American International University- Bangladesh (AIUB)
Faculty of Engineering (EEE)

Course Name :	Electronic Devices	**Course Code :**	EEE 2103
Semester :	Spring 2023	**Sec : K**	
POI	**P.b.2.C4**	**Assignment No :**	Non-OBE
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Assignment Problem

1 ***Analyze*** the transfer characteristics curve of D-MOSFET and E-MOSFET (any one channel is ok) using the Shockley's equation and shorthand method. Consider the pinch-off voltage is [use appropriate sign here] [three digits before the last digit of your ID] mV and IDSS is [three digits before the last digit of your ID] mA. **[4]**

Ans-to-the-ques-no-1

Given, $I_{DSS} = 38mA$

$V_{GS(TH)} = +38mV$ for (E-mosfet) n-channel

$V_{GS(TH)} = -38mV$ for (D-mosfet) n-channel

Here, assuming for the range upto 50mV,

$$K = \frac{I_{D(ON)}}{(V_{GS(ON)} - V_{GS(TH)})^2}$$

$$= \frac{38mA}{(50-38)^2}$$

$$= 0.26$$

For, Enhancement-mosfet,

When, $I_D = 0mA$, $V_{GS} = 38mV$

when, $V_{GS} = 45mV$, $I_D = k[V_{GS(ON)} - V_{GS(TH)}]^2$

$$= 0.26[45-38]^2$$

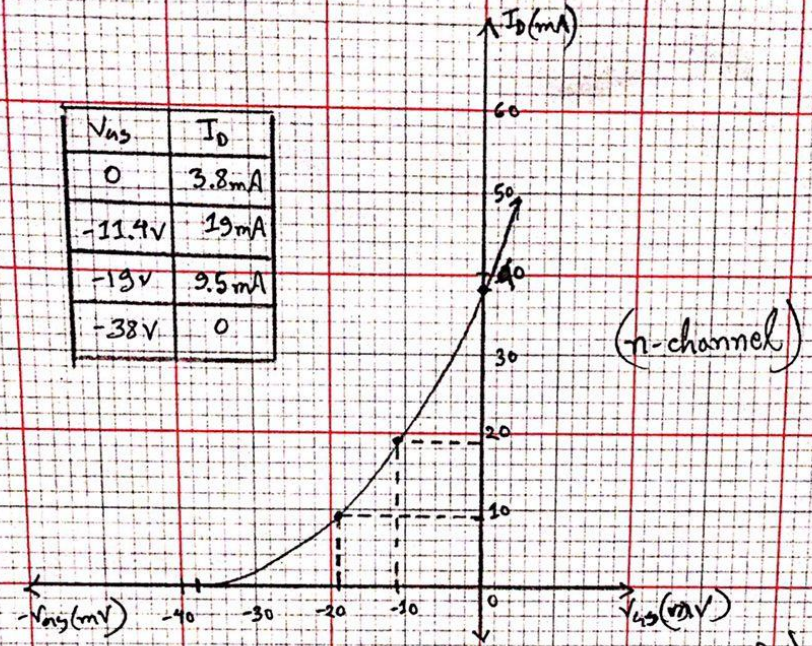
$$= 12.74mA$$

when, $V_{GS} = 50mV$, $I_D = k[V_{GS(ON)} - V_{GS(TH)}]^2$

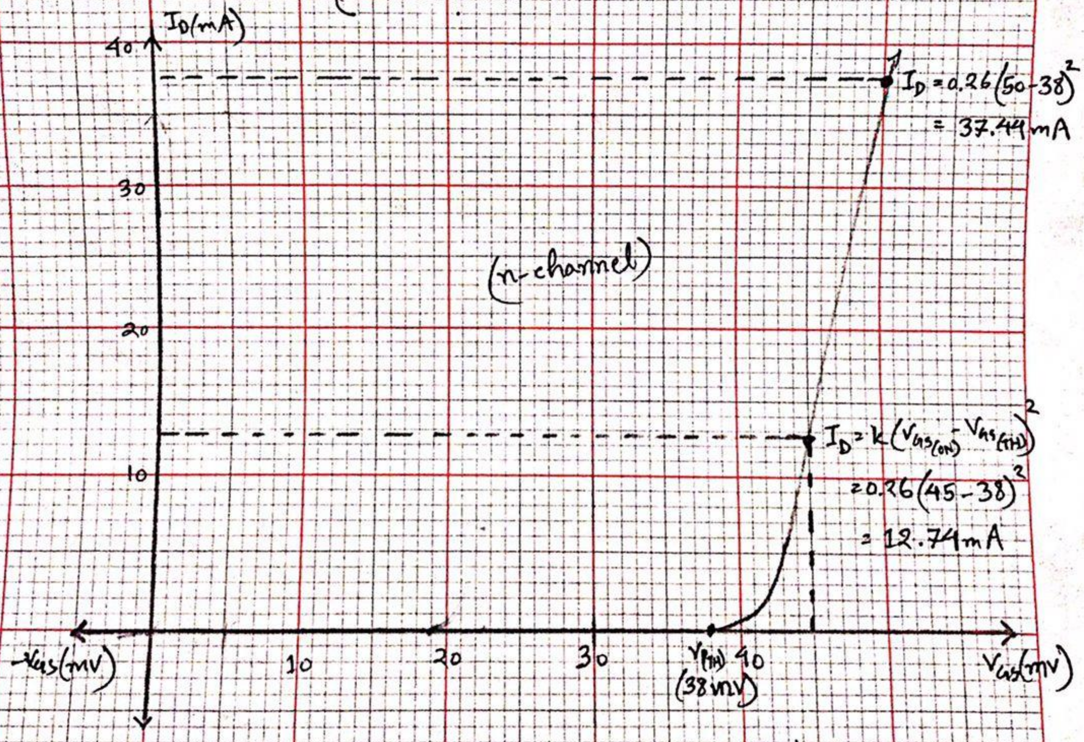
$$= 0.26[50-38]^2$$

$$= 37.44mA$$

V_{GS}	I_D
0	3.8mA
-11.4V	19mA
-19V	9.5mA
-38V	0



