D-MOSFET

MOSFET DC BIASING

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TOPIC OUTLINE

D-MOSFET Construction

Regions of Operation

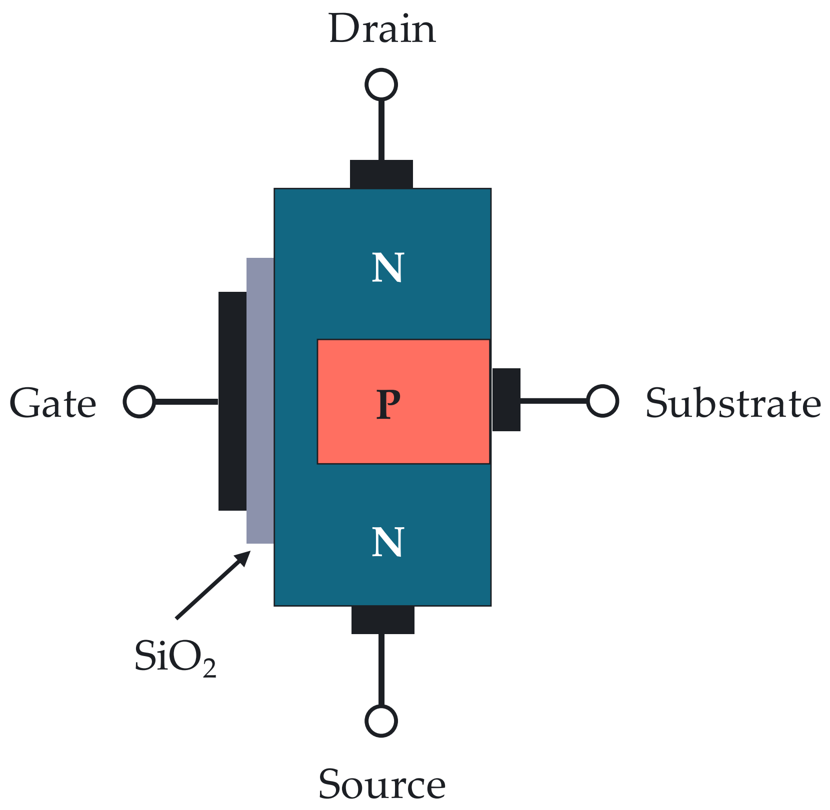
D-MOSFET DC Biasing

D-MOSFET CONSTRUCTION

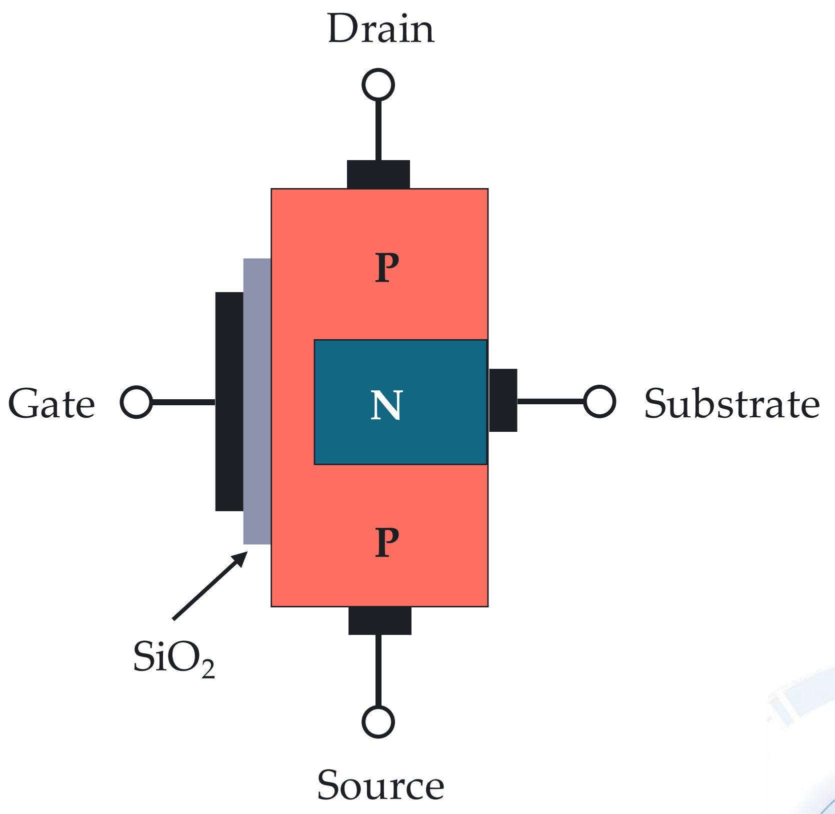
CONSTRUCTION

D-MOSFET

Depletion Mode Metal-Oxide Semiconductor Field-Effect Transistor



N-Channel

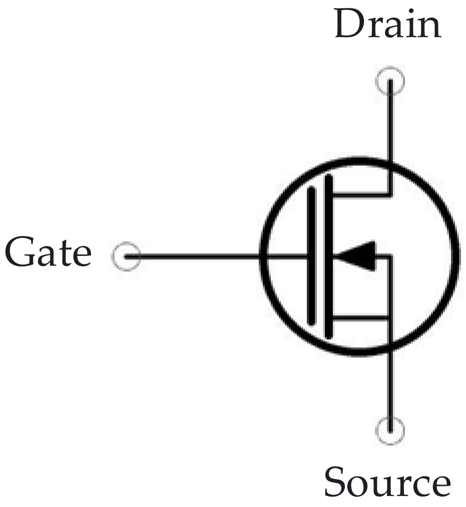


P-Channel

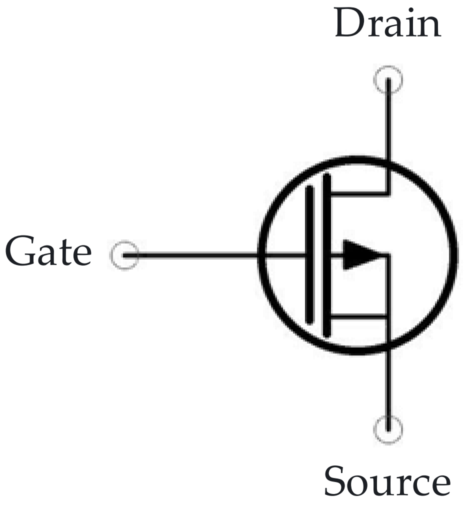
SCHEMATIC SYMBOL

D-MOSFET

Depletion Mode Metal-Oxide Semiconductor Field-Effect Transistor



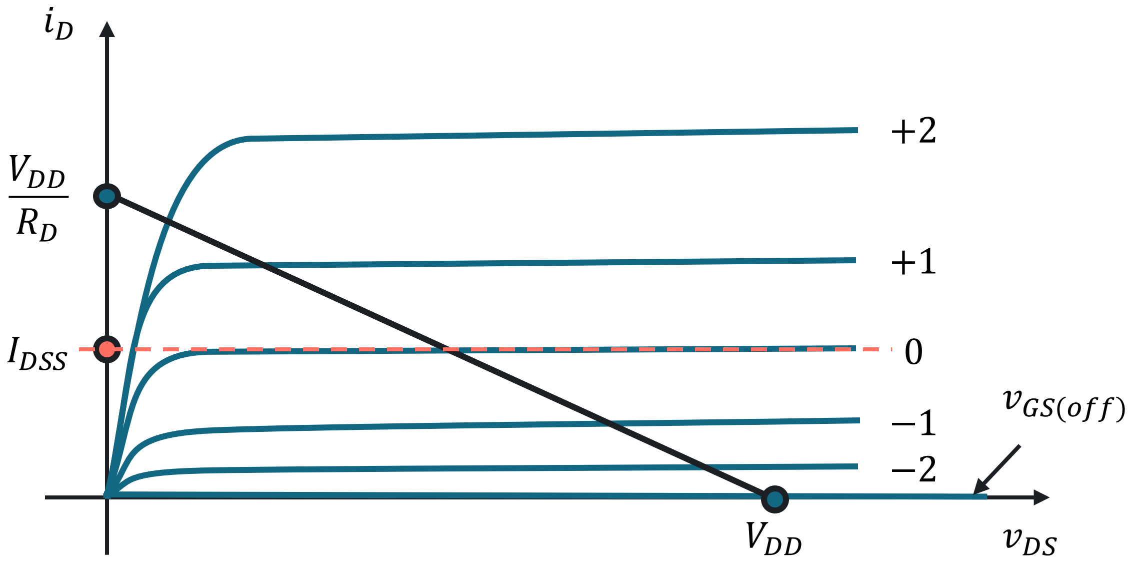
N-Channel



P-Channel

REGIONS OF OPERATION

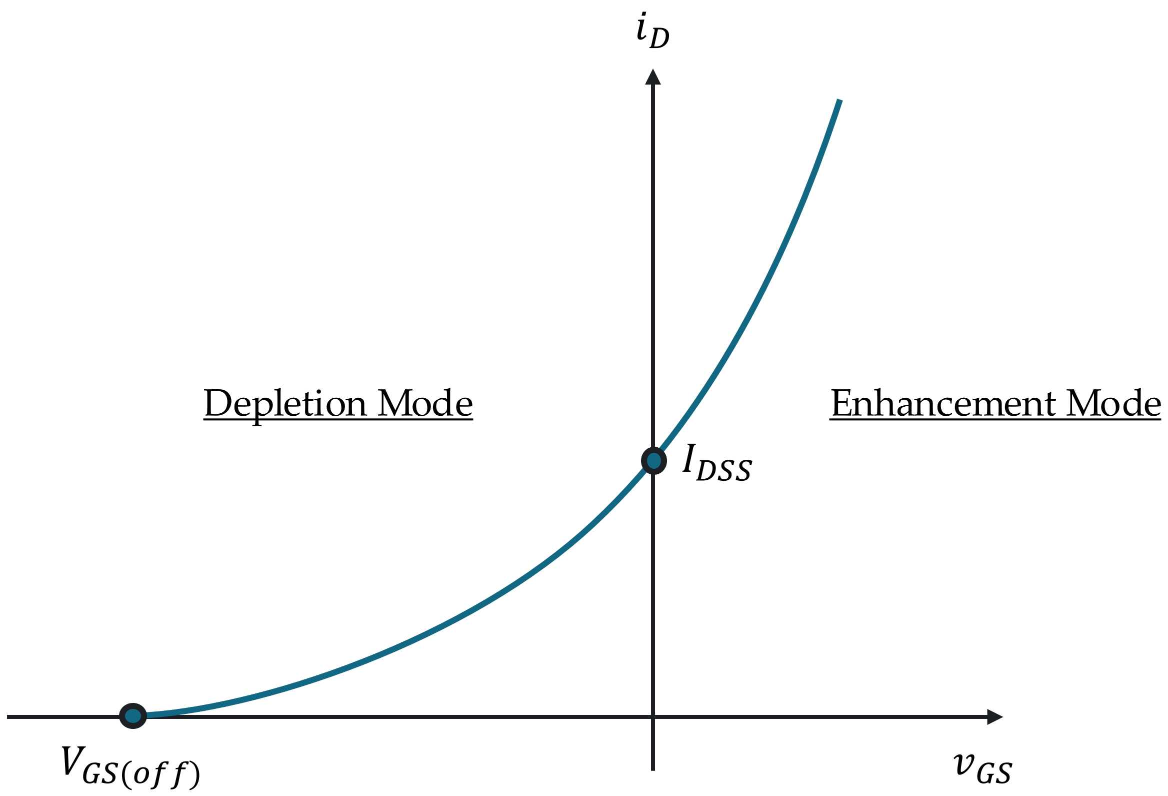
DRAIN CURVE



