HW 6

1) circuit A: $V_D=2$ $V_S=0.5$ $V_G=0.5$ → $V_{GS}=V_G-V_S=0.5-0.5=0$ → $V_{GS}\le 0.7=V_{t0}$ → off

circuit B: $V_D=2$ $V_S=0.5$ $V_G=1.5$ → $V_{GS}=V_G-V_S=1.5-0.5=1$ → $V_{GS}-V_{t0}=1-0.7=0.3$

$V_{DS}=V_D-V_S=2-0.5=1.5$ $V_{GS}>0.7=V_{t0}$ $V_{DS}\ge 0.3=V_{GS}-V_{t0}$ → saturation

circuit C: $V_D=0.5V$ $V_S=0.5$ $V_G=1.5$ $V_{GS}=1.5-0.5=1$, $V_{GS}-V_{t0}=1-0.7=0.3$, $V_{DS}=0.5-0.5=0$

$V_{GS}>V_{t0}$ $V_{DS}<V_{GS}-V_{t0}$ → resistor

circuit D: $V_D=0.5$ $V_S=0$ $V_G=1.5$, $V_{GS}=V_G-V_S=1.5-0=1.5$, $V_{GS}-V_{t0}=1.5-0.7=0.8$, $V_{DS}=0.5-0=0.5$

$V_{DS}<V_{GS}-V_{t0}$, $V_{GS}>V_{t0}$ → resistor

circuit E: $V_D=0.5V$ $V_S=0$ $V_G=1.5$ $V_{GS}=1.5-0=1.5$ $V_{GS}-V_{t0}=0.8$ $V_{DS}=0.5-0=0.5V$

$V_{DS}<V_{GS}-V_{t0}$, $V_{GS}>V_{t0}$ → resistor

circuit F: $V_D=0.5$ $V_S=0$ $V_G=0.5$ $V_{GS}=0.5-0=0.5$ $V_{GS}-V_{t0}=0.5-0.7=-0.2$ $V_{GS}\le V_{t0}$ → off

circuit G: $V_D=0$ $V_S=-0.5$ $V_G=0$ $V_{GS}=0.5V$ $V_{GS}=0-(-0.5)=0.5$ $0.5<0.7$ → off

circuit H: $V_D=0$ $V_S=-1$ $V_G=0$ → $V_{GS}=0-(-1)=1V$ $V_{GS}-V_{t0}=0.3V$ $V_{DS}=0-(-1)=1$, $V_{GS}>V_{t0}$, $V_{DS}\ge V_{GS}-V_{t0}$

$V_{DS}\ge V_{GS}-V_{t0}$ → saturation

circuit I: $V_D=0.5$ $V_S=-0.5$ $V_G=0$ → $V_{GS}=0-(-0.5)=0.5V$ → $V_{GS}\le V_{t0}$ → off

	V_D	V_S	V_G	state
A	2	0.5	0.5	off
B	2	0.5	1.5	sat
C	0.5	0.5	1.5	resis
D	0.5	0.5	1.5	resis
E	0.5	0	1.5	resis
F	0.5	0	0.5	off
G	0	-0.5	0	off
H	0	-1	0	sat
I	0.5	-0.5	0	off

2) a) $g_m = di_D/dV_{GS} = \frac{d}{dV_{GS}}\left(K(V_{GS}-V_{th})^2\right) = 2K(V_{GS}-V_{th})$

$= 2\cdot 0.24\cdot 10^{-3}\cdot(5-0.7) = 2.064$ mA/V

b) $R_{out} = R_D = 1000\,\Omega$

c) $A_v = v_o/v_{in} = -g_m R_D = 2.064$ mA/V $\cdot$ 1kΩ $= -2.064$ V

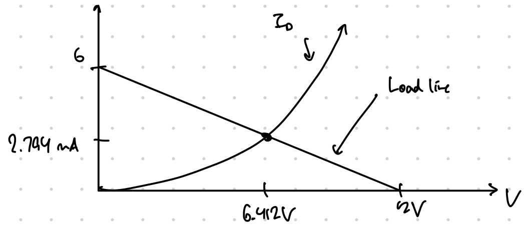
d) mode op of transistor is common src. since input enters gate, output exits drain, source ||.

