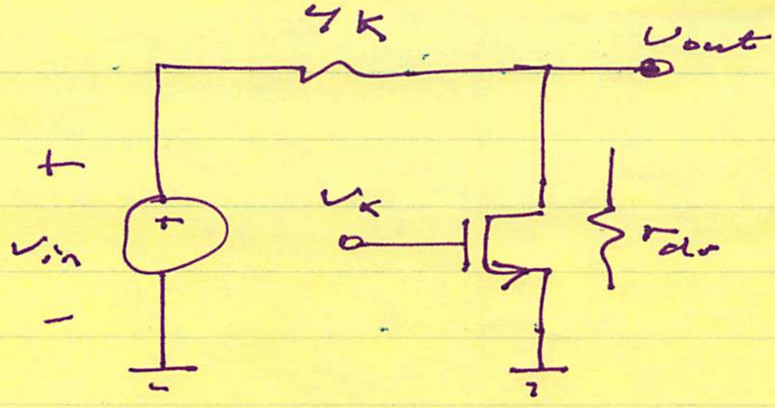
5.29



$K_n' = 50\ \mu A/V^2$

$V_T = 0.6\ V$

want $\frac{V_{out}}{V_{in}} = 0.1$ for $V_x = V_{GS} = 5V$

$$\frac{r_{ds}}{r_{ds} + 4K} = \frac{1}{10} \longrightarrow r_{ds} = \frac{4}{9} K$$

$$r_{ds}^{-1} = 2.25 \times 10^{-3}\ ℧$$

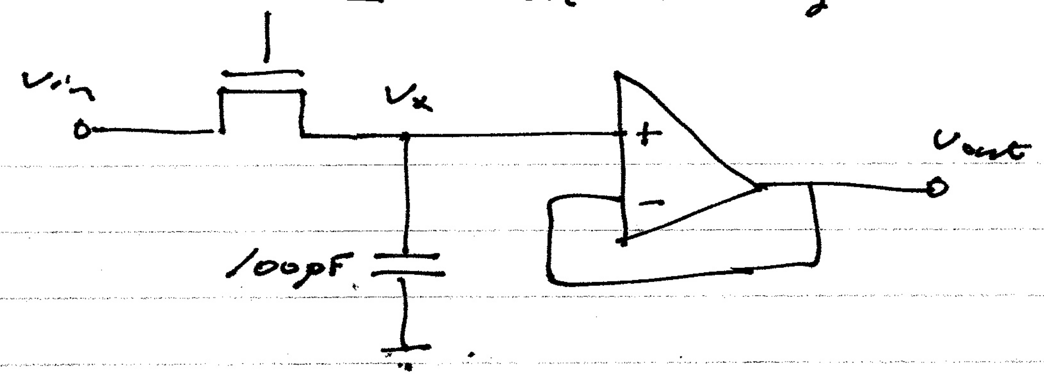
But $r_{ds}^{-1} = K' \frac{W}{L} (\overset{5}{V_{GS}} - V_T)$

$$\longrightarrow \frac{W}{L} = \frac{2.25 \times 10^{-3}}{50 \times 10^{-6} \times 4.4}$$

$$= 10.2$$

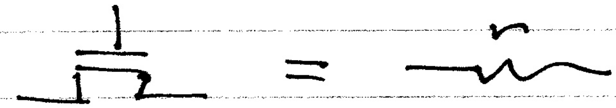
5.31

← "on" for $v_g = 5V$



$K_n' = 50\ \mu A/V^2$
$V_{Tn} = 0.6\ V$

a) Let $v_x = 1.024\ V$ (max)
Turn on MOSFET when $v_{in} = 0$ (min)
Assume $1.024/100$ max error.