As with a JFET, when $v_{GS} = 0$ V, the drain current will equal I_{DSS}.

This demonstrates that the D-MOSFET is a **normally on** device

TRANSCONDUCTANCE CURVE



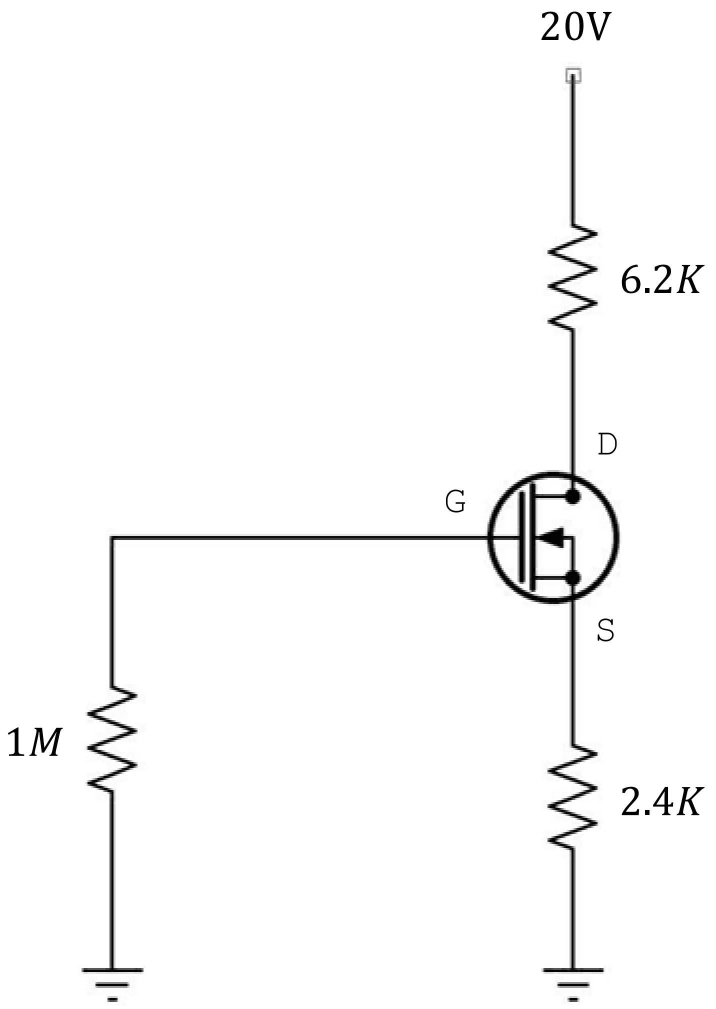
The primary difference between JFET and D-MOSFET is that D-MOSFETs permit operating points with **positive values** of v_{GS} and levels of i_D that **exceeds** i_{DSS}.

Shockley's Equation

$$i_D = I_{DSS}\left(1 - \frac{v_{GS}}{V_{GS(off)}}\right)^2$$

D-MOSFET DC BIASING

EXERCISE



$I_{DSS} = 8\ mA$

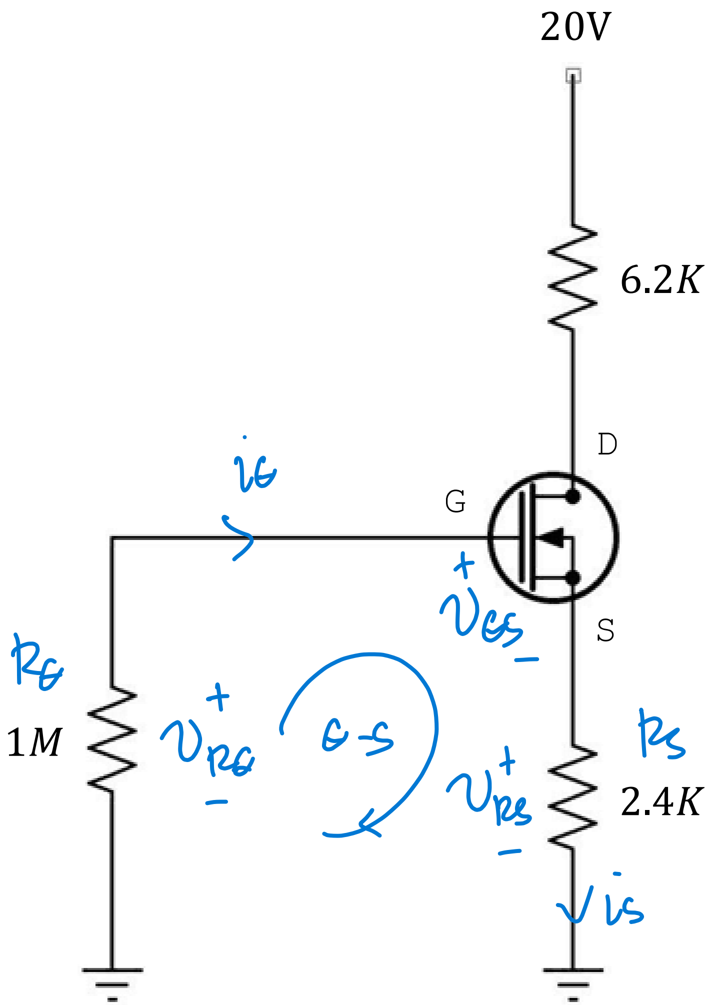
$V_P = -8\ V$

For the given network, determine the following:

- Gate-source voltage (v_{GSQ})
- Drain current (i_{DQ})
- Drain voltage (v_D)

and sketch the transconductance curve.