3) $I_D = K(V_{GS}-V_{th})^2 = 0.24\ mA/V^2 \cdot (V_{GS}-3)^2$

$= \frac{V_{DD}-V_{GS}}{R_D} = \frac{12V - V_{GS}}{2} \rightarrow \frac{6V_{GS}^2}{25} - \frac{47V_{GS}}{50} - \frac{96}{25} = 0$

$\rightarrow$ wolfram alpha eq. solver $\rightarrow V_{GS} = -2.495,\ 6.412\ V$

$V_{DS} = 0,\ i_D = V_{DD}/R_D = 12/2000 = 6mA$



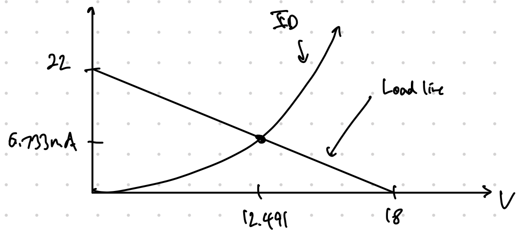
$I_{DQ} = 0.24\ mA/V^2 \cdot (6.412-3)^2 = 2.794\ mA$
$V_{GSQ} = 6.412V$
$V_{DSQ} = 6.412V$

4) $V_G = 40 \cdot \frac{18}{18+22} = 18 \rightarrow V_S = i_D \cdot 820 \rightarrow V_{GS} = 18 - 820\ i_D$

$0 = 18 - 820 i_D \rightarrow i_D = 22mA$

$V_{GS} = 18 - 820 \cdot 0 = 18\ V \rightarrow \quad i_D = -\frac{22}{18}\ mA/V\ \ V_{GS} + 22$

$i_D = K(V_{GS}-V_{th})^2 = 0.12 \cdot 10^{-3} A/V^2 \cdot (V_{GS}-5)^2 = 0.12 \cdot (V_{GS}-5)^2$



wolfram alpha intersection of

$y = \frac{18}{22}x + 22 \quad \& \quad y = 0.12 \cdot (V_x - 5)^2$

$V_{GSQ} = 12.491V \quad \& \quad i_{DQ} = 6.733\ mA$

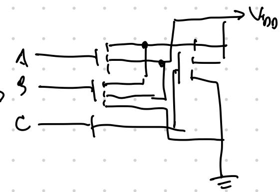
top loop $\rightarrow -40 + 820 \cdot 6.733mA + V_{DSQ} + 2k \cdot 6.733m = 0$

$V_{DSQ} = 14.28V$

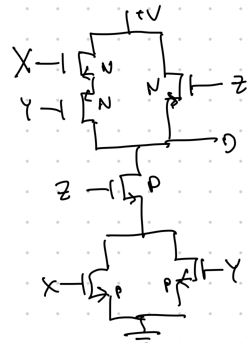
5) $Y = (A+B)C$

A	B	C	Y
0	0	0	0
1	1	1	1
1	0	1	1
1	0	0	0
0	1	0	0
0	1	1	1
1	1	0	0
0	0	1	0

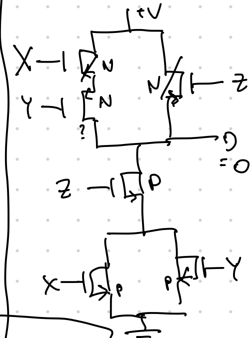
$\rightarrow$

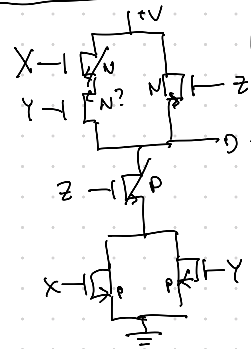


6)

