Problems on MOSFET

Ex-1. For the circuit shown, find I_D and V_{DS}

Assume, $V_{th} = 1\,V$,

(i) $k_n'\left(\frac{W}{L}\right) = \cancel{0.5\,mA/V^2}$
$= 0.5\,mA/V^2$

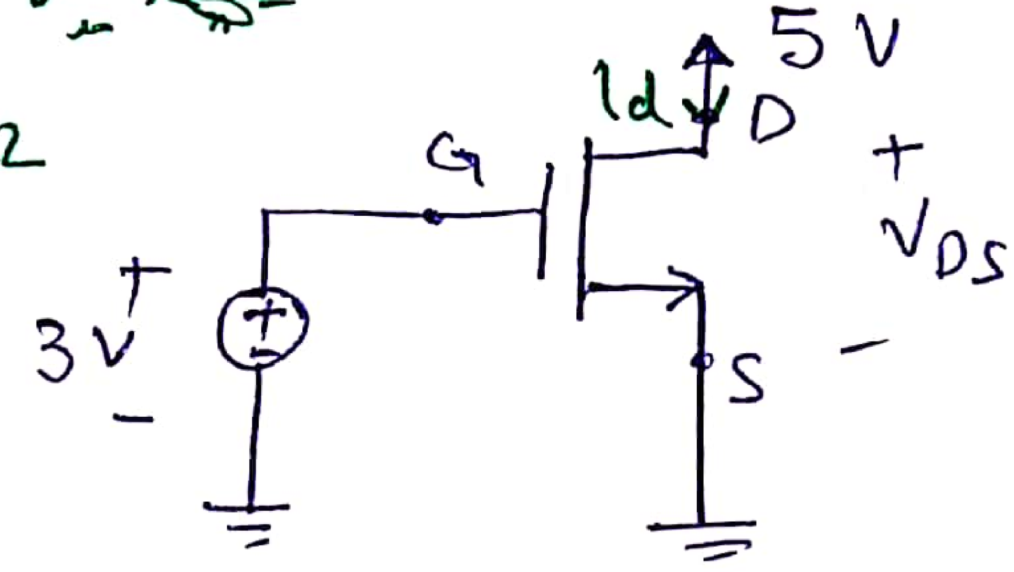


Fig-(a)

Soln

For the circuit in fig (a), $V_{GS} = 3\,V$, $V_{DS} = 5\,V$

Clearly $V_{GS} > V_{th} \Rightarrow$ NMOS is ON

$V_{ov} = V_{GS} - V_{th} = 3 - 1 = 2$

Since, $V_{DS} \geq (V_{GS} - V_t) \Rightarrow$ NMOS operating in Saturation

$\therefore\ I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_{th})^2$

$= \frac{1}{2} \times 0.5 \times 2^2 = 1\,mA$

(ii)

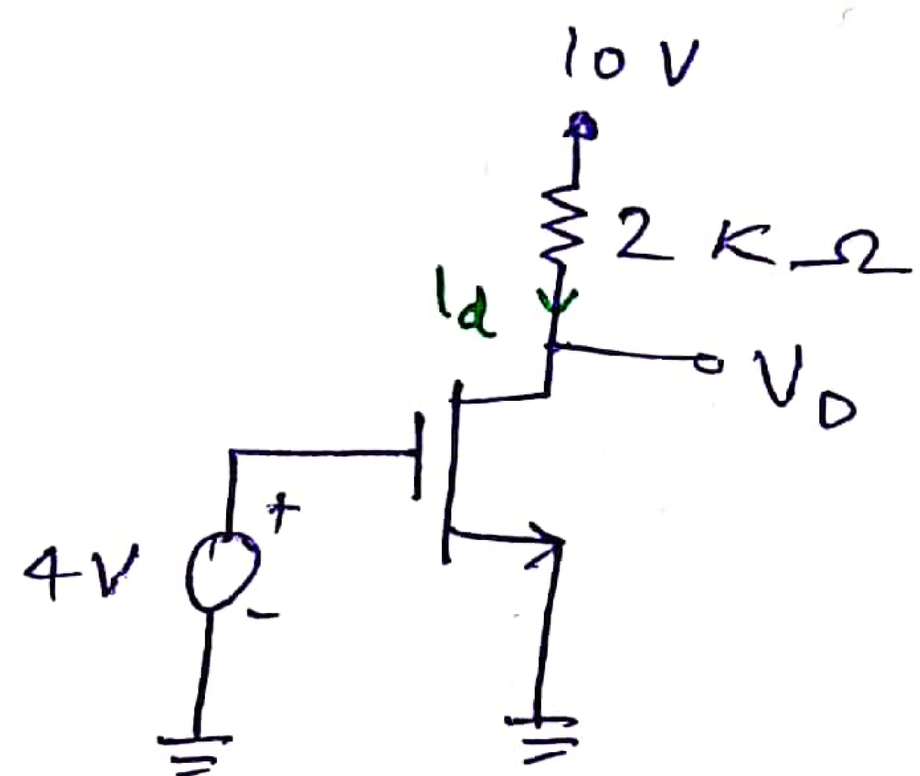


fig-(b)