$$v_x = 1.024\, e^{\frac{-t}{rc}}$$

At $t = 10\ ns$, $v_x = \frac{1.024}{100}$

$$\rightarrow e^{\frac{-t}{rc}} = \frac{1}{100}$$

$$t = rc \ln 100$$

$$r = \frac{10^{-8}}{10^{-10} \ln 100} = 21.7\ \Omega$$

$$= \frac{1}{K' \frac{W}{L}(V_{gs} - V_t)}$$

$$\frac{W}{L} = \frac{1}{21.7 \times 50 \times 10^{-6} \times (5 - 0.6)}$$

$$= 210$$

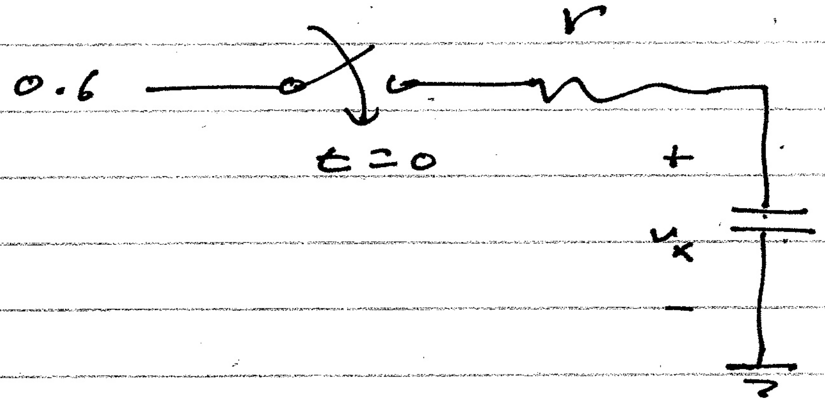
$v_{ov} = 5 - 0.5$

b) $v_{in} = 0.6$

$$r = \frac{1}{k'\left(\frac{W}{L}\right)\underbrace{(v_{ov} - v_T)}_{3.9}}$$

$\frac{W}{L}$: 210

$= 24.4\,\Omega$



+

0.5 at $t = 0^-$

−

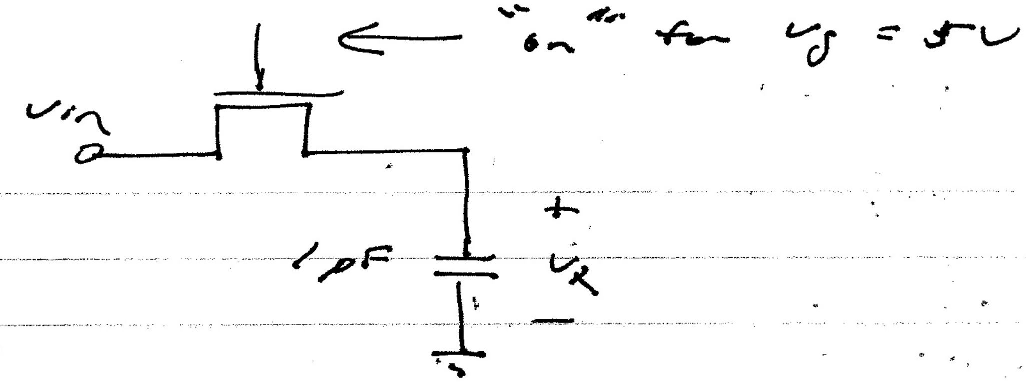
$$v_x = v_x(\infty) + \left[v_x(0+) - v_x(\infty)\right] e^{-\frac{t}{rC}}$$

$$= 0.6 - 0.1\, e^{-\frac{t}{rC}}$$

At $t = 10\,ns$, $e^{-\frac{t}{rC}} = 1.66 \times 10^{-2}$

Error $= v_x(10\,ns) - 0.6 = -1.66\,mV$

5.32



$K_n' = 65\ \mu A/V^2 \quad V_{Tn} = 0.6V$

$W = 20\ \mu m, \quad L = 1.2\ \mu m$

$C_{ox} = 80\ nF/cm^2$

$v_{in} = 1V \longrightarrow v_{GS} = 5 - 1 = 4V$

$v_x \rightarrow 1V$

Q (under gate) $= C_{ox} W L (v_{GS} - V_{Tn})$

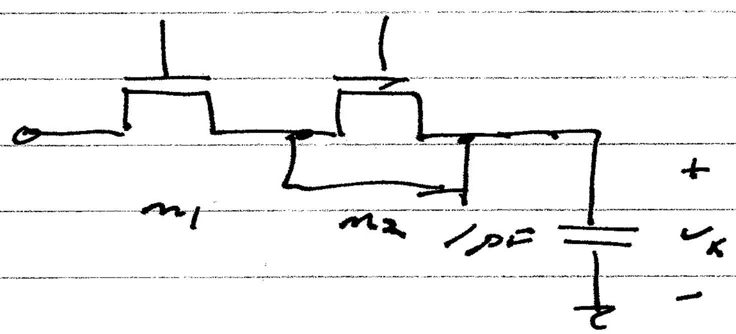
$= 80 \times 10^{-9} \times 20 \times 10^{-4} \times 1.2 \times 10^{-4} \times 3.4$