EXERCISE



$I_{DSS} = 8\ mA$

$V_P = -8\ V$

Solution

KVL @ G-S

$$-v_{RG} + v_{GS} + v_{RS} = 0$$

$$v_{GS} = v_{RG} - v_{RS}$$

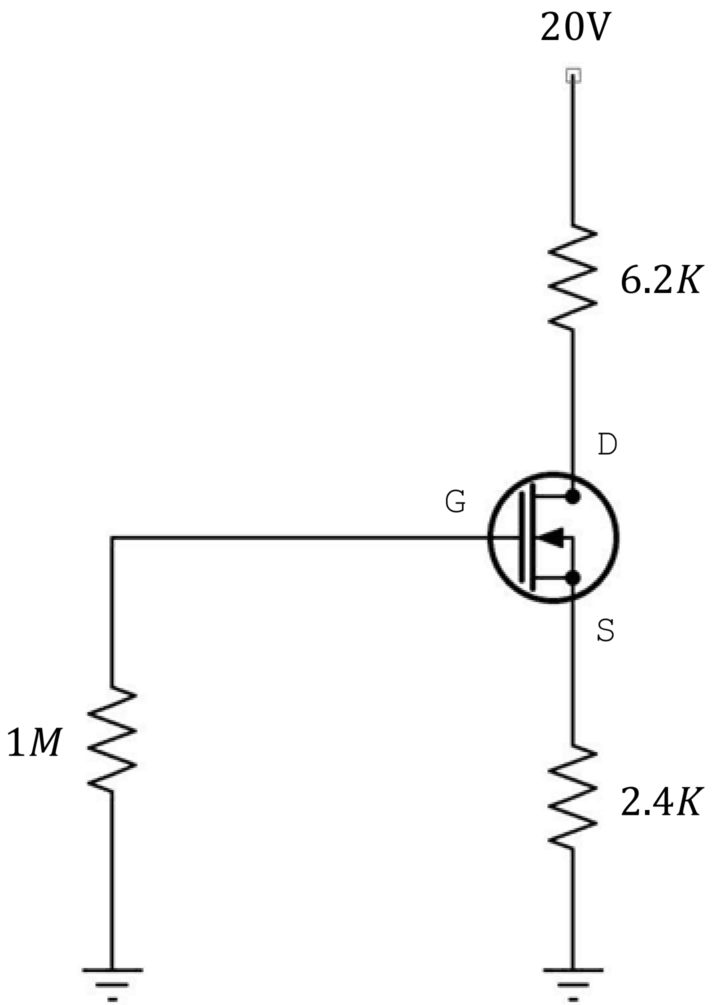
$$v_{GS} = \cancel{i_G}^{\,0} R_G - \cancel{i_S}^{\,i_D} R_S$$

$$v_{GS} = -i_D R_S$$

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

$$v_{GS} = -I_{DSS} R_S \left(1 - \frac{2v_{GS}}{V_P} + \frac{v_{GS}^2}{V_P^2}\right)$$

EXERCISE



$I_{DSS} = 8\ mA$

$V_P = -8\ V$

Solution

$$v_{GS} = -(8m \cdot 2.4k)\left[1 - \frac{2v_{GS}}{-8} + \frac{v_{GS}^2}{(-8)^2}\right]$$

$$v_{GS} = \underline{-19.2}\left(1 + \frac{1}{4}v_{GS} + \frac{1}{64}v_{GS}^2\right)$$

$$\cancel{v_{GS}}^{\,0} = -19.2 - 4.8v_{GS} - 0.3v_{GS}^2$$

$$\underline{-v_{GS}} \qquad\qquad \underline{-v_{GS}}$$

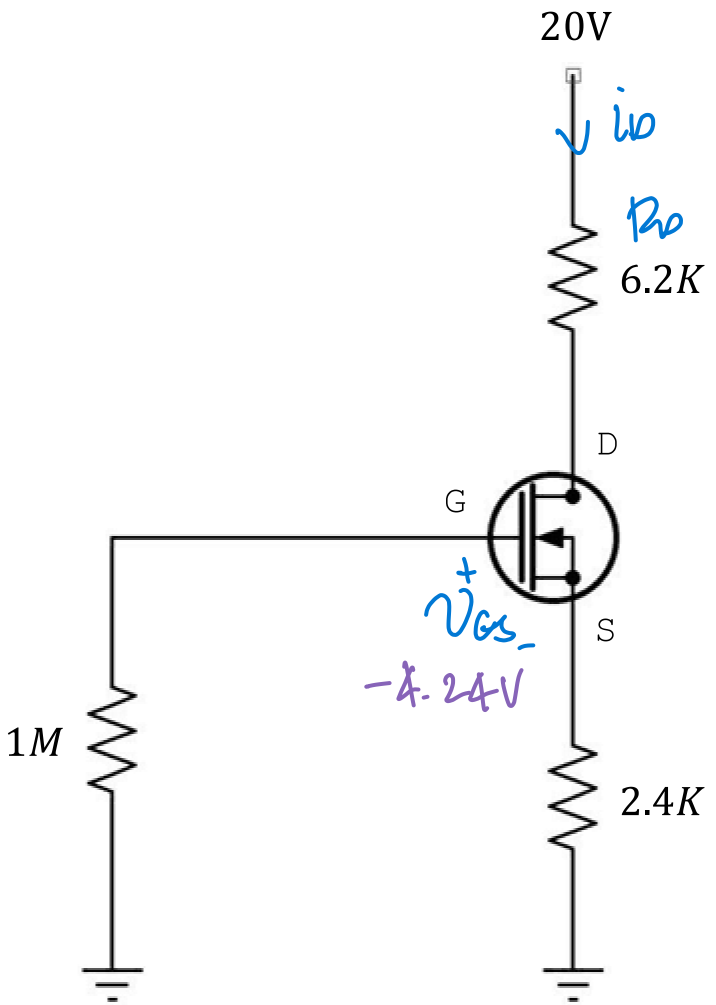
$$0 = -19.2 - 5.8v_{GS} - 0.3v_{GS}^2$$

$$v_{GS} = -15.09\ V$$

$$\boxed{v_{GSQ} = -4.24\ V}$$

ans

EXERCISE



$I_{DSS} = 8\ mA$

$V_P = -8$ V

Solution

<u>Shockley's Equation</u>

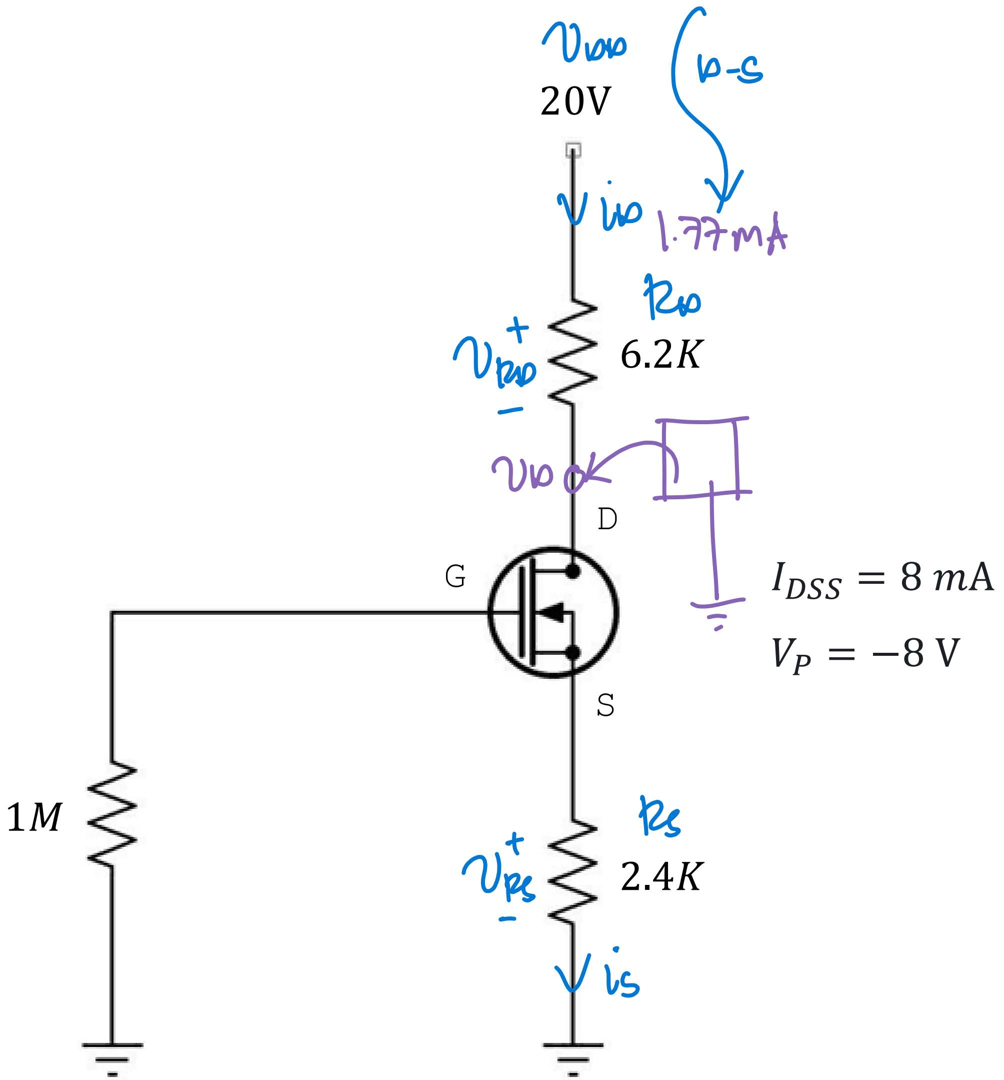
$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$i_D = 8m\left(1 - \frac{-4.24}{-8}\right)^2$$

