \frac{V_{GS}^2}{16}\right)$

$V_{GS} = 1.823 - 12 - 6V_{GS} - 0.75V_{GS}^2$

04.

$\rightarrow$ $0.75 V_{GS}^2 + 7V_{GS} + 10.177 = 0$

$V_{GS} = -1.8V$ ✓ (we select this value, since $V_{GS} < V_P$)

OR

$V_{GS} = -7.53V$ ✗

$\therefore$ $\boxed{V_{GS} = -1.8V}$ --- 3 M

$\rightarrow$ $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$= 8mA\left(1 - \frac{(-1.8)}{(-4)}\right)^2$

$= 8mA \times 0.3025$

$\boxed{I_D = 2.42\ mA}$ --- 2M

KVL applied to Drain to source loop, gives

$V_{DD} - I_D R_D - V_{DS} - I_D R_S = 0$ $(I_D = I_S)$

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

$= 16 - 2.42mA(2.4K\Omega + 1.5K\Omega)$

$\boxed{V_{DS} = 6.562\ V}$ --- 2M

Circuit B

Graphical method:-

→ $V_G = \frac{R_2}{R_1+R_2} V_{DD} = \frac{270K\Omega}{270K\Omega + 2.1M\Omega} \times 16 = 1.82V$

→ $V_S = I_D R_S$

→ $\boxed{V_{GS} = 1.82 - I_D(1500)}$ — ① (1m)

↳ load line equation

In above equation,

i) Put $I_D = 0$ → $V_{GS} = 1.82V$

1st point ≡ (1.82V, 0) ($\frac{1}{2}$m)

ii) Put $V_{GS} = 0$ → $I_D = \frac{1.82}{1500} = 1.213mA$

2nd point ≡ (0, 1.213mA) ($\frac{1}{2}$m)

Joining above two points gives us load line
co-ordinates

To plot transfer curve, we require few readings of I_D & V_{GS}.

→ $I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2$ — ①

→ $V_{GS} = V_P\left(1-\sqrt{\frac{I_D}{I_{DSS}}}\right)$ — ②

i) If $V_{GS} = 0.5V_P$ → $I_D = \frac{1}{4} I_{DSS}$ ---From ①

ii) If $I_D = \frac{I_{DSS}}{2}$ → $V_{GS} = 0.3V_P$ ---From ②

V_{GS}	I_D
0	I_{DSS}
$0.3V_P$	$I_{DSS}/2$
$0.5V_P$	$I_{DSS}/4$
V_P	0

ie

V_{GS}	I_D
0	8mA
−1.2V	4mA
−2V	2mA
−4V	0

1M

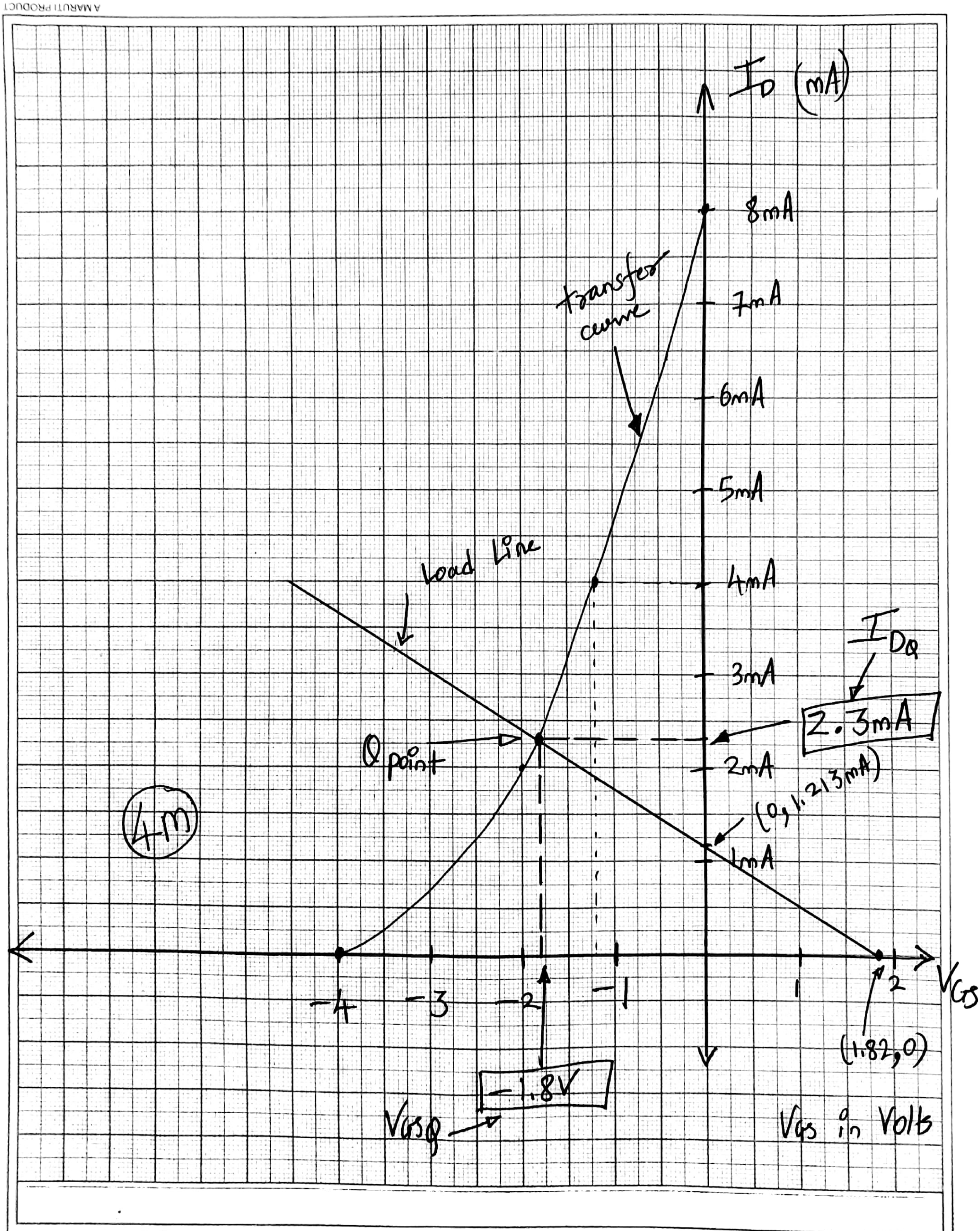
Using the values of V_{GS} & I_D to plot transfer curve.

→ The interaction of Load line curve and transfer curve gives us the Q-point.

ie $\boxed{V_{GSQ} = -1.8V}$ & $\boxed{I_{DQ} = 2.3mA}$

• $V_{DS} = V_{DD} - I_D(R_D+R_S) = 16 - 2.3mA(2.4K+1.5K)$

$\boxed{V_{DS} = 7.03V}$ 1M


I_D (mA)
8mA
7mA
6mA
5mA
4mA
3mA
2mA
1mA
transfer curve
Load Line
I_DQ
2.3mA
Q point
(0, 1.213mA)
4m
-4
-3
-2
-1
1
2
V_GS
(1.82,0)
-1.8V
V_GSQ
V_GS in Volts