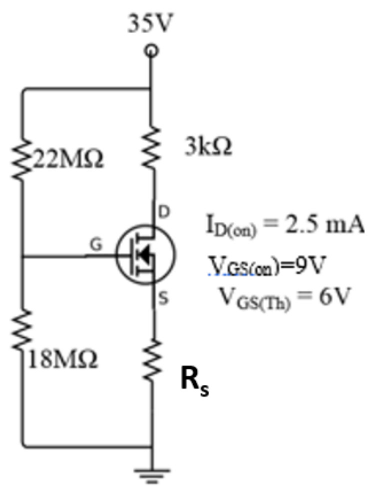
(Transfer characteristic curve for D-mosfet)



(Transfer charasteristic curve for E-mosfet)

2 ***Analyze*** the Q points (**I_{DQ}**, **V_{GSQ}**,) for different values of the **R_s** (220 Ω and 770 Ω) for the E-MOSFET voltage divider configuration given in Fig. 2. [**4**]

<u>Figure for Question 2</u>



Ans-to-the-ques-no-2

Assuming that given device is working in saturation region,

$$k = \frac{I_{D(ON)}}{[V_{GS(ON)} - V_{GS(TH)}]^2} = \frac{2.5mA}{(9-6)^2} = 0.28\ mA/V^2$$

Now, $I_D = k[V_{GS(ON)} - V_{GS(TH)}]^2 = 0.28[V_{GS} - 6]^2 mA$ ——— (i)

AND, $V_{GS} = V_G - V_S = V_G - I_D R_S$ ——— (ii)

~~Solving (i) & (ii),~~

~~$V_{GS} = 15.75$~~

Using V.D.R, $V_G = \frac{18M\Omega}{18M\Omega + 22M\Omega} \times 35V$

$\therefore V_G = 15.75\ V$

Solving (i) & (ii), For $R_S = 220\Omega$

$V_{GS} = 15.75V - (0.22k\Omega) \times [0.28(V_{GS} - 6)^2]$

$\Rightarrow V_{GS} = 15.75V - (0.22k\Omega) \times (0.28) \times (V_{GS}^2 - 12V_{GS} + 36)$

$\Rightarrow V_{GS} = 15.75V - (0.0616V_{GS}^2 - 0.7392V_{GS} + 2.2176)$

$\Rightarrow 0.0616V_{GS}^2 + 0.2608V_{GS} - 13.5324 = 0$

$\Rightarrow V_{GS} = 12.85V$ & $-17.088V$

As V_{gs} should be greater than the threshold voltage in order for the MOSFET to be in On state, we consider, $V_{gs} = 12.85\ V$.