$= 6.53 \times 10^{-14}$ Coul

$\frac{1}{2} Q \longrightarrow C$

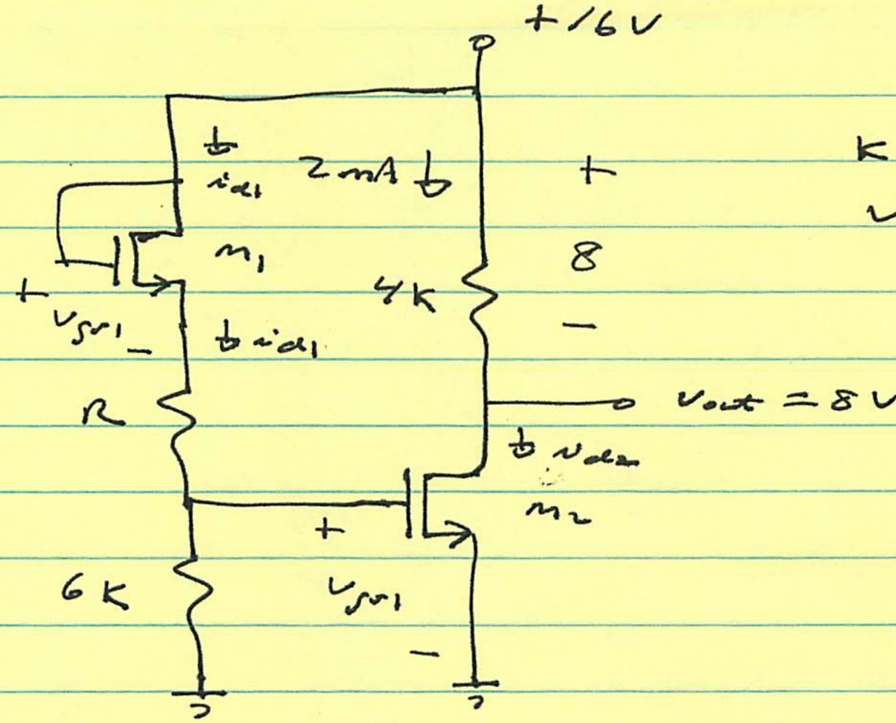
$$\Delta V = \frac{\Delta Q}{C} = \frac{3.26 \times 10^{-14}}{10^{-12}} = 32.6\ mV$$

5.37



Make M_2 $\frac{W_2}{L_2} = \frac{1}{2} \frac{W_1}{L_1}$ so that M_2 absorbs charge under M_1 ($\frac{1}{2} Q$).

5.43



$K'\frac{W}{L} = 1\ mA/V^2$

$V_T = 1V$

$i_{d2} = 2mA$

$\hookrightarrow \quad 2 = \frac{1}{2}(1)(v_{gs2} - 1)^2 \longrightarrow v_{gs2} = 3, \cancel{-1}$

