Assignment 3
CSE251

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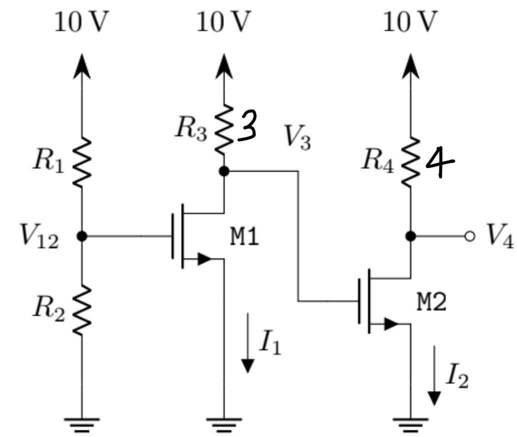
CSE 251: Electronic Devices and Circuits

1.



Relevant information for the circuit configuration on the right is given in the tables below:

Resistor values in (**kΩ**)

R_1	R_2	R_3	R_4
4	6	3	4

Transistor Parameters

$k_n = 2\,\text{mA/V}^2$
$V_T = 1\,\textbf{V}$

a) Explain, in short, which of the two models (S and SR) of MOSFET is a better approximation? [1]

b) Determine the value of V_{12}. [1]

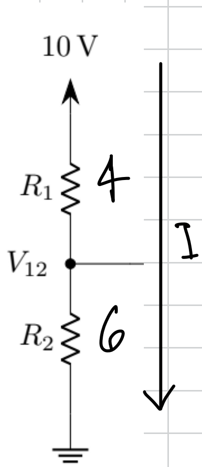
c) Calculate the value of drain-to-source voltage of the transistor $M1$. In the process, determine the operating mode of $M1$. [3]

d) Determine which one of the four resistors will consume the least amount of power. [Hint, Power = I^2R] [3]

e) Determine how the operating mode of $M2$ would change if R_2 were set to zero. [2]

(a) The SR-model of is generally a better approximation for compared to the S model. This is because the model includes more detailed effects like the body effect and velocity saturation, making it more accurate in representing real-world MOSFET characteristics.

(b)



In M1, $I_G = 0$

$\therefore 10 - 0 = 4I + 6I$

$\Rightarrow 10I = 10$

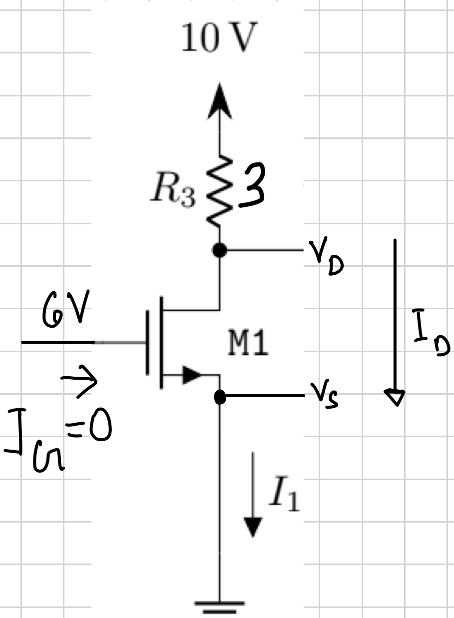
$\Rightarrow I = 1\,mA$

$\therefore \frac{V_{12} - 0}{6k} = 1\,mA$

$\Rightarrow V_{12} = 6V$

(Ans)

(c)



$$V_{GS} = V_G - V_S = 6 - 0 = 6V$$

$$V_{OV} = V_{GS} - V_T = 6 - 1 = 5V$$

As $V_{GS} \geq V_T$, So, M_1 would be in triode or saturation mode.

Let's assume that the operating mode is saturation.

$\therefore I_D = \frac{K_n}{2} \times V_{ov}^2$

$= \frac{\cancel{2}}{\cancel{2}} \times 5^2$

$= 25\, mA$

Again,

$\frac{10 - V_D}{3} = I_D$

$\Rightarrow 10 - V_D = 3 \times 25$

$\Rightarrow 10 - V_D = 75$

$\Rightarrow V_D = 10 - 75 = -65$

$\Rightarrow V_D = -65\, V$

$\therefore V_{DS} = V_D - V_S$

$= -65 - 0$

$= -65\, V$

$V_{GS} > V_T$

$V_{DS} > V_{ov}$

$\therefore V_{GS} > V_T$ but

$\boxed{V_{DS} = -65 \not> V_{ov} = 5\, V}$

$\therefore$ Assumption wrong.

