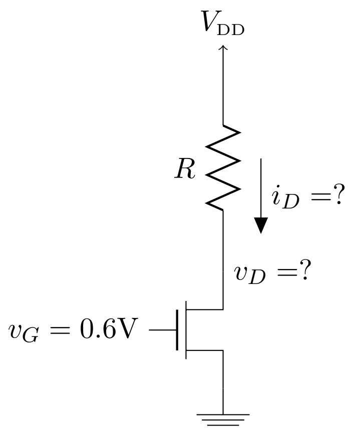
For all problems in this set, assume $V_{DD} = 5V$. You are allowed to use SPICE to check your answers (in fact it is encouraged), however you must also show that you can get the answer through manual analysis. Here is an example SPICE file for a simple MOSFET circuit:

```
* Example SPICE simulation for homework problems

* Generic MOSFET models:
.model nmos nmos (level=2 KP=250u VT0=0.5 lambda=0.01)
.model pmos pmos (level=2 KP=75u VT0=-0.75 lambda=0.01)

* Nodes:
* 1  -- VDD
* 2  -- Drain of NMOS
* 3  -- Gate of NMOS

VDD 1 0 DC 5V
VG 3 0 DC 0.6V
R1 1 2 1k

* MOSFET statement: MX Drain Gate Source Substrate ModelName
M1 2 3 0 0 nmos

* Operating point simulation:
.op

.end
```

Also note that SPICE analysis should not be necessary for logic problems.

Problem 1. The MOSFET circuit shown below uses a MOSFET with the indicated characteristics. For each of the cases listed, solve MOSFET's device current and drain voltage, and indicate whether the device is operating in saturation or triode. [**Hint:** To perform this analysis, first assume the device is in saturation, and solve accordingly. Then check for *consistency*. If the result is inconsistent, then repeat the analysis using the triode equation.]

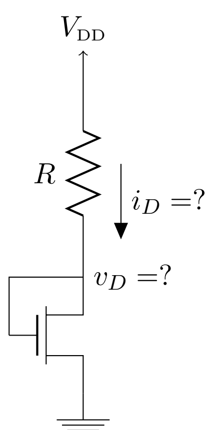


$K_n = 250\mu\mathrm{A}/\ \mathrm{V}^2$

$V_{\mathrm{ThN}} = 0.5\mathrm{V}$

(A) $R = 100\Omega$
(B) $R = 1\mathrm{k}\Omega$
(C) $R = 10\mathrm{k}\Omega$

Problem 2. The MOSFET circuit shown below uses a MOSFET with the indicated characteristics. For each of the cases listed, solve MOSFET's device current and drain voltage, and indicate whether the device is operating in saturation or triode.

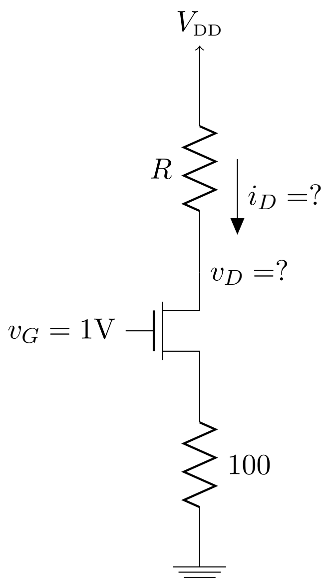


$K_n = 250\mu\mathrm{A}/\ \mathrm{V}^2$

$V_{\mathrm{ThN}} = 0.5\mathrm{V}$

(A) $R = 100\Omega$
(B) $R = 1\mathrm{k}\Omega$
(C) $R = 10\mathrm{k}\Omega$

Problem 3. The MOSFET circuit shown below uses a MOSFET with the indicated characteristics. For each of the cases listed, solve MOSFET's device current and drain voltage, and indicate whether the device is operating in saturation or triode.



$K_n = 250\mu\text{A}/\ \text{V}^2$

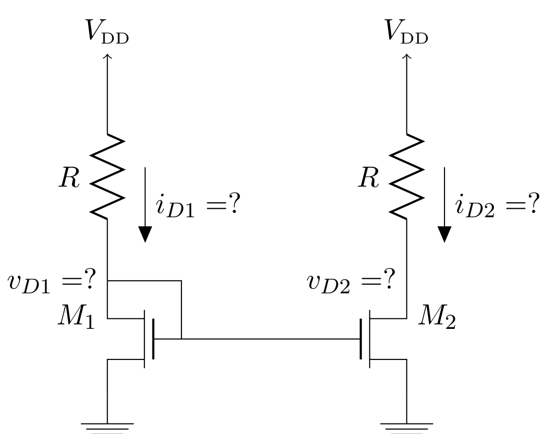
$V_{\text{ThN}} = 0.5\text{V}$

(A) $R = 100\Omega$

(B) $R = 1\text{k}\Omega$

(C) $R = 10\text{k}\Omega$

Problem 4. The MOSFET circuit shown below uses a pair of identical MOSFETs with the indicated characteristics. For each of the cases listed, solve MOSFETs' device currents and drain voltages, and indicate whether each device is operating in saturation or triode.