$$\boxed{i_{DQ} = 1.77mA}$$

ans

EXERCISE



Solution

KVL@ D-S

$$-V_{DD} + V_{RD} + V_D = 0$$

$$V_D = V_{DD} - V_{RD}$$

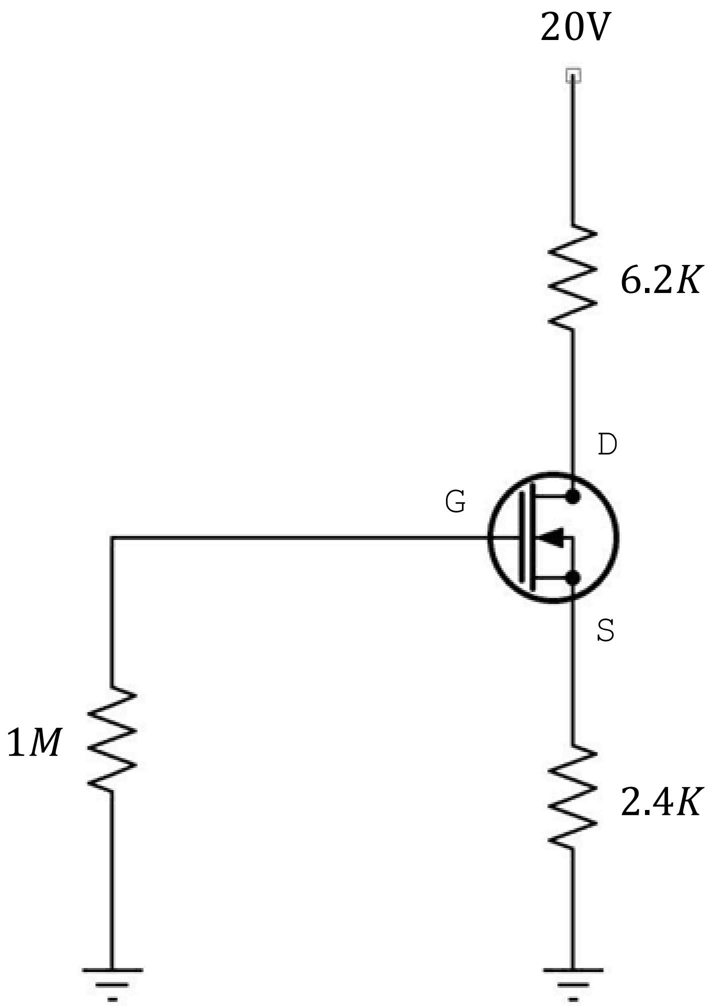
$$V_D = V_{DD} - i_D R_D$$

$$V_D = 20 - 1.77m(6.2k)$$

$$\boxed{V_D = 9.03V}$$

ans

EXERCISE



$I_{DSS} = 8\ mA$

$V_P = -8\ V$

Solution

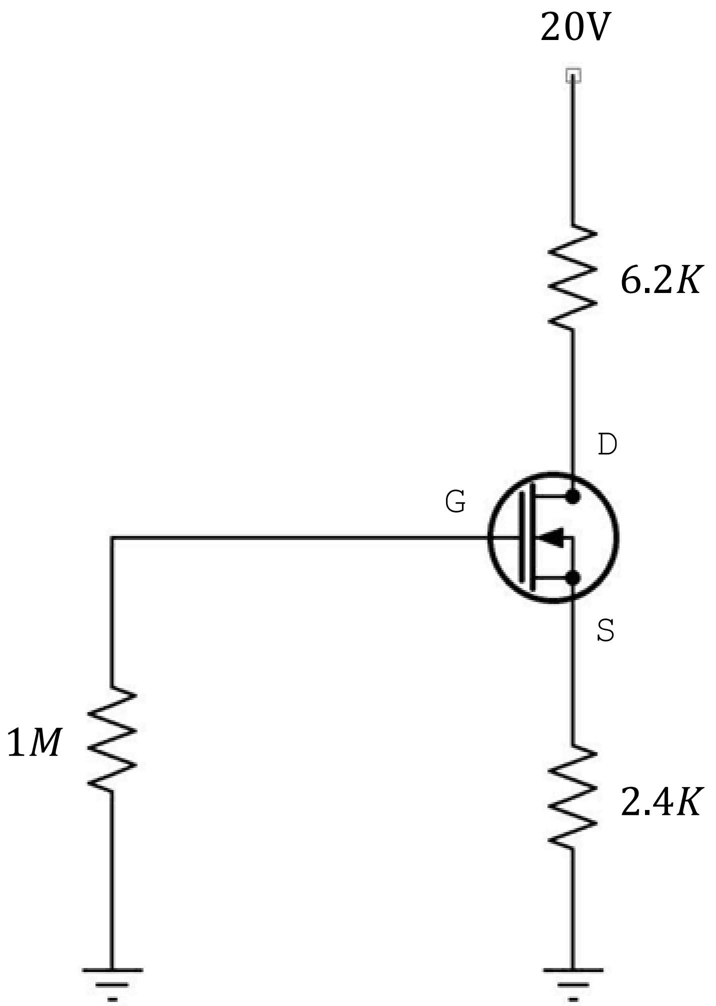
Transconductance Curve

$i_D = \frac{1}{4} I_{DSS} \;\Big|\; v_{GS} = \frac{1}{2} V_P$

$i_D = \frac{1}{4}(8mA) \;\Big|\; v_{GS} = \frac{1}{2}(-8V)$

$i_D = 2mA \;\Big|\; v_{GS} = -4V$

EXERCISE



$I_{DSS} = 8\ mA$

$V_P = -8\ \mathrm{V}$

Solution

$$v_{GS} = 0.3V_P \mid i_D = \frac{1}{2} I_{DSS}$$