$\longrightarrow \quad i_{d1} = \frac{3}{6K} = 0.5\ mA$

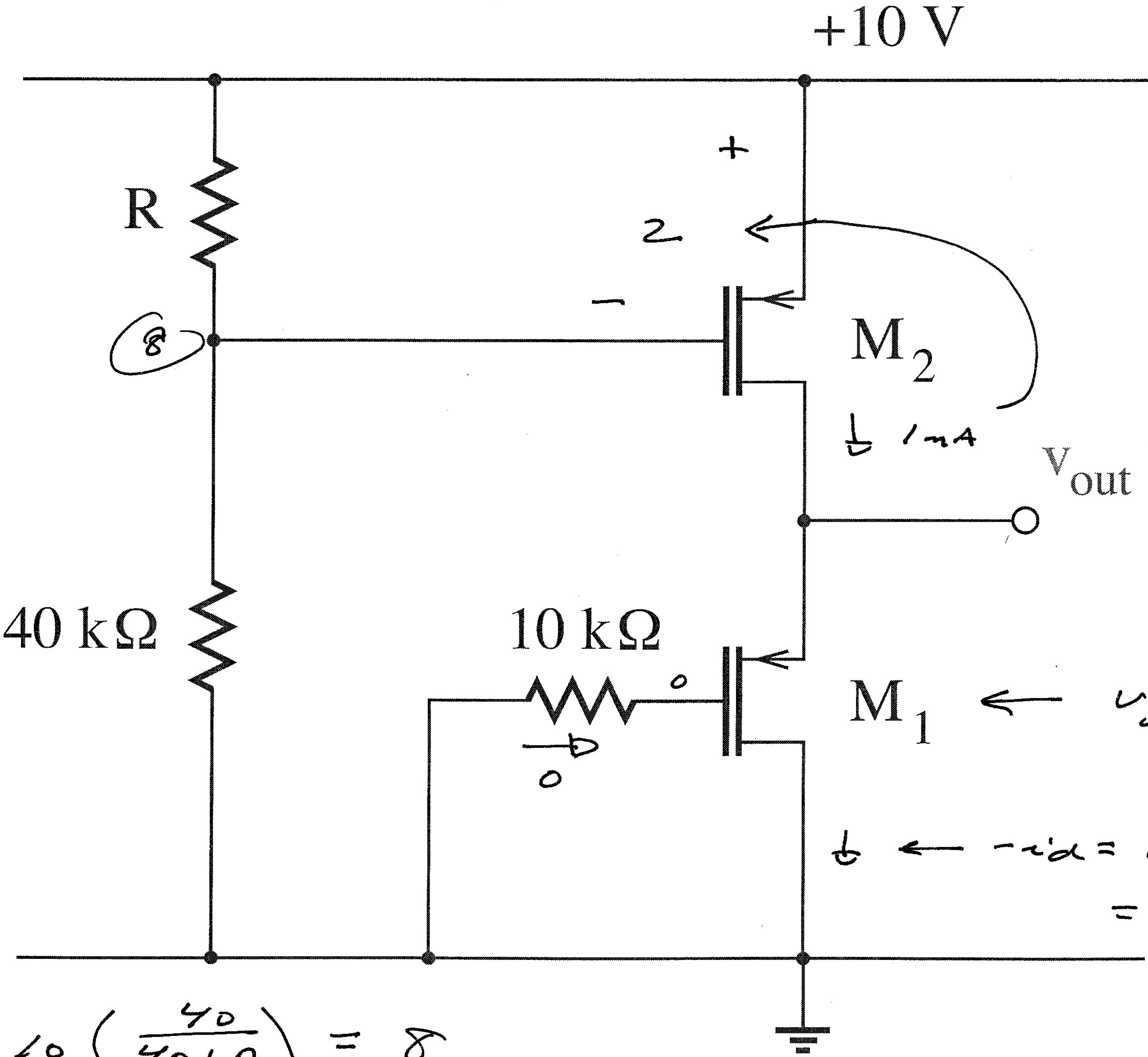
$0.5 = \frac{1}{2}(1)(v_{gs1} - 1)^2 \longrightarrow v_{gs1} = 2, \cancel{0}$