$\therefore I_D = 0.28[12.85 - 6]^2 = 13.14mA$

For $R_S = 770\Omega$,

$$V_{GS} = 15.75V - (0.77k\Omega) \times [0.28(V_{GS}-6)^2]$$

$$\Rightarrow V_{GS} = 15.75V - (0.2156) \times [V_{GS}^2 - 12V_{GS} + 36]$$

$$\Rightarrow V_{GS} = 15.75V - (0.2156V_{GS}^2 - 2.5872V_{GS} + 7.7616)$$

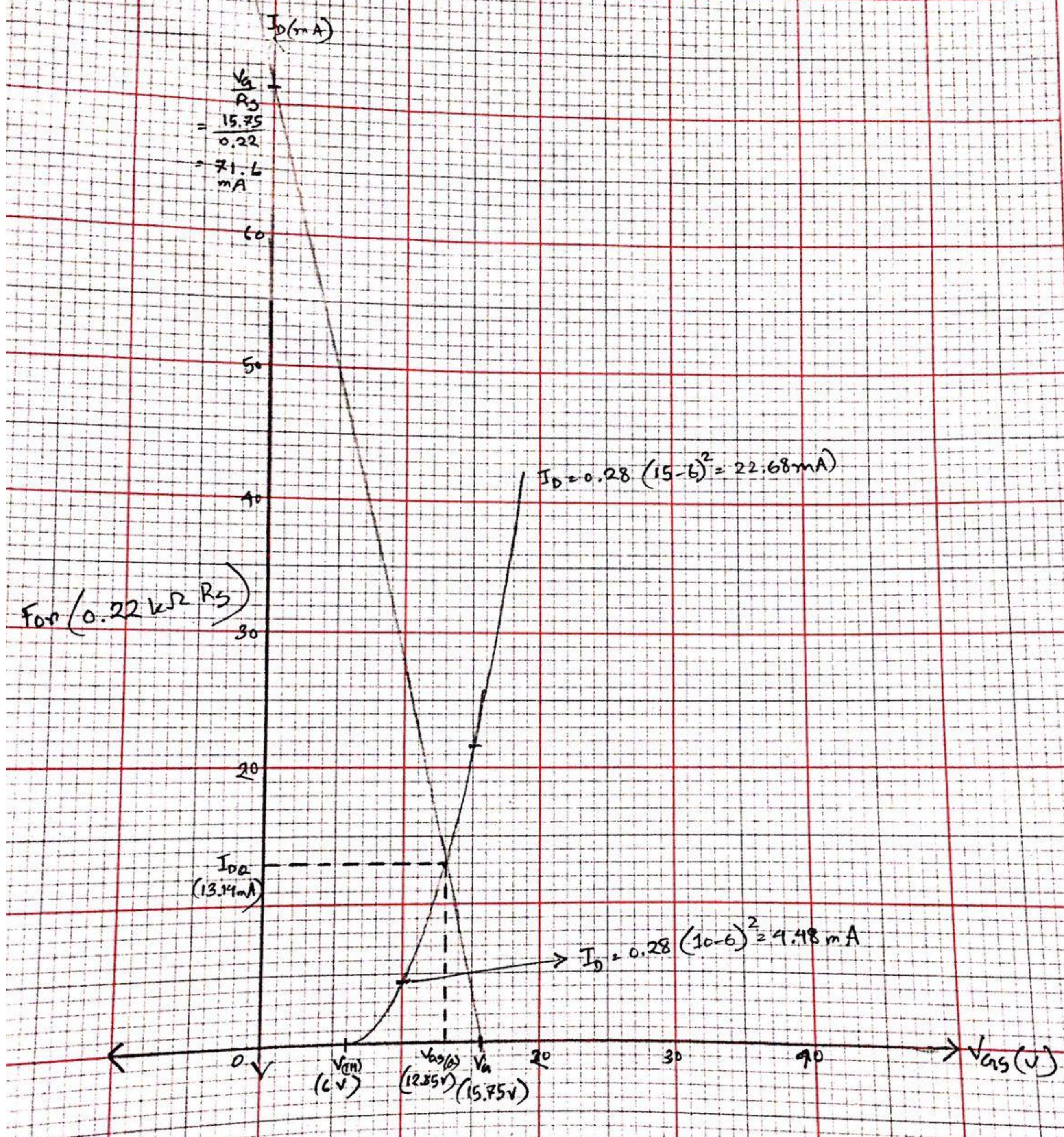
$$\Rightarrow 0.2156V_{GS}^2 - 1.5872V_{GS} - 7.9884 = 0$$