$K_n = 250\mu\text{A}/\ \text{V}^2$

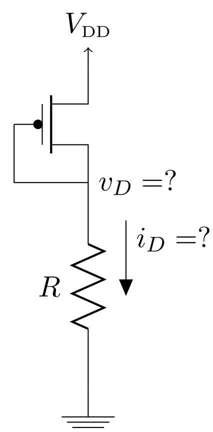
$V_{\text{ThN}} = 0.5\text{V}$

(A) $R = 100\Omega$

(B) $R = 1\text{k}\Omega$

(C) $R = 10\text{k}\Omega$

Problem 5. The MOSFET circuit shown below uses a MOSFET with the indicated characteristics. For each of the cases listed, solve MOSFET's device current and drain voltage, and indicate whether the device is operating in saturation or triode.



$K_p = 75\mu\text{A}/\text{ V}^2$

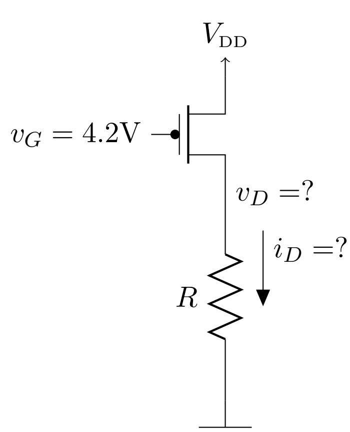
$V_{\text{ThN}} = 0.75\text{V}$

(A) $R = 100\Omega$

(B) $R = 1\text{k}\Omega$

(C) $R = 10\text{k}\Omega$

Problem 6. The MOSFET circuit shown below uses a MOSFET with the indicated characteristics. For each of the cases listed, solve MOSFET's device current and drain voltage, and indicate whether the device is operating in saturation or triode.



$K_p = 75\mu\text{A}/\text{ V}^2$

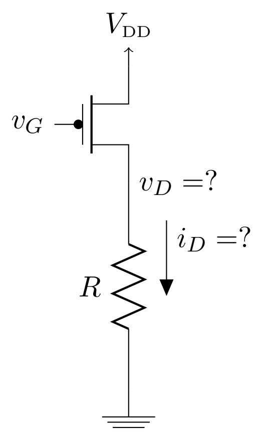
$V_{\text{ThN}} = 0.75\text{V}$

(A) $R = 100\Omega$

(B) $R = 1\text{k}\Omega$

(C) $R = 10\text{k}\Omega$

Problem 7. The MOSFET circuit shown below uses a MOSFET with the indicated characteristics. For each of the cases listed, solve MOSFET's device current and drain voltage, and indicate whether the device is operating in saturation or triode.



$$K_p = 75\mu\text{A}/\ \text{V}^2$$

$$V_{\text{ThN}} = 0.75\text{V}$$

$$R = 1\text{k}\Omega$$

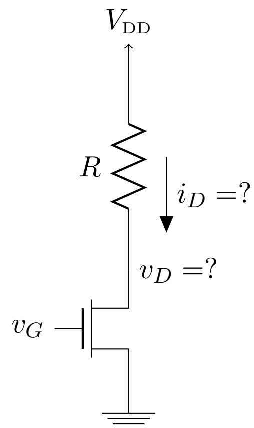
(A) $v_G = 4.5\text{V}$

(B) $v_G = 4.0\text{V}$

(C) $v_G = 3.0\text{V}$

(D) Assuming the device is in *deep triode* (i.e. it is in the *linear region*), solve for the case when $v_G = 0\text{V}$ by approximating the device as a resistor with resistance R_{ON}.

Problem 8. The MOSFET circuit shown below uses a MOSFET with the indicated characteristics. For each of the cases listed, solve MOSFET's device current and drain voltage, and indicate whether the device is operating in saturation or triode. [**Hint:** To perform this analysis, the usual procedure is to assume the device is in saturation, and solve accordingly. Then check for *consistency*. If the result is inconsistent, then you must repeat the analysis using the triode equation.]



$K_n = 250\mu\text{A}/\ \text{V}^2$

$V_{\text{ThN}} = 0.5\text{V}$

$R = 1\text{k}\Omega$

(A) $v_G = 0.25\text{V}$

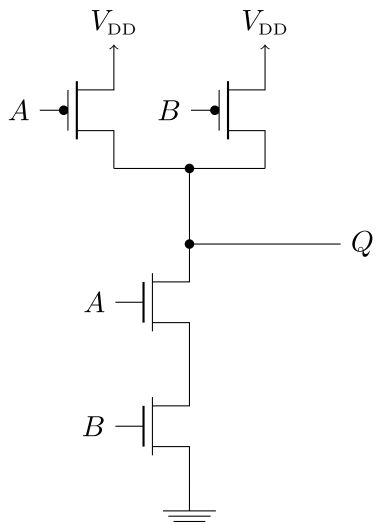
(B) $v_G = 0.74\text{V}$

(C) $v_G = 3\text{V}$

(D) Assuming the device is in *deep triode* (i.e. it is in the *linear region*), solve for the case when $v_G = 5\text{V}$ by approximating the device as a resistor with resistance R_{ON}.