$\hookrightarrow \quad R = \frac{(16-2) - 3}{0.5} = \underline{22K}$

5.44

$K'\frac{W}{L} = 2\,mA/V^2$

$V_T = -1V$



$\leftarrow v_{GS} = -2$

$\leftarrow -i_d = \frac{1}{2}(2)(-2+1)^2$

$= 1\,mA$

$10\left(\frac{40}{40+R}\right) = 8$

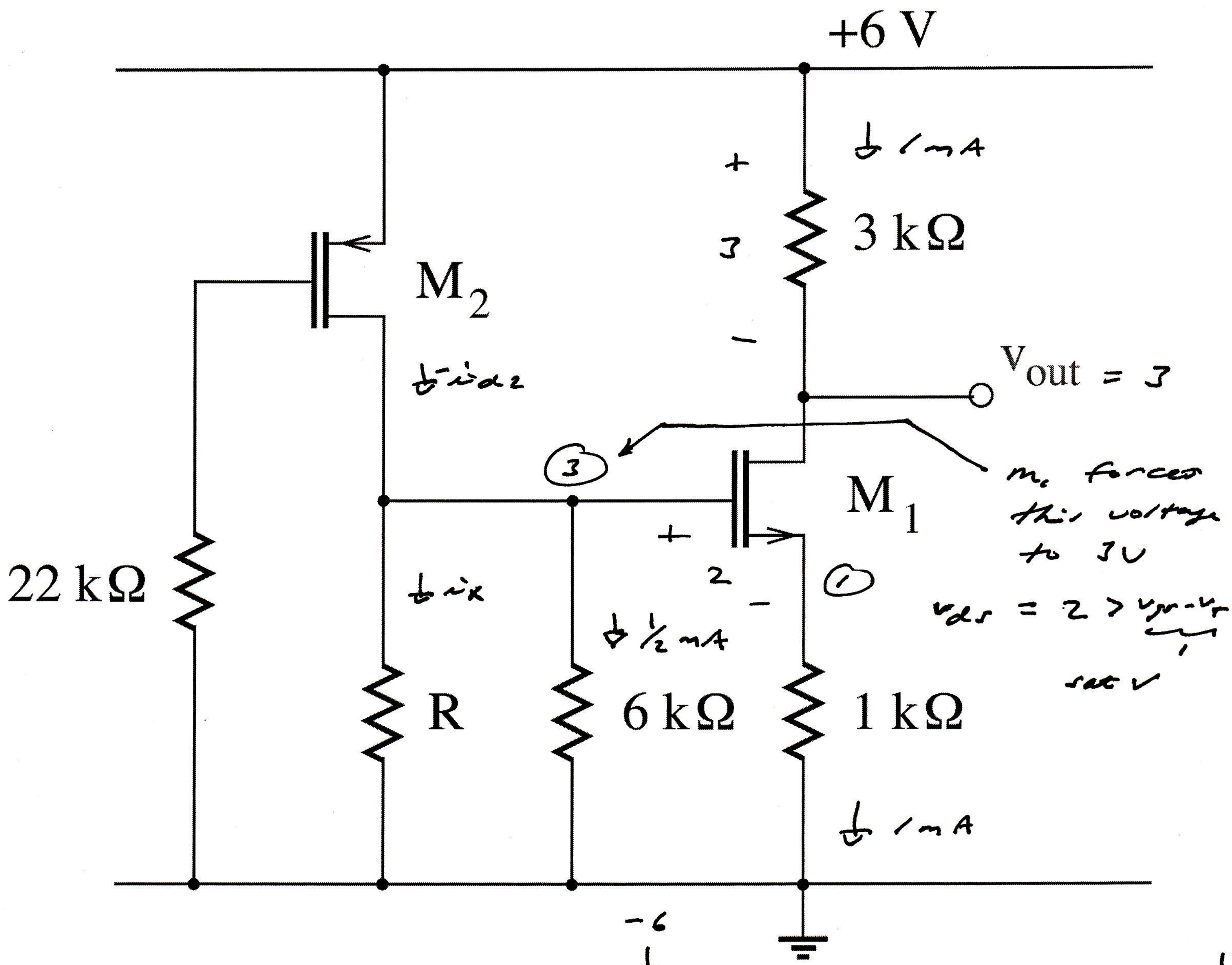
$\longrightarrow R = 10K$

5.45 $M_1 : k_n' \frac{W}{L} = 2 mA/V^2 , V_T = 1V$

$M_2 : k_p' \frac{W}{L} = 0.25 mA/V^2 , V_T = -1V$

$M_1 \longrightarrow i_{d1} = 1 = \frac{1}{2}(2)(v_{gs} - 1)^2 \longrightarrow v_{gs} = 2V$

$\cancel{v_{gs} = 0V}$



$M_2 :$ $v_{ds} = -3 > v_{gs} - V_T = -5$ negative!

