HW3

1. (a) $C_{ox} = \frac{\varepsilon_{si}}{t_{ox}} = \frac{3.45\times10^{-11}}{4\times10^{-9}} = 8.625\times10^{-3}\,F/m^2$ #

$k_n' = \mu_n \cdot C_{ox} = 450\times 8.625\times10^{-7} = 388\,\mu A/V^2$ #

(b) $k_n = k_n'\frac{W}{L} = 388\times10^{-3}\times\frac{2.4\times10^{-9}}{0.18\times10^{-9}} = 5175\,\mu A/V^2$

$I_D = \frac{1}{2}\cdot k_n (V_{ov})^2$

$\Rightarrow V_{ov}^2 = \frac{2I_D}{k_n} = \frac{2\times0.1\times10^{-3}}{5175\times10^{-6}}$

$\Rightarrow V_{ov} = 196.6\,mV$ #

$V_{ov} = V_{GS} - V_{th}$

$\Rightarrow V_{GS} = V_{ov} + V_{th}$

$= 196.6 + 500 = 696.6\,mV$ #

$V_{DSmin} = V_{GS} - V_t$

$= V_{ov}$

$= 196.6\,mV$ #

(c) $r_{DS} = \frac{1}{k_n'\cdot\frac{W}{L}V_{ov}}$

$\Rightarrow V_{ov} = \frac{1}{k_n'\cdot\frac{W}{L}\cdot r_{DS}} = \frac{1}{388\times10^{-6}\times\frac{2.4}{0.18}\times500} = 0.386\,V = 386\,mV$ #

$V_{GS} = V_{ov} + V_t$

$= 386 + 500 = 886\,mV$ #

2. (a) $I_D = \frac{1}{2}k_n'\cdot\frac{W}{L}\cdot(V_{ov})^2$

$\Rightarrow 50\times10^{-6} = \frac{1}{2}\times2\times10^{-3}\times(V_{ov})^2$

$\Rightarrow V_{ov}^2 = \frac{50\times10^{-6}}{10^{-3}} = 0.05$

$\Rightarrow V_{ov} \doteq 0.2236\,V = 223.6\,mV = V_{DS}$ #

$V_{OV} = V_{GS} - V_{th}$

$\Rightarrow 0.2236 = V_{GS} - 0.4$ (V)

$\Rightarrow V_{GS} = 623.6\,mV$ #

(b) $I_D = \frac{1}{2}k_n'\cdot\frac{W}{L}\cdot(V_{ov})^2$

$\Rightarrow 200\times10^{-6} = \frac{1}{2}\times2\times10^{-3}\times(V_{ov})^2$

$\Rightarrow V_{ov}^2 = \frac{200\times10^{-6}}{10^{-3}} = 0.2$

$\Rightarrow V_{ov} \doteq 447.2\,mV = V_{DS}$ #

$V_{OV} = V_{GS} - V_{th}$

$\Rightarrow 0.4472 = V_{GS} - 0.4$ (V)

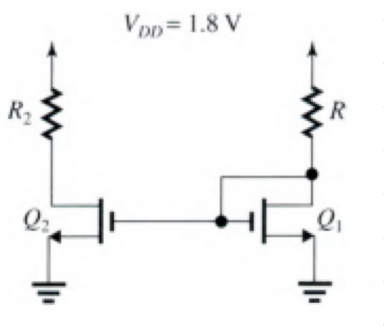
$\Rightarrow V_{GS} = 847.2\,mV$ #

3.

	V_S	V_G	V_D	V_{SG}	$\lvert V_{OV}\rvert$	V_{SD}	Region of operation
a	+2	+2	0	0	0	2	Cut-off ($V_{GS}=0$)
b	+2	+1	0	1	0	2	Cut-off/saturation ($V_{SD}=V_{SG}-V_t$)
c	+2	0	0	2	1	2	saturation ($V_{SD}\geq V_{SG}-V_t$)
d	+2	0	+1	2	1	1	Triode/saturation ($V_{SD}=\lvert V_{OV}\rvert$)
e	+2	0	+1.5	2	1	0.5	Triode ($V_{SD}\leq V_{SG}-V_t$)
f	+2	0	+2	2	1	0	Triode ($V_{SD}\leq V_{SG}-V_t$)

$V_{SG} = V_S - V_G$
$V_{OV} = V_{SG} - |V_{tp}|$

4.



$V_t = 0.5V$
$k_n' = 0.4mA/V^2$
$L_1 = L_2 = 0.36\mu m$
$W_1 = 1.8\mu m$
$\lambda = 0$

(a) $I_D = \frac{1}{2} \cdot k_n' \cdot \frac{W_1}{L_1} (V_{GS} - V_{th})^2$

$100\times10^{-6} = \frac{1}{2} \cdot 4\cdot10^{-3} \cdot \frac{1.8}{0.36} (V_{GS}-0.5)^2$

$\Rightarrow V_{GS} = 0.8162V = 816.2mV$

$I_D = \frac{V_{DD}-V_{DS1}}{R}$

$\Rightarrow 10^{-6} = \frac{1.8-0.8162}{R}$

$\Rightarrow R = 9.837k\Omega$ *

(b) $V_{DS2} = V_{GS} - V_t$
$= 0.8162 - 0.5$
$= 0.3162V$

$I_{ref} = \frac{V_{DD}-V_{DS2}}{R_2}$

$\Rightarrow 0.5\times10^{-3} = \frac{1.8-0.3162}{R_2}$

$\Rightarrow R_2 = 2.9676k\Omega$ *

$\frac{I_{ref}}{I} = \frac{W_2}{W_1}$

$\Rightarrow \frac{0.5}{100\times10^{-3}} = \frac{W_2}{1.8\mu m}$

$\Rightarrow W_2 = 9\mu m$ *