Here, $V_{GS} = 10.8V$ & $V_{GS} = -3.43V$

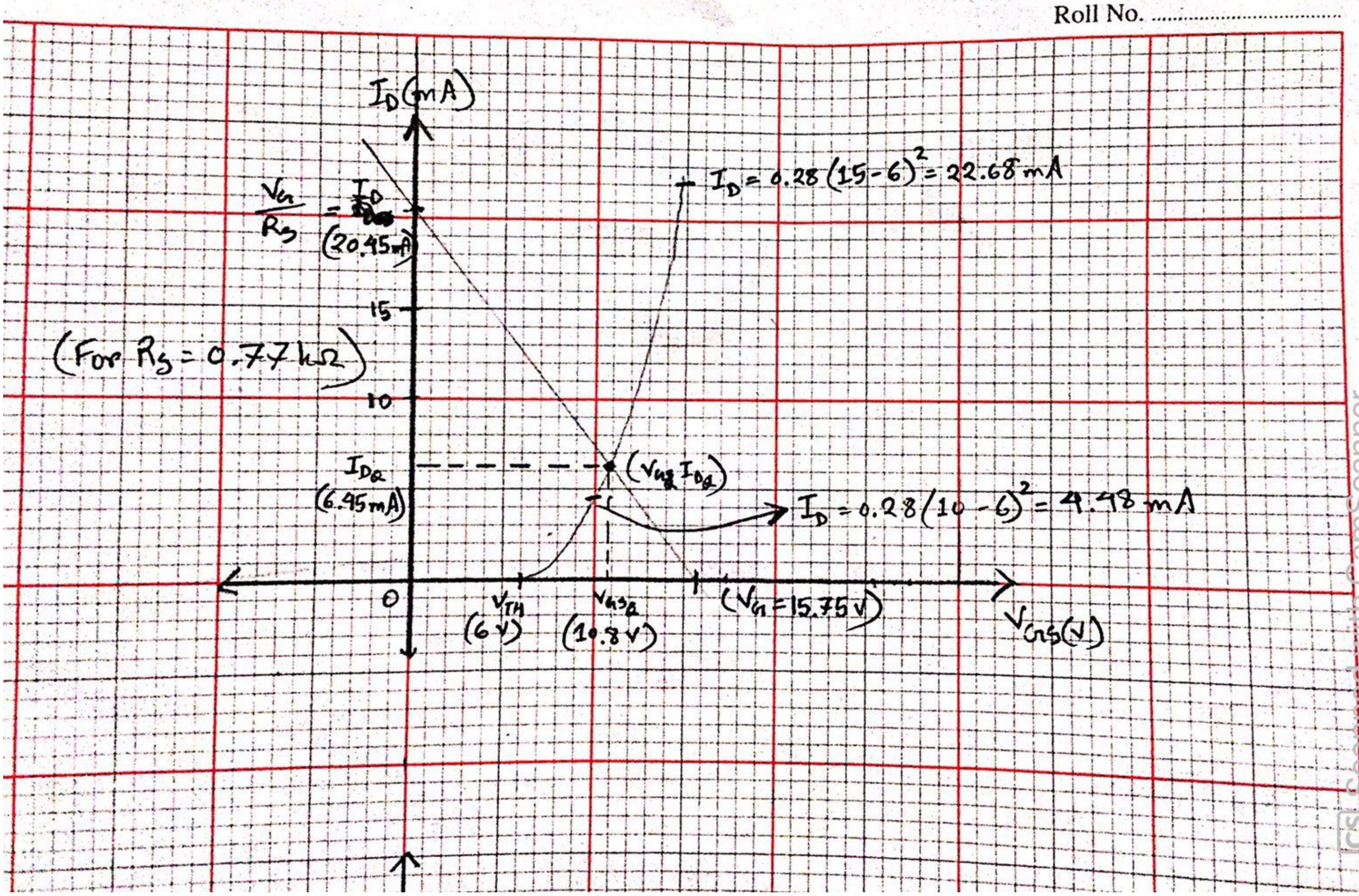
As $V_{GS} = 10.8V > V_{(TH)} = 6V$

$\therefore V_{GS} = 10.8V$

Now, $I_D = 0.28[10.8-6]^2 = 6.45 mA$


I_D (mA)
V_G / R_S
= 15.75 / 0.22
= 71.6 mA
60
50
40
30
20
I_D = 0.28 (15-6)^2 = 22.68 mA
For (0.22 kΩ R_S)
I_DQ
(13.14mA)
I_D = 0.28 (10-6)^2 = 4.48 mA
0
V_(TH)
(6V)
V_GS(Q)
(12.85V)
V_G
(15.75V)
20
30
40
V_GS (V)

Roll No. ....



I_D(mA)
$I_D = 0.28(15-6)^2 = 22.68$ mA
$\frac{V_G}{R_S} = I_D$
(20.45mA)
15
(For $R_S = 0.77$ kΩ)
10
I_{DQ}
(6.45mA)
(V_{GSQ} I_{DQ})
$I_D = 0.28(10-6)^2 = 4.48$ mA
0
V_{TH}
(6 V)
V_{GSQ}
(10.8 V)
(V_G = 15.75 V)
V_{GS}(V)

3 ***Analyze*** the g_m at different dc bias points of (-0.90 V, -1.40 V and -2.2 V) both graphically and mathematically for a JFET having I_{DSS} of 6 mA and V_p = -5 V and comment on it. **[4]**

Ans-to-the-ques-no-3

(Mathematical)

Here, $g_{m_0} = \frac{2 I_{DSS}}{|V_p|} = \frac{2 \times 6\,mA}{5V} = 2.4\,mS$

At $V_{GS} = -0.90V$,

$$g_m = g_{m_0}\left[1 - \frac{V_{GS}}{V_p}\right] = 2.4mS\left[1 - \frac{-0.9}{-5}\right] = 1.968\,mS$$