$-i_{d2} = \frac{1}{2} k' \frac{W}{L} \left[\underbrace{2(v_{gs} - V_T)v_{ds} - v_{ds}^2}_{21}\right] = 2.625 mA$

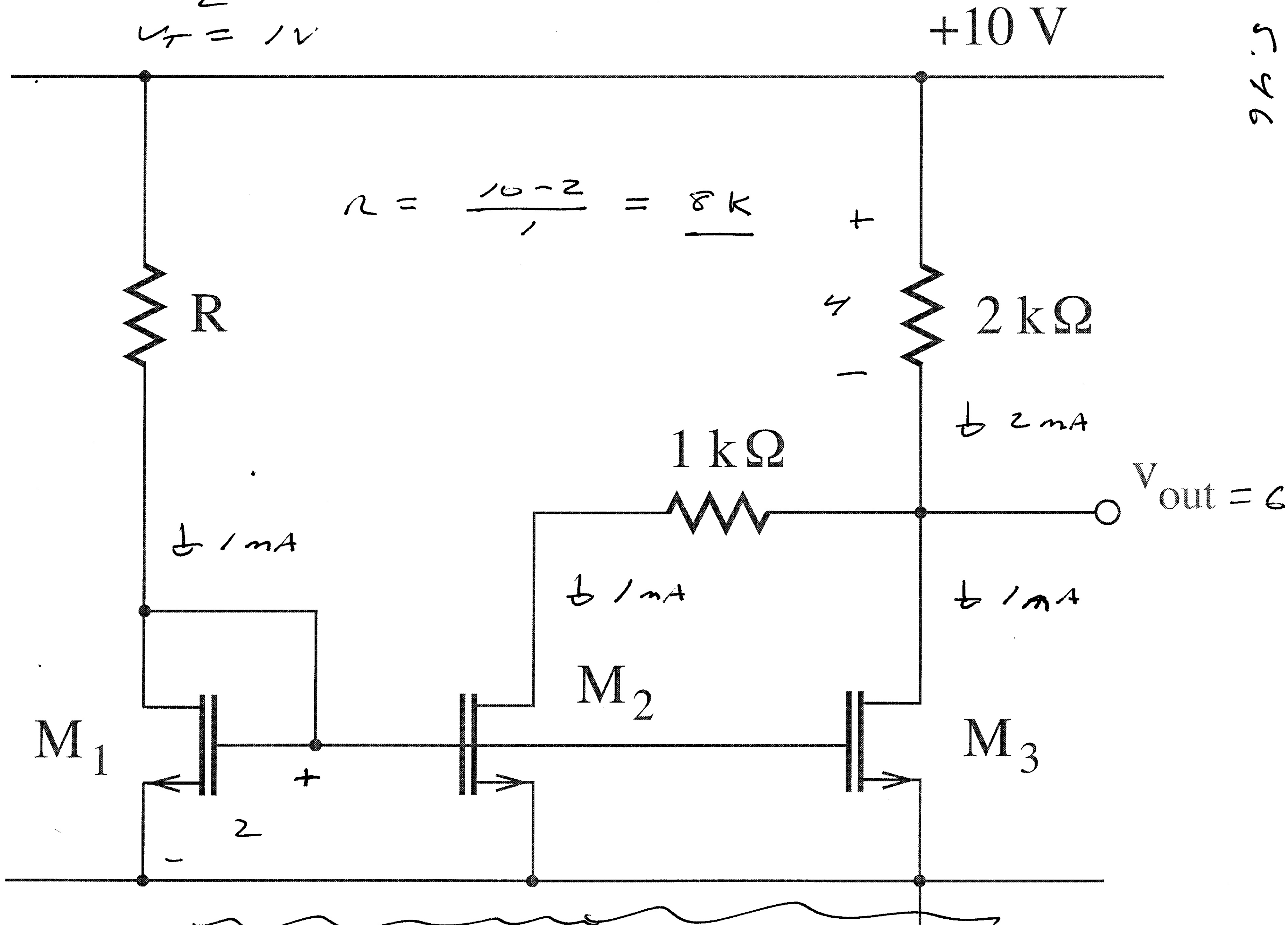
$\longrightarrow i_x = 2.125 mA$

$R = \frac{3}{2.125} = \underline{1.41 K}$

5.46

$K'\frac{W}{L} = 2\,mA/V^2$

$V_T = 1V$



$1 = \frac{1}{2}(2)(v_{GS1} - 1)^2$

$v_{GS1} = 2, \cancel{0}$

same v_{GS}

$v_{DS1} = 2 > 2 - 1$ ✓