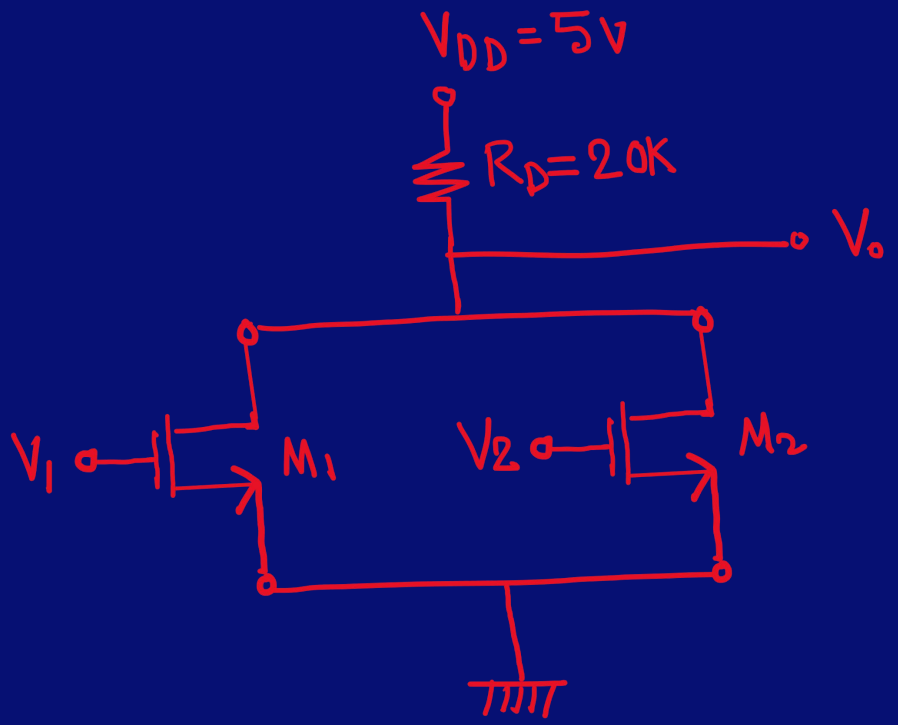
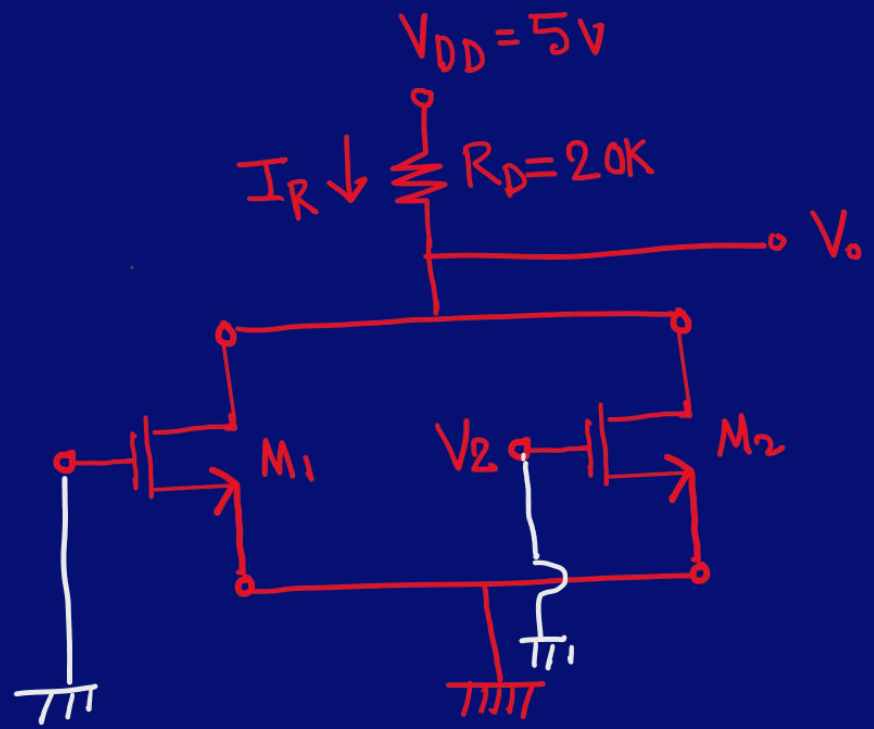
MOSFET NOR GATE

$K_n = 0.1\,mA/V^2$, $V_{TN} = 0.8V$ for both Mosfets (M_1 & M_2)