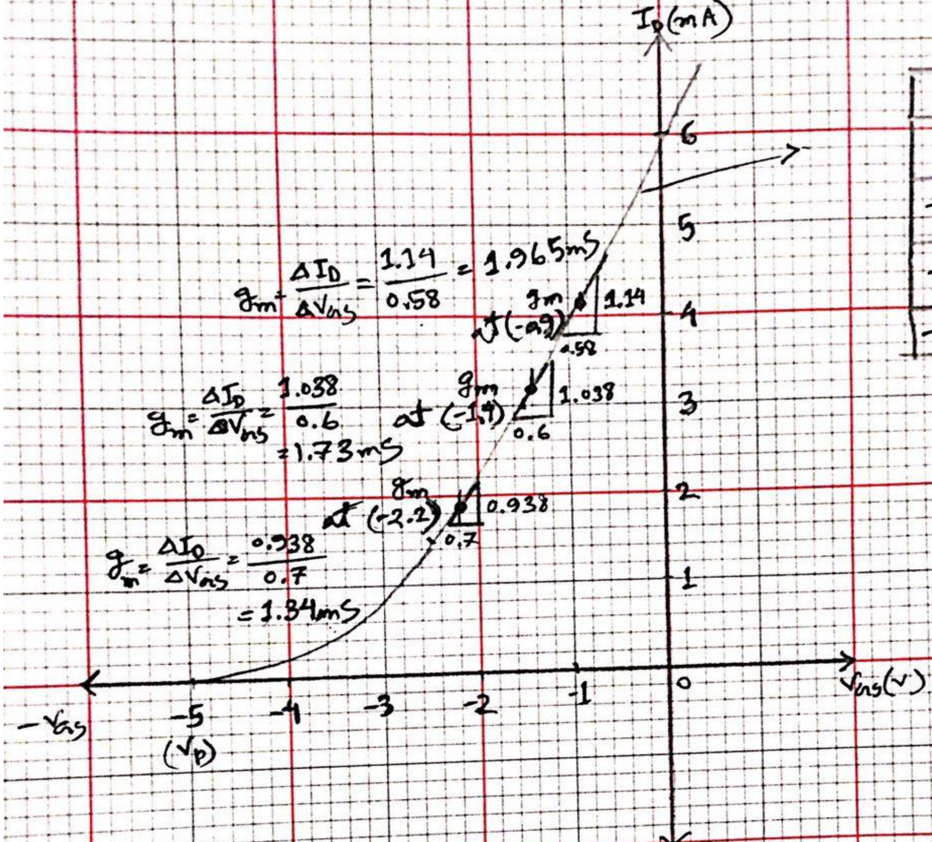
At $V_{GS} = -1.40V$,

$$g_m = g_{m_0}\left[1 - \frac{V_{GS}}{V_p}\right] = 2.4mS\left[1 - \frac{-1.4}{-5}\right] = 1.728\,mS$$

At $V_{GS} = -2.2V$,

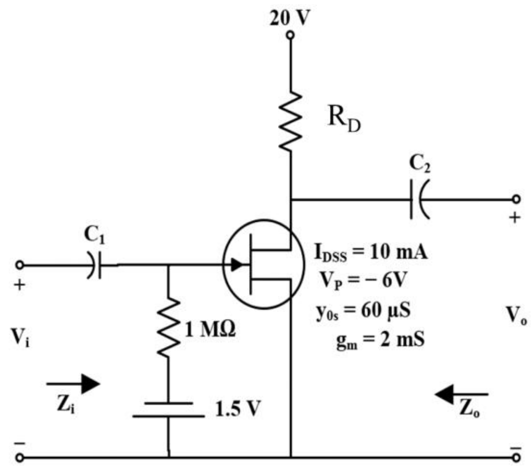
$$g_m = g_{m_0}\left[1 - \frac{V_{GS}}{V_p}\right] = 2.4mS\left[1 - \frac{-2.2}{-5}\right] = 1.344\,mS$$

The maximum value of g_m occurs when $V_{GS} = 0V$ and the minimum value at $V_{GS} = V_p$. The more negative the value of V_{GS} the less the value of g_m.



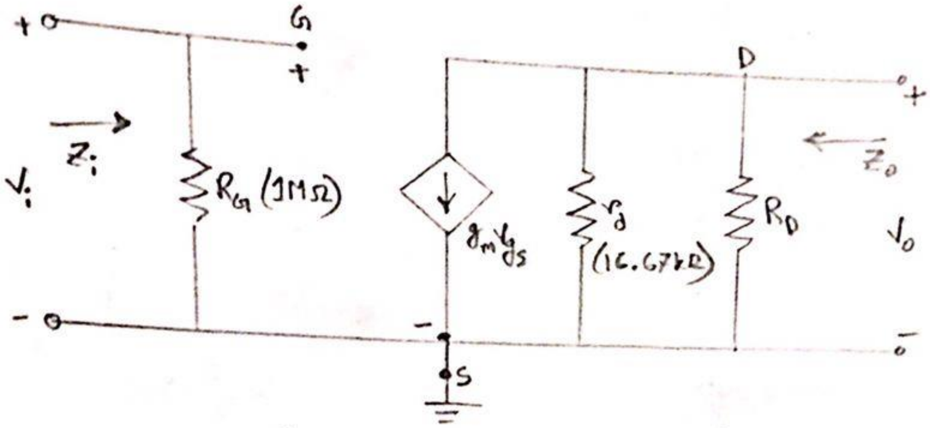
V_{GS}	I_D
0	6mA
-1.5V	3mA
-2.5V	1.5mA
-5V	0