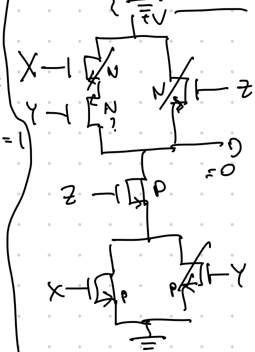


Z = Y = X = 1

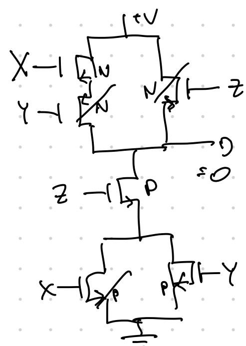




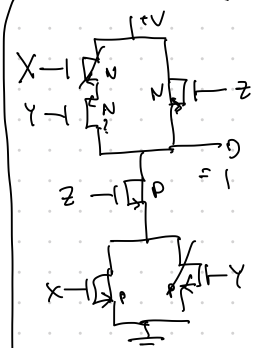
Z = 0 Y = 1 X = 1



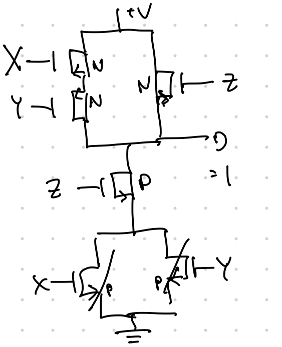
Z = 1 Y = 0 X = 1



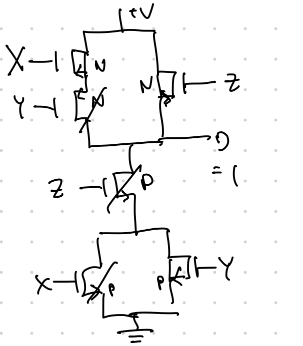
Z = 1 Y = 1 X = 0



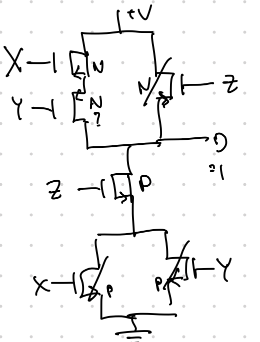
Z = 0 Y = 0 X = 1



Z=0 Y=0 X=0



Z=0 Y=1 X=0



Z	X	Y	D
1	1	1	0
0	1	1	1
1	1	0	0
1	0	1	0
0	0	1	1
1	0	0	1
0	1	0	1
0	0	0	1

$$D = \bar{Z}\bar{Y}\bar{X} + \bar{Z}\bar{Y}X + \bar{Z}Y\bar{X} + \bar{Z}YX + Z\bar{Y}\bar{X}$$

$$= \bar{Z}\bar{Y}(\bar{X}+X) + \bar{Z}Y\bar{X} + \bar{Z}YX + Z\bar{Y}\bar{X} = \bar{Z}\bar{Y} + \bar{Z}Y\bar{X} + \bar{Z}YX + Z\bar{Y}\bar{X}$$

$$= \bar{Z}(\bar{X}+\bar{Y}] + \bar{Z}YX + Z\bar{Y}\bar{X} = \bar{Z}\bar{Y} + \bar{Z}(YX+\bar{X}) + Z\bar{Y}\bar{X}$$

$$= \bar{Z}(Y+\bar{X}) + \bar{Y}(\bar{X}+\bar{Z}) = \bar{Z}Y + \bar{Z}\bar{X} + \bar{Y}\bar{X} + \bar{Y}\bar{Z}$$

$$= \bar{Z} + \bar{Z}\bar{X} + \bar{Y}\bar{X} = \bar{Z} + \bar{Y}\bar{X} \rightarrow (\text{NOT}(Z)) \text{ OR } X \text{ NOR } Y$$