$$v_{GS} = 0.3(-8V) \mid i_D = \frac{1}{2}(8mA)$$

$$v_{GS} = -2.4V \mid i_D = 4mA$$

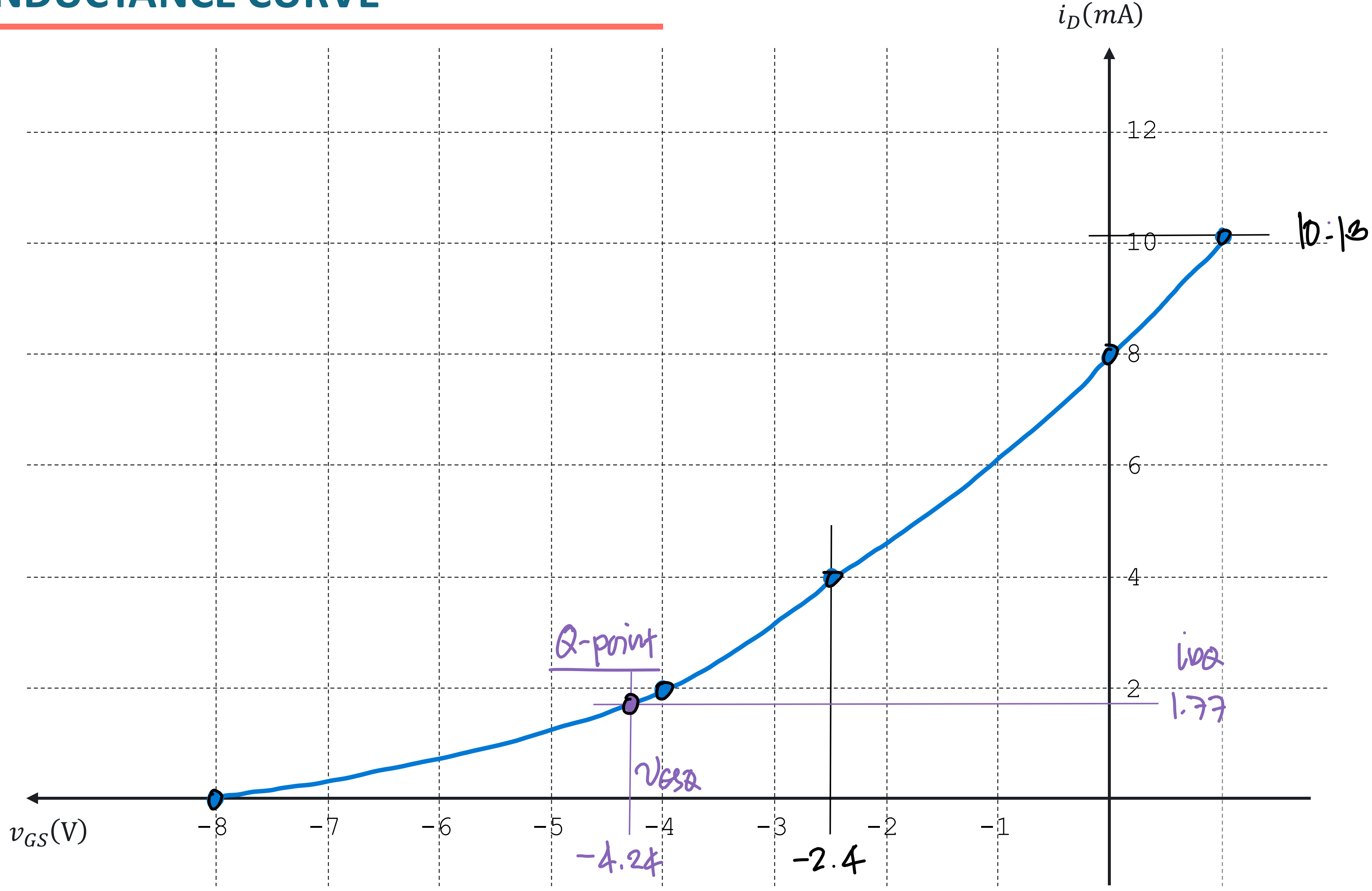
for $v_{GS} = 1V$

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

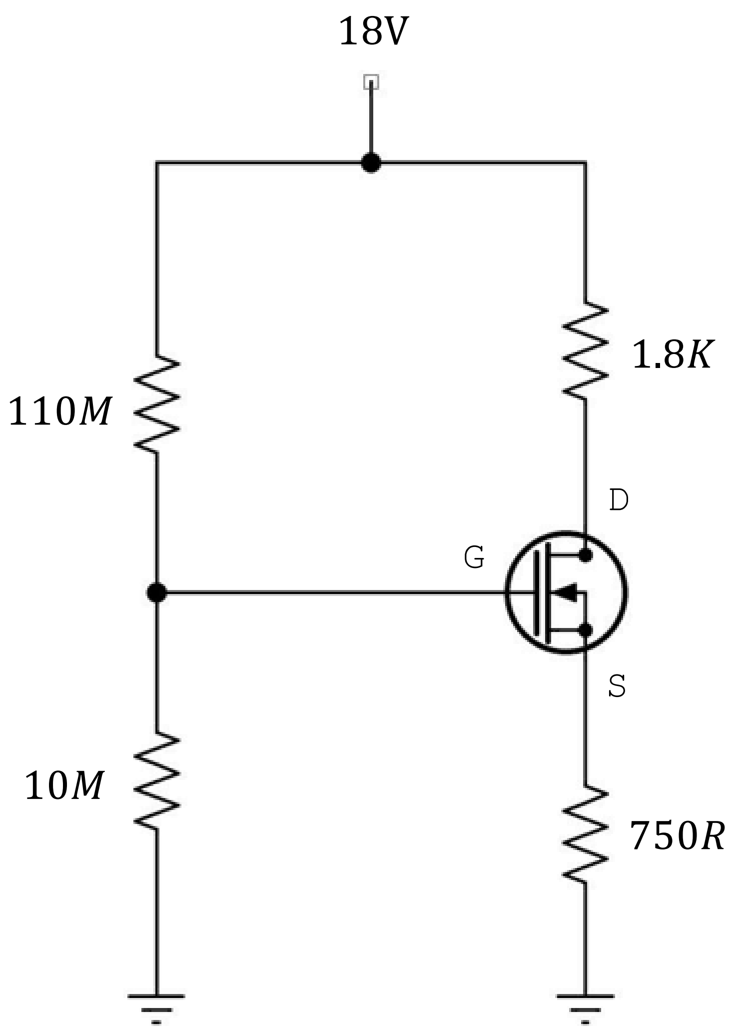
$$i_D = 8m\left(1 - \frac{1}{-8}\right)^2$$

$$i_D = 10.13\ mA$$

TRANSCONDUCTANCE CURVE



EXERCISE



$I_{DSS} = 6\ mA$

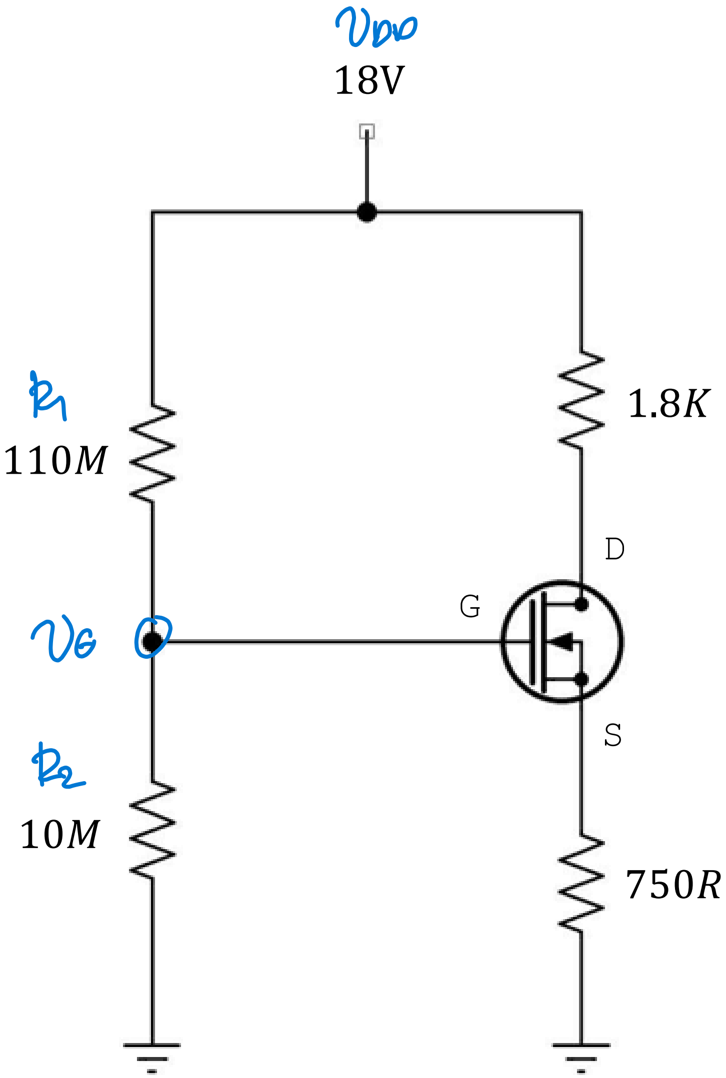
$V_P = -3$V

For the given network, determine the following:

- Gate-source voltage $\left(v_{GSQ}\right)$
- Drain current $\left(i_{DQ}\right)$
- Drain voltage (v_D)

and sketch the transconductance curve.