Find V_o for the following conditions



	V_1	V_2	V_o
1.	0V	0V	5V
2.	0V	5V	0.29V
3	5V	0V	0.29V
4.	5V	5V	0.15V



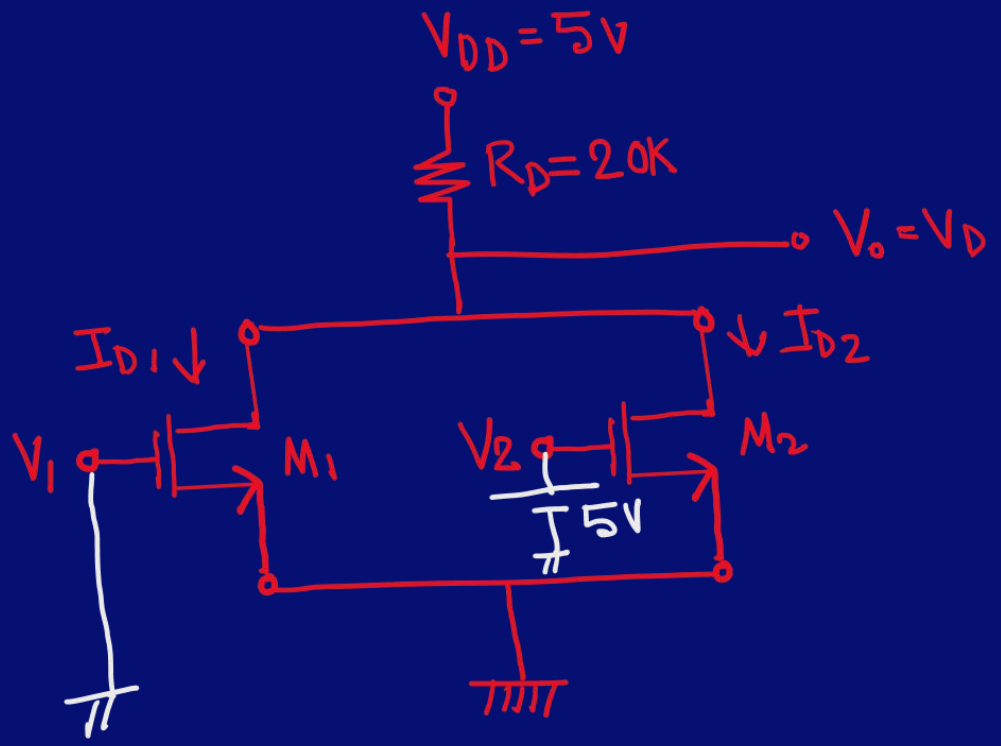
1. $V_1 = V_2 = 0V$

Checking V_{GS}: $V_1 - 0 = 0 < V_{TN}$ [No ch. Ind.]

Cut-off Region

$I_{D_1} = 0$, $I_{D_2} = 0$ $\therefore$ $I_R = I_{D_1} + I_{D_2} = 0$

$V_o = V_{DD} - I_R R_D = V_{DD} = 5V$



Here,

$V_{DS}=V_D-V_S=V_D=V_o$

2. $V_1=0V$ & $V_2=5V$

M_1 : $V_{GS}=0<V_{TN}$ [No ch. Ind.]

Cut-off. $I_{D_1}=0$

M_2 : $V_{GS}=V_G-V_S=V_2-V_S=5-0>V_{TN}$ [Ch. Ind.]

Triode Region

$$I_{D_2}=k_n\left[2(V_{GS}-V_{TN})V_{DS}-V_{DS}^2\right]$$

$$I_R=\frac{V_{DD}-V_D}{R_D}=I_{D1}+I_{D_2}=0+I_{D_2}$$

$$\Rightarrow \frac{5-V_o}{20} = 0.1\left[2(5-0.8)V_o - V_o^2\right]$$

$$\Rightarrow 5-V_o = 2\left[8.4V_o - V_o^2\right]$$

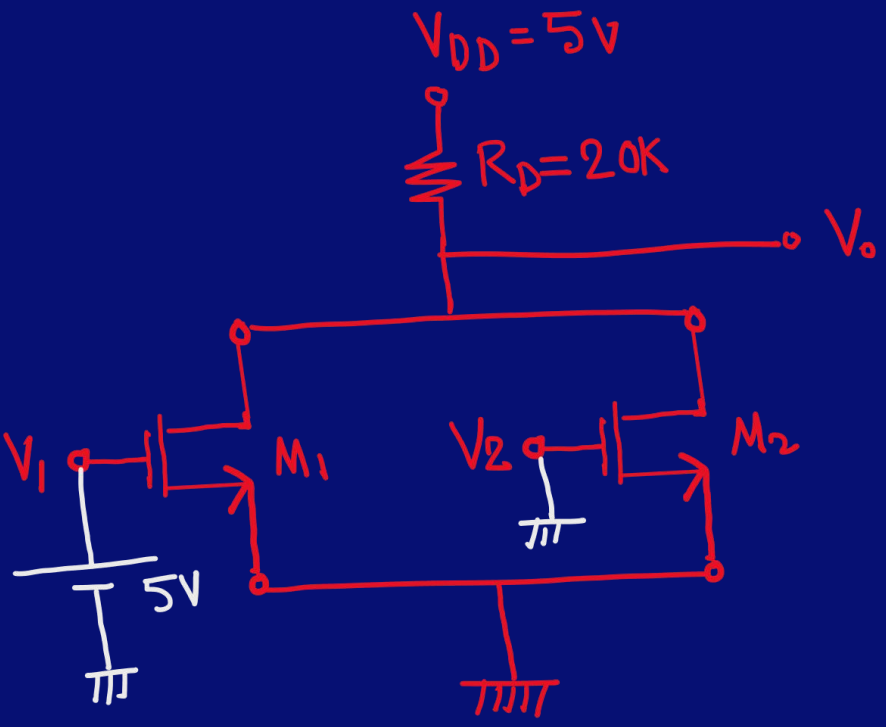
$$\Rightarrow 5-V_o = 16.8V_o - 2V_o^2$$