Problem 9. The logic circuits shown below use both NMOS and PMOS devices as switches. Analyze each circuit and complete the truth tables by entering "L" or "H" in each position within the table. From your analysis, state the logic operation implemented by each circuit.

(A)

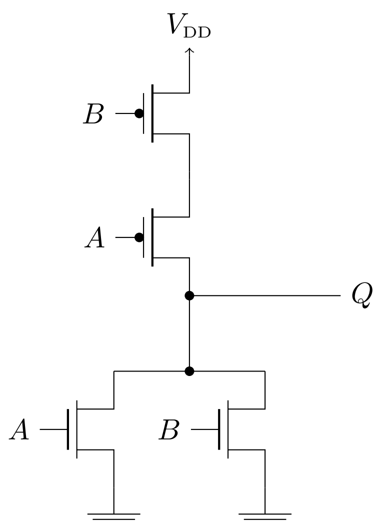


Truth table:

A	B	Q
L	L	
H	L	
L	H	
H	H	

What kind of logic gate is this?

(B)

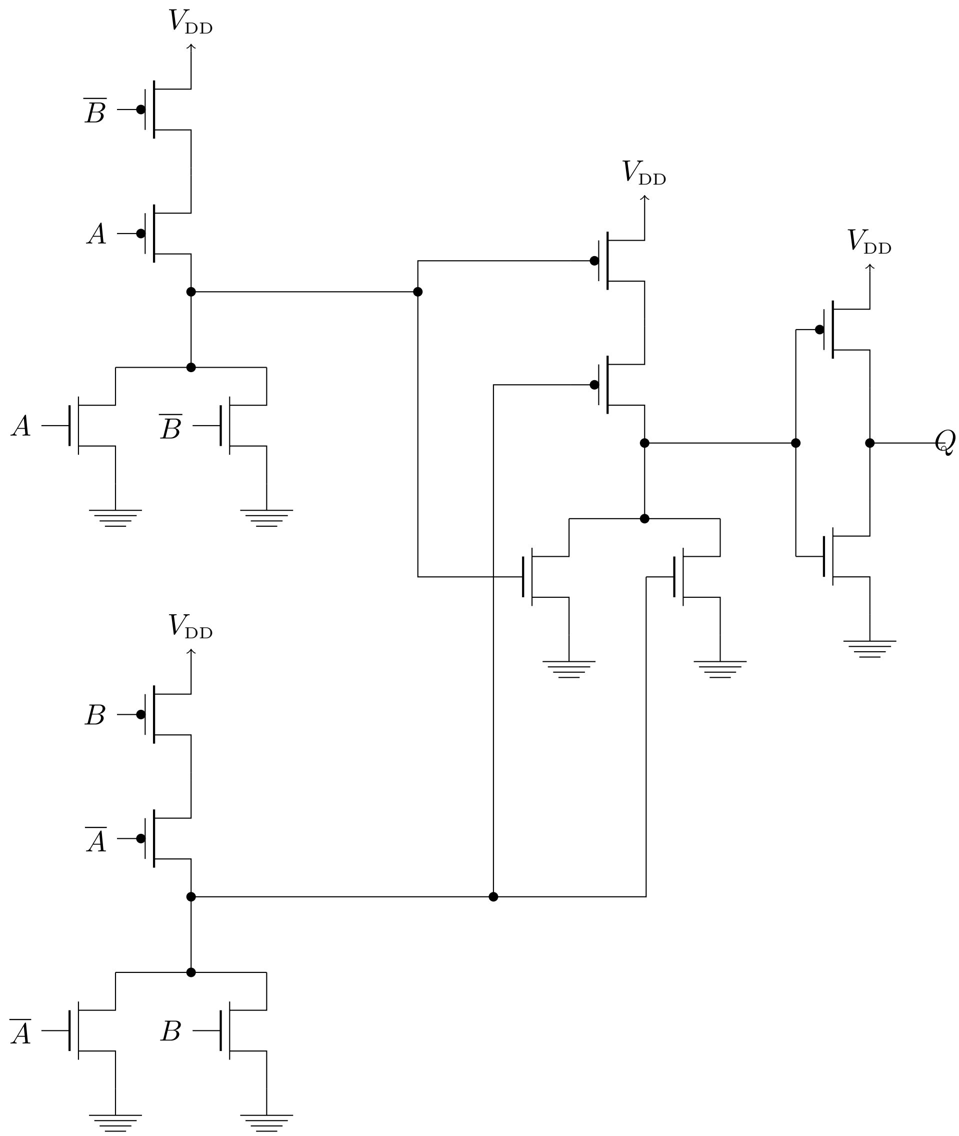


Truth table:

A	B	Q
L	L	
H	L	
L	H	
H	H	

What kind of logic gate is this?

(C) For this circuit, recall that $\overline{A}$ refers to the logical inverse of A, i.e. if $A = H$ then $\overline{A} = L$. For this problem, first identify standard logic gates and then analyze the circuit using traditional logic-gate methods.



Truth table:

A	B	Q
L	L	
H	L	
L	H	
H	H	

What kind of logic gate is this?