4 For the network given in Fig. 4, ***analyze*** $\mathbf{A_v}$ by determining the values $\mathbf{Z_i}$, $\mathbf{Z_o}$ for $\mathbf{R_D}$ = 3 kΩ and 5 kΩ. **[4]**



<u>Figure for Question 4</u>

Ans-to-the-ques-no-4



(JFET ac equivalent circuit)

Here, For $R_D = 3\ k\Omega$,

$r_d \geq 10 R_D$

$\Rightarrow 16.67\ k\Omega \ngeq 10 \times 3\ k\Omega$

$r_d = \frac{1}{y_{os}} = \frac{1}{60\mu S} = 16.67\ k\Omega$

$\therefore Z_i = R_G = 1M\Omega$

$\therefore Z_o = R_D \| r_d = (3 \| 16.67)k\Omega = \left(\frac{1}{3} + \frac{1}{16.67}\right)^{-1} k\Omega = 2.54\ k\Omega$

Now, For $R_D = 5\ k\Omega$,

$r_d \geq 10 R_D \Rightarrow 16.67\ k\Omega \ngeq 10 \times 5\ k\Omega$

$\therefore Z_i = R_G = 1M\Omega$

$\therefore Z_o = R_D \| r_d = (5 \| 16.67)k\Omega = \left(\frac{1}{5} + \frac{1}{16.67}\right)^{-1} k\Omega = 3.85\ k\Omega$

Now, $A_{v(3k\Omega)} = -g_m (R_D \| r_d) = -(2mS)(2.54\ k\Omega) = -5.08$

$A_{v(5k\Omega)} = -g_m (R_D \| r_d) = -(2mS)(3.85\ k\Omega) = -7.7$

So, after analyzing voltage gain for $R_D = 3k\Omega$ and $5k\Omega$, we can say that, ~~increases~~ increase in drain resistance result in increase in voltage gain.

5 Design a self-bias network using a JFET transistor with I_{DSS} = 10 mA and V_P = -4 V to have a Q -point at I_{DQ} = 6 mA using a supply of 16 V. Assume that R_D = 3RS and use standard values. **[4]**

Ans-to-the-ques-no-5

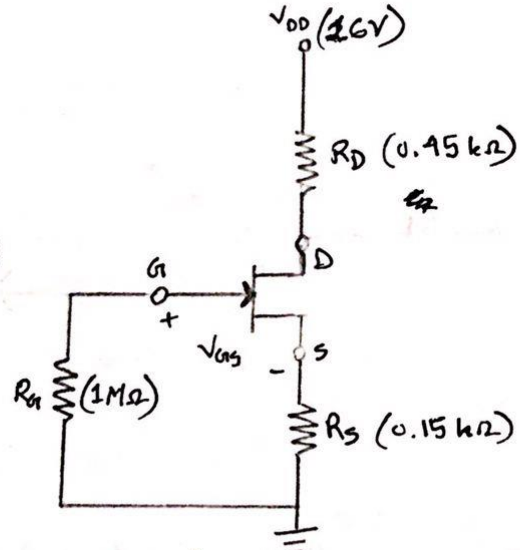
Given, $I_{DSS} = 10\,mA$

$V_p = -4V$

$I_{DQ} = 6mA$

$V_{cc} = 16\,V$

$R_D = 3R_s$



From shockley's eqn,

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

$$\Rightarrow 6mA = 10mA\left(1 + \frac{V_{GS}}{4}\right)^2$$

$$\Rightarrow 1 + \frac{V_{GS}}{4} = \sqrt{\frac{6}{10}} \Rightarrow \frac{V_{GS}}{4} = \sqrt{\frac{6}{10}} - 1$$

$$\Rightarrow V_{GS} = 4 \times (-0.025)$$

$$\therefore V_{GS} = -0.9\,V$$

Using KVL, $V_{GS} = -I_D R_S$

$$\Rightarrow R_s = -\frac{V_{GS}}{I_D} = \frac{0.9\,V}{6\times10^3 A}$$

$$\therefore R_s = 0.15\,k\Omega$$

Now, $R_D = 3R_s = 0.45\,k\Omega$