$$\Rightarrow 2V_o^2 - 17.8V_o + 5 = 0$$

$V_o = 8.6V$, $0.29V$ → Valid

↙ NOT possible

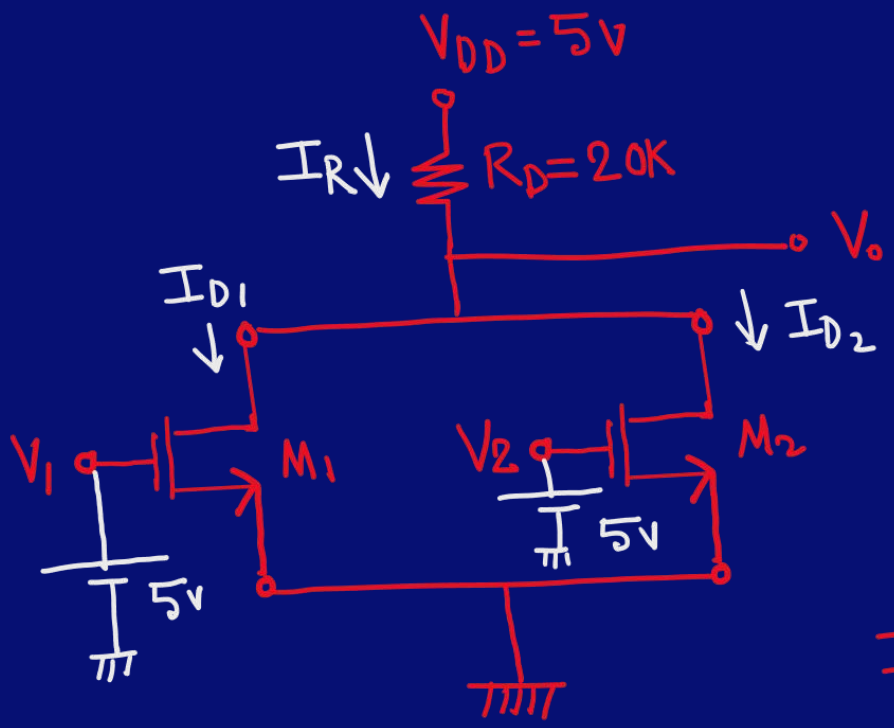
$$V_o = 0.29V$$



3. Same as (2).

$V_1 = 5V$, $V_2 = 0V$

$V_o = 0.29V$



4. $V_1 = V_2 = 5V$

By checking V_{GS}, Both Mosfels (M_1 & M_2), $V_{GS} > V_{TN}$ [Ch. Ind.]

$$I_R = I_{D1} + I_{D2}$$

$$I_R = \frac{V_{DD} - V_D}{R_D} = I_{D1} + I_{D2}$$

$$=$$

$$\frac{V_{DD} - V_D}{R_D} = k_n \left[2(V_{GS} - V_{TN}) V_{DS} - V_{DS}^2 \right] + k_n \left[2(V_{GS} - V_{TN}) V_{DS} - V_{DS}^2 \right]$$

$$\frac{5 - V_o}{20} = 0.1 \left[2(5 - 0.8) V_o - V_o^2 \right] + 0.1 \left[2(5 - 0.8) V_o - V_o^2 \right]$$

$$\frac{5-V_o}{20} = 0.2\left[2(5-0.8)V_o - V_o^2\right]$$

$$\Rightarrow \quad 5-V_o = 4\left[8.4V_o - V_o^2\right]$$

$$\Rightarrow \quad 4V_o^2 - 33.6V_o + 5 = 0$$

$$V_o = 8.248\text{V},\ 0.15\text{V} \rightarrow \text{Valid}$$

8.248V → Not acceptable