Ex. 9.5

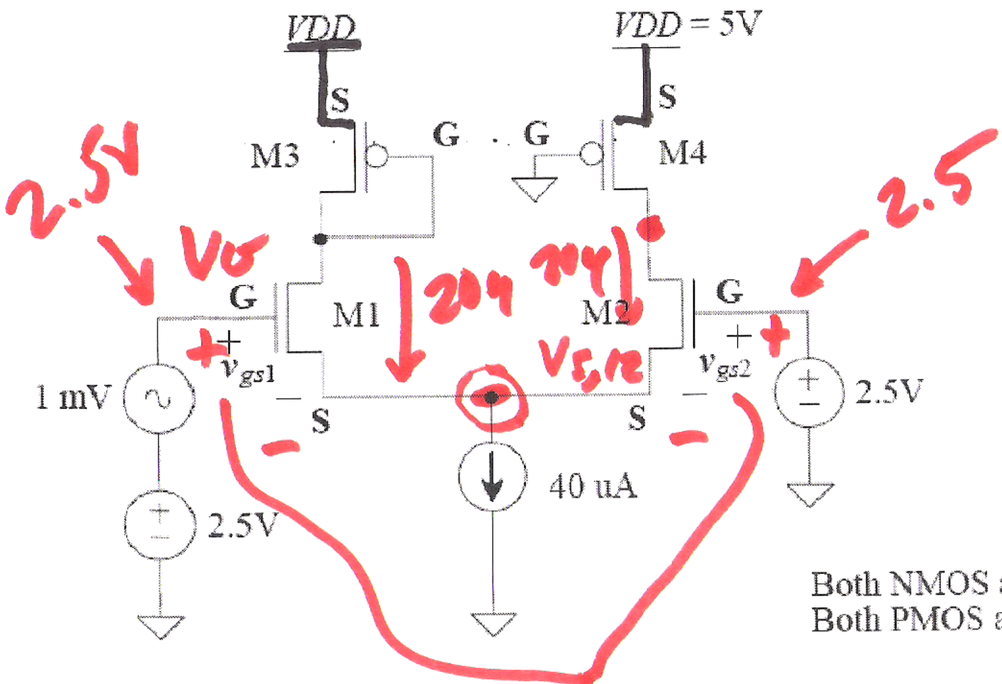
$i_d = g_m v_{gs}$

$I_D = \frac{KP_n}{2}\frac{W}{L}(V_{GS} - V_{THN})^2$

$V_{GS} = \sqrt{\frac{2 I_D \cdot L}{W \cdot KP_n}} + V_{THN}$

$= \sqrt{\frac{2 \cdot 20\mu \cdot 2}{10 \cdot 120\mu}} + 0.8$

$V_{GS} = 1.058$



Both NMOS are 10/2
Both PMOS are 30/2

Figure 9.17 Circuit discussed in Ex. 9.5.

1.058

$$\boxed{\begin{aligned} I_{D1} &= I_{D2} = 20\mu \\ V_{G1} &= V_{G2} = 2.5V \\ V_{S1,2} &= 1.\cancel{058}\,442 \end{aligned}}$$

$V_{GS} = V_G - V_S = 1.058 = 2.5 - V_S$

$V_S = 1.442$

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1)

$V_{SG} > V_{THP}$