Let's assume that the operating mode is triode,

$$I_D = K_n\left[V_{ov} V_{DS} - \frac{1}{2} V_{DS}^2\right]$$

$$\Rightarrow \frac{10-V_D}{3} = 2\left[5 V_D - \frac{1}{2} V_D^2\right]$$

$$\Rightarrow \frac{10-V_D}{3} = 10 V_D - V_D^2$$

$$\Rightarrow 10 - V_D = 30 V_D - 3 V_D^2$$

$$\Rightarrow 3V_D^2 - 31 V_D + 10 = 0$$

$\therefore$ $V_D = 10, \frac{1}{3}$

$\therefore$ $V_D \neq 10$ as the voltage drop would be 0.

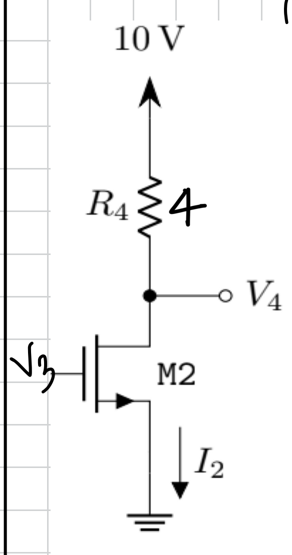
$\therefore$ $V_D = \frac{1}{3}$

$\therefore$ $V_{DS} < V_{ov}$

$\therefore$ So, the assumption is true. M_1 is in triode mode.

(Ans)

(d)



In M_2,

$$V_3 = \frac{1}{3} = 0.33$$

$$\Rightarrow V_3 < V_T$$

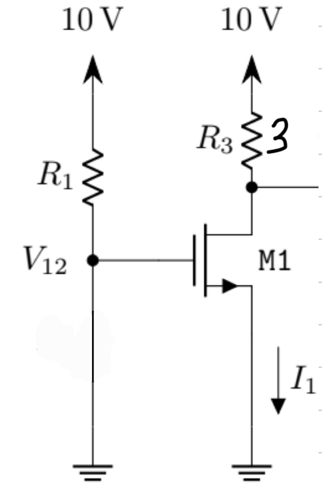
So, the M2 will remain off.

There will be no current flow.

$\therefore$ R4 will consume least power.

(Ans)

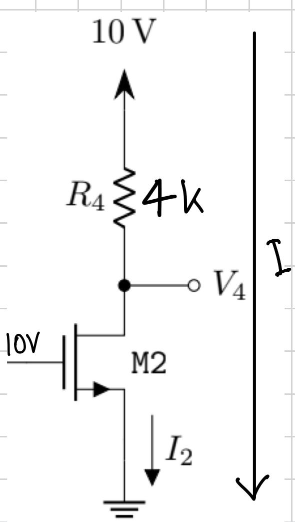
(e)



When $R2 = 0$,

the M1 MOSFET is in the cutoff mode, because $V_{GS} < V_T$

So, the gate voltage for M2 is $V_G = 10V$,



Let's assume that
M_2 is in Triode mode.

$$\therefore V_{OV} = V_{GS} - V_T$$
$$= V_G - V_S - V_T$$
$$= 10 - 0 - 1$$
$$= 9V$$

$$I_D = K_n\left[V_{OV} V_{DS} - \frac{1}{2} V_{DS}^2\right]$$

$$\Rightarrow \frac{10 - V_D}{4} = 2\left(9V_D - \frac{1}{2} V_D^2\right)$$

$$\Rightarrow \frac{10 - V_D}{4} = 18 V_D - V_D^2$$

$\Rightarrow 10 - V_D = 72 V_D - 4 V_D^2$

$\Rightarrow 4 V_D^2 - 73 V_D + 10 = 0$

$\therefore V_D \neq 18.11$

$V_D = 0.138$

$\therefore V_{DS} = V_D - V_S$

$= 0.138 - 0$

$= 0.138$

$\therefore V_{DS} < V_{ov}$

$\therefore$ Assumption Connect. M2 is in Triode Mode. (Ans)