In the fig. (b) $V_{GS} = 4\,V$, $V_{DS} = ?$

Since $V_{GS} \geq V_t \Rightarrow$ NMOS is ON,

but it is not clear that whether it is in saturation or triode, since V_{DS} is unknown, it depends on I_D

so let us assume that it is operating in saturation,

$$\Rightarrow \quad I_d = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \times 0.5 \times (4-1)^2 = \underline{2.25 \text{ mA}}$$

then $V_D = 10 - 2 \times 2.25$

$$= 10 - 4.5 = 5.5 \text{ V}$$

Verify the region of op.

$$V_{DS} = 5.5 \text{ V}$$

$$V_{GS} - V_{th} = 4 - 1 = 3 \text{ V}$$

Clearly $V_{DS} > V_{GS} - V_{th} \Rightarrow$ Saturation

$\Rightarrow$ Assumption is correct

$$\Rightarrow \boxed{I_d = 2.25 \text{ mA}, \quad V_{DS} = 5.5 \text{ V}}$$

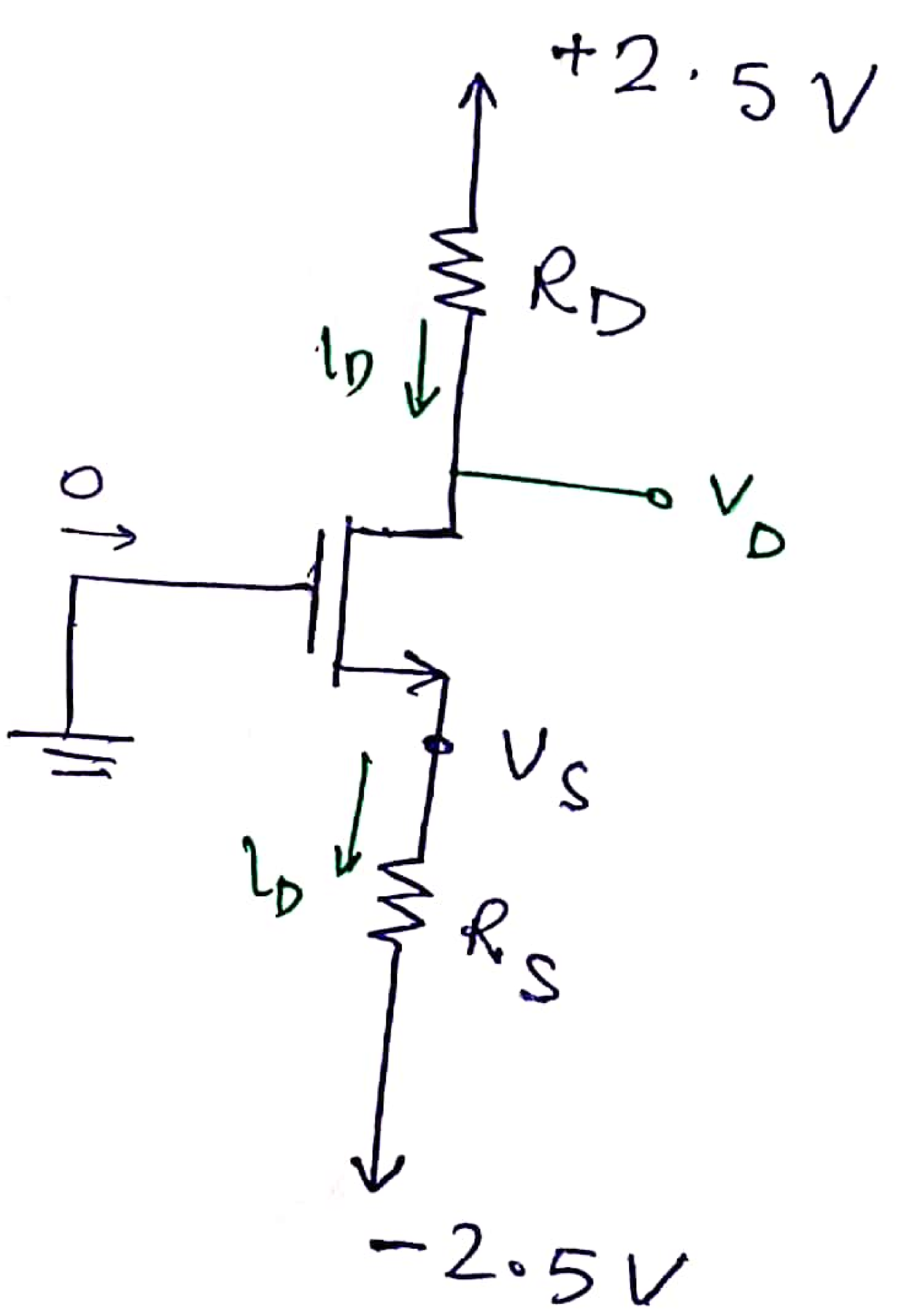
Ex-2 Determine the value of R_D & R_S, so that the transistor operates at $I_D = 0.4$ mA and $V_D = 0.5$V.