EXERCISE



$I_{DSS} = 6\ mA$

$V_P = -3V$

Solution

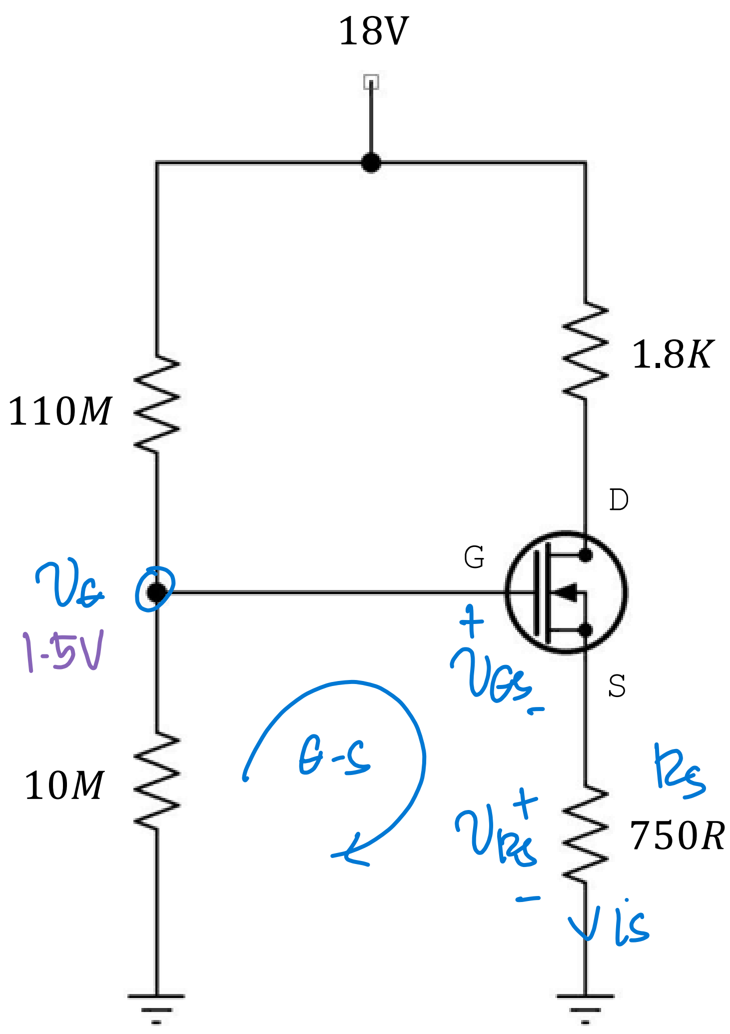
by VDT

$$V_G = V_{DD} \frac{R_2}{R_1 + R_2}$$

$$V_G = 18 \frac{10M}{110M + 10M}$$

$$V_G = 1.5V$$

EXERCISE



$I_{DSS} = 6\ mA$

$V_P = -3V$

Solution

KVL @ G-S

$$-V_G + V_{GS} + V_{RS} = 0$$

$$V_{GS} = V_G - V_{RS}$$

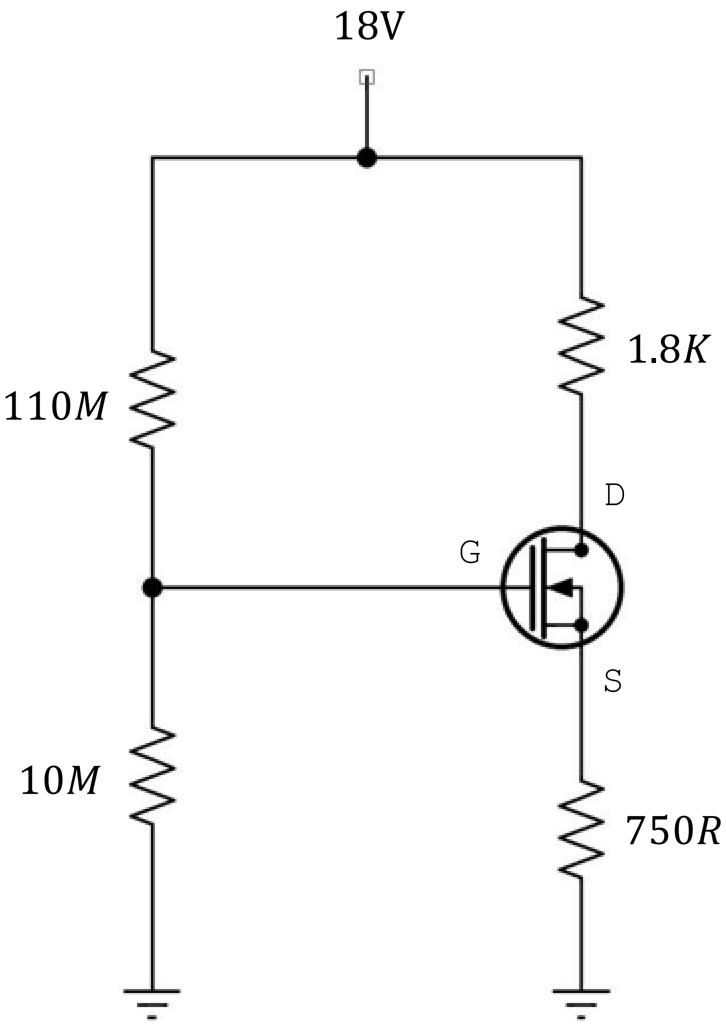
$$V_{GS} = V_G - \cancel{i_s}^{\,i_D} R_S$$

$$V_{GS} = V_G - i_D R_S$$

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

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

EXERCISE



$I_{DSS} = 6\ mA$

$V_P = -3\text{V}$

Solution

$$V_{GS} = 1.5 - (6m \cdot 750)\left[1 - \frac{2V_{GS}}{-3} + \frac{V_{GS}^2}{(-3)^2}\right]$$

$$V_{GS} = 1.5 - 4.5\left(1 + \frac{2}{3}V_{GS} + \frac{1}{9}V_{GS}^2\right)$$

$$\cancel{V_{GS}}\ 0 = 1.5 - 4.5 - 3V_{GS} - 0.5V_{GS}^2$$

$$-V_{GS} \qquad\qquad -V_{GS}$$

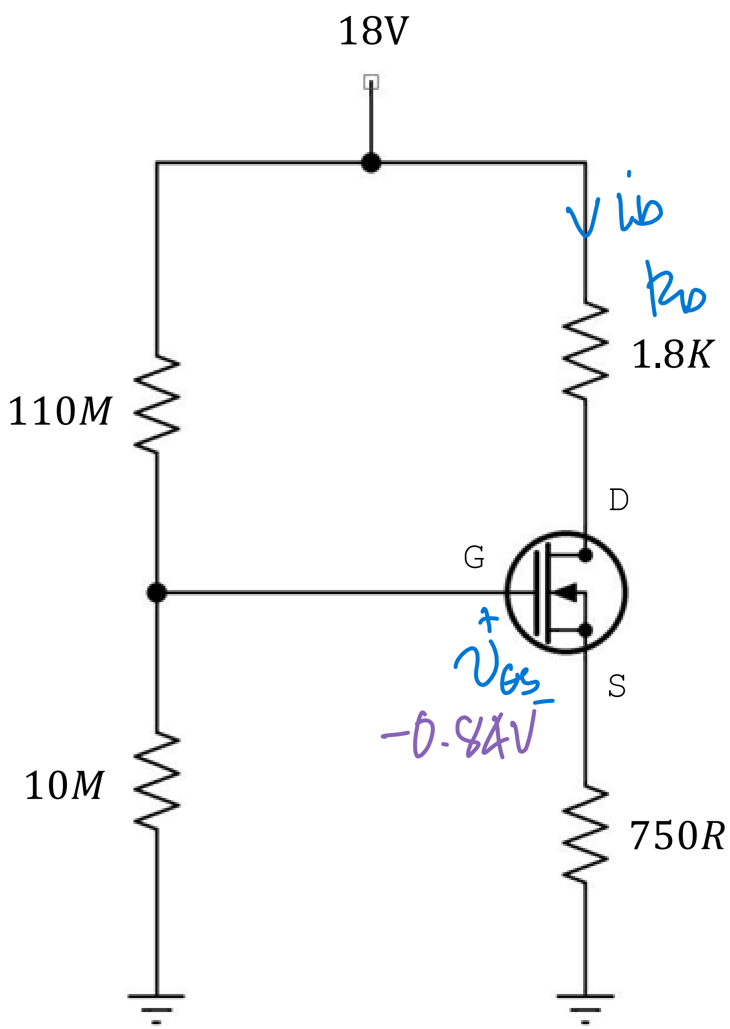
$$0 = -3 - 4V_{GS} - 0.5V_{GS}^2$$

$$V_{GS} = -7.16\text{V}$$

$$\boxed{V_{GSQ} = -0.84\text{V}}$$

ans

EXERCISE



$I_{DSS} = 6\ mA$

$V_P = -3V$

Solution

Shockley's Equation

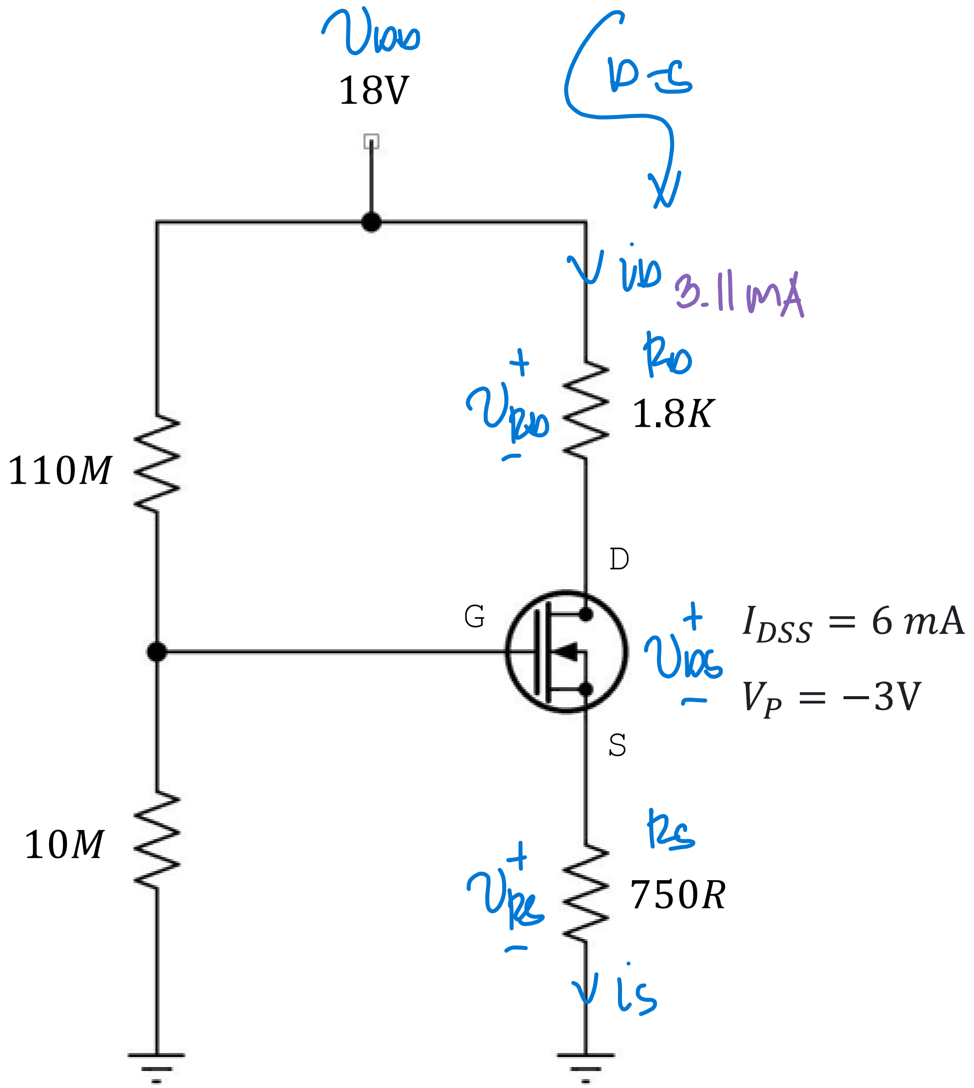
$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$i_D = 6m\left(1 - \frac{-0.84}{-3}\right)^2$$