Assume $V_{th} = 0.7$ V, $\mu_n C_{ox} = 100 \mu A/V^2$, $L = 1 \mu A$

$W = 32 \mu m$

Sol

[Since $I_G = 0$ (always)
Same I_D flow in D and S]



In the upper part,

$$I_D = 0.4 \text{ mA}, \quad V_D = 0.5 \text{ V}$$

$$2.5 - I_D R_D = V_D$$

$$R_D = \frac{2.5 - 0.5}{0.4} = \underline{5 \text{ k}\Omega}$$

Assuming Source voltage, V_S

$$V_{GS} = 0 - V_S = -V_S$$

It is also clear that $V_D > V_G \Rightarrow V_{DS} > V_{GS} - V_t$

$\Rightarrow$ Saturation Region

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

$$400 = \frac{1}{2} \times 100 \times \frac{32}{1} (V_{GS} - V_t)^2$$

$$(V_{GS} - V_t) = 0.5 \text{ V}$$

$$V_{GS} = 0.5 + V_t = 0.5 + 0.7 = 1.2 \text{ V}$$

$\because V_{GS} = -V_S \Rightarrow \boxed{V_S = -1.2 \text{ V}}$

Now in the lower part of the circuit, using KVL,

$$V_S - I_D R_S = -2.5 \text{ V}$$

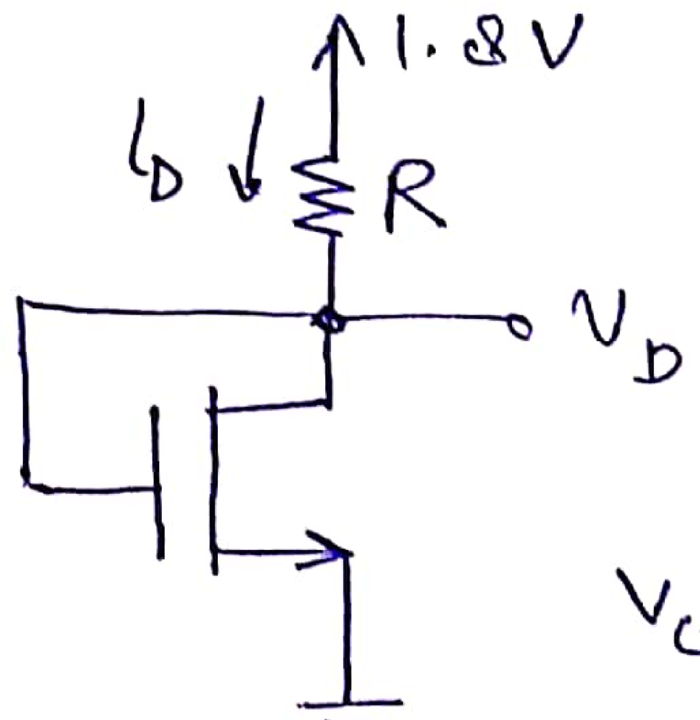
$$R_S = \frac{V_S + 2.5}{I_D} = \frac{-1.2 + 2.5}{0.4} = \underline{\underline{3.25 \text{ k}\Omega}}$$

Ex-3 Design the circuit to obtain a $V_D = 0.8$V

Assume $V_{th} = 0.5$V, $\mu_n C_{ox} = 0.4 \text{ mA/V}^2$, $W/L = \frac{0.72 \ \mu m}{0.18 \ \mu m}$

We need to find R so that $V_D = 0.8$ V

$$I_D = \frac{1.8 - 0.8}{R} = \frac{1}{R} \quad \text{—(1)}$$



In this circuit,

$V_D = V_G$.

$\because$ Always $V_{DS} \geq V_{GS} - V_t$

$\therefore$ Transistor will always operate in Saturation.

$V_{GS} = V_{DS} = 0.8$ V

$$I_D = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right) (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \times 0.4 \times \frac{0.72}{0.18} (0.8 - 0.5)^2 = 0.072 \text{ mA}$$

From (1)

But $R = \frac{1}{I_D} = \frac{1}{0.072} \text{ k}\Omega = \underline{13.88 \text{ k}\Omega}$