$$\boxed{i_{DQ} = 3.11\ mA}$$

ans

EXERCISE



Solution

KVL @ D-S

$$-V_{DD} + V_{RD} + V_{DS} + V_{RS} = 0$$

$$V_{DS} = V_{DD} - V_{RD} - V_{RS}$$

$$V_{DS} = V_{DD} - i_D R_D - \cancel{i_S}\, R_S \quad i_D$$

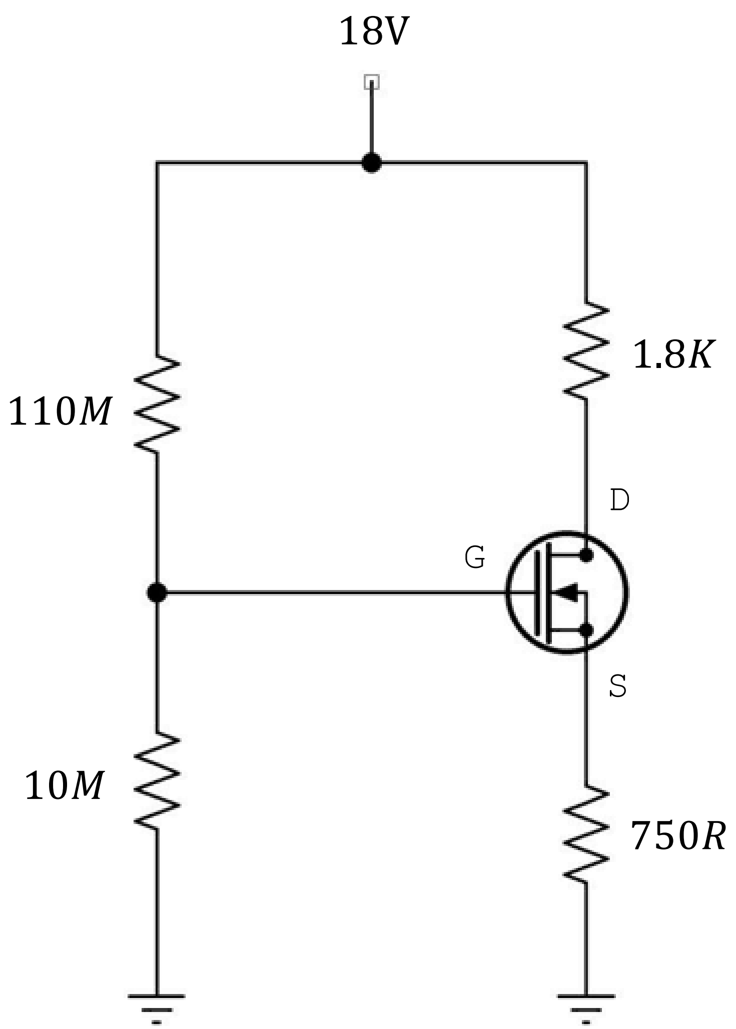
$$V_{DS} = V_{DD} - i_D(R_D + R_S)$$

$$V_{DS} = 18 - 3.11m(1.8K + 750)$$

$$\boxed{V_{DS} = 10.07V}$$

ans

EXERCISE



$I_{DSS} = 6\ mA$

$V_P = -3\text{V}$

Solution

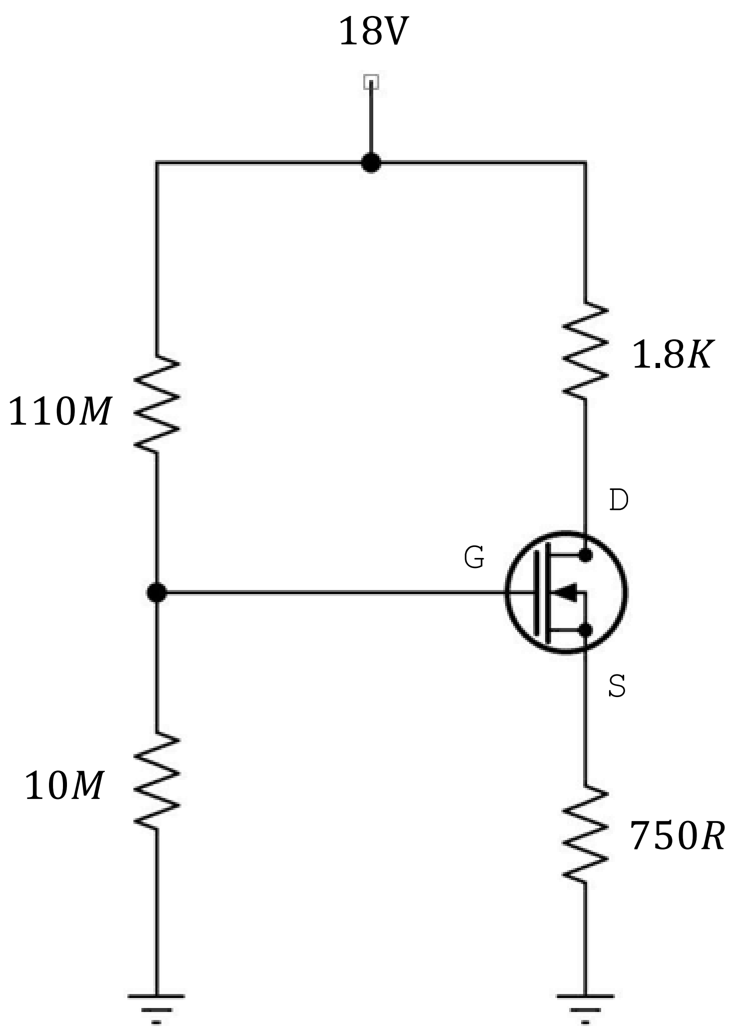
Transconductance Curve

$i_D = \frac{1}{4} I_{DSS} \Big|_{v_{GS} = \frac{1}{2} V_P}$

$i_D = \frac{1}{4}(6mA) \Big|_{v_{GS} = \frac{1}{2}(-3V)}$

$i_D = 3mA \Big|_{v_{GS} = -1.5V}$

EXERCISE



$I_{DSS} = 6\ mA$

$V_P = -3V$

Solution

$V_{GS} = 0.3V_P \mid i_D = \frac{1}{2} I_{DSS}$

$V_{GS} = 0.3(-3V) \mid i_D = \frac{1}{2}(6\,mA)$

$V_{GS} = -0.9V \mid i_D = 3\,mA$

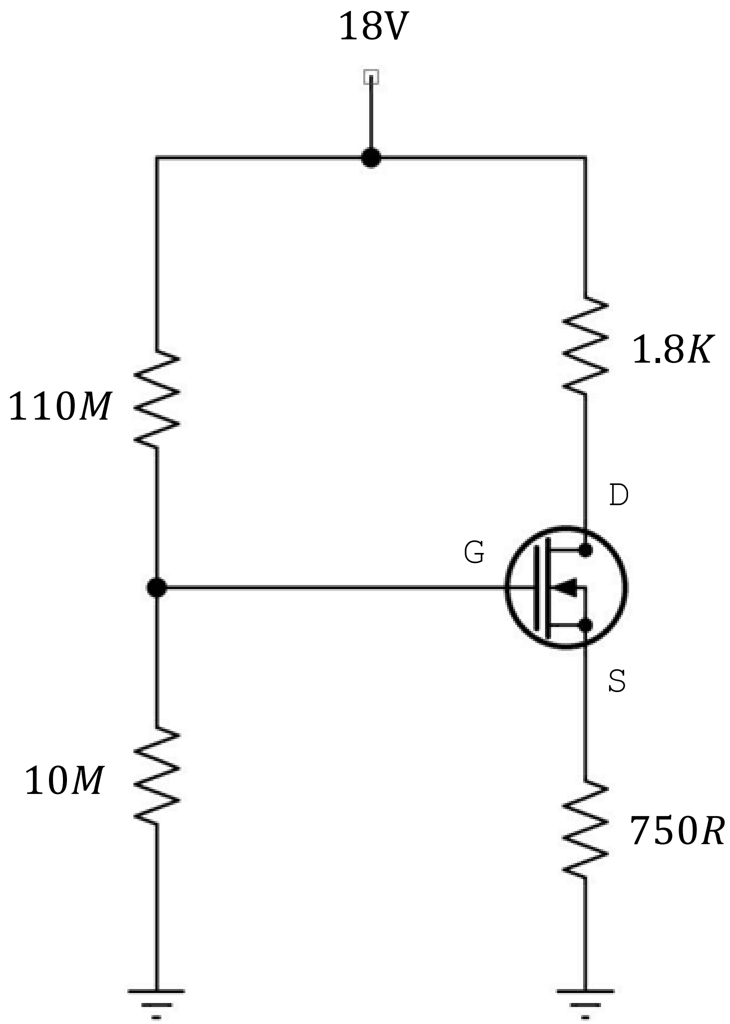
for $V_{GS} = 1V$

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

$$i_D = 6m\left(1 - \frac{1}{-3}\right)^2$$

$$i_D = 10.67\,mA$$

EXERCISE

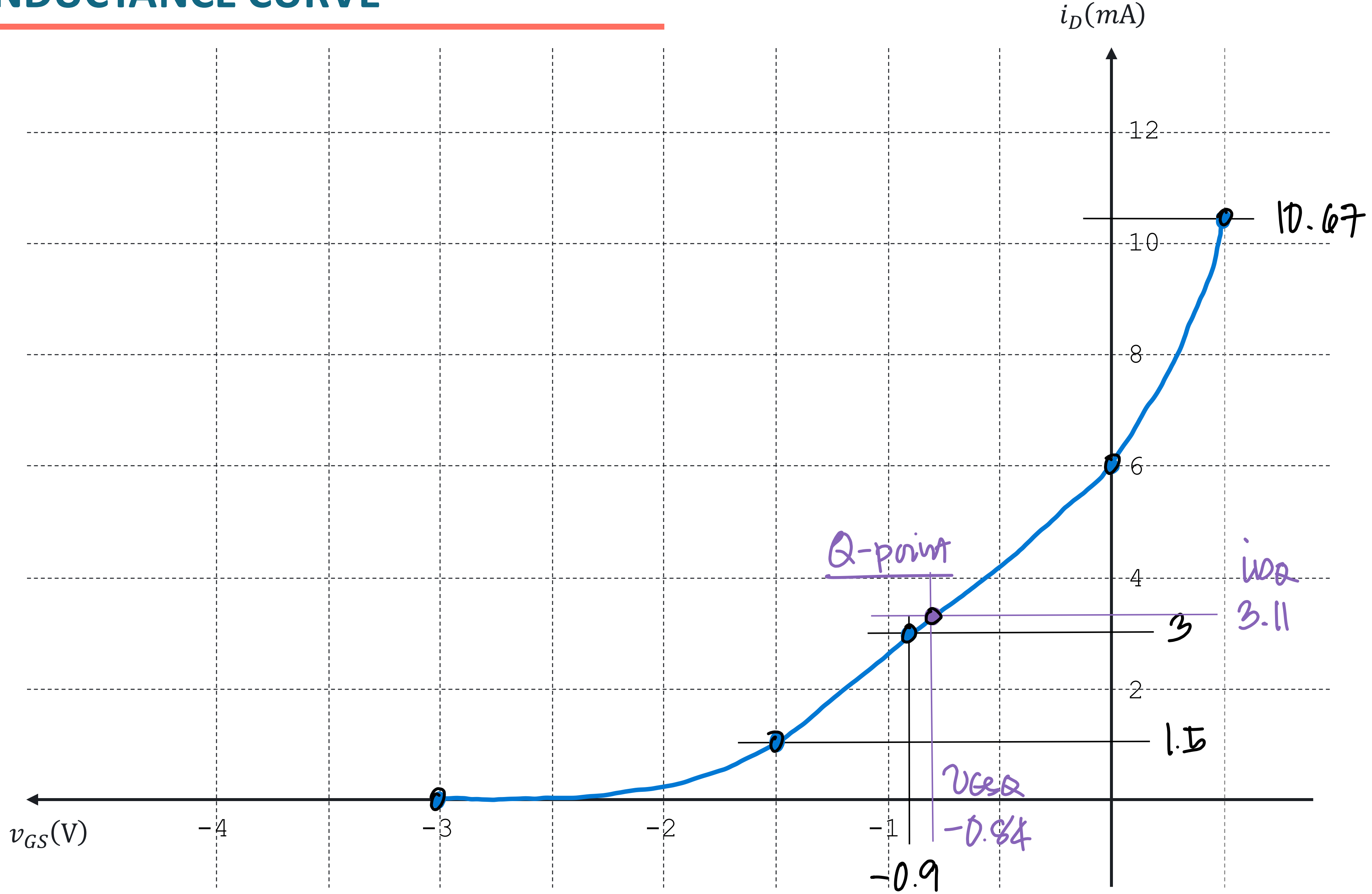


$I_{DSS} = 6\ mA$

$V_P = -3V$

Solution

TRANSCONDUCTANCE CURVE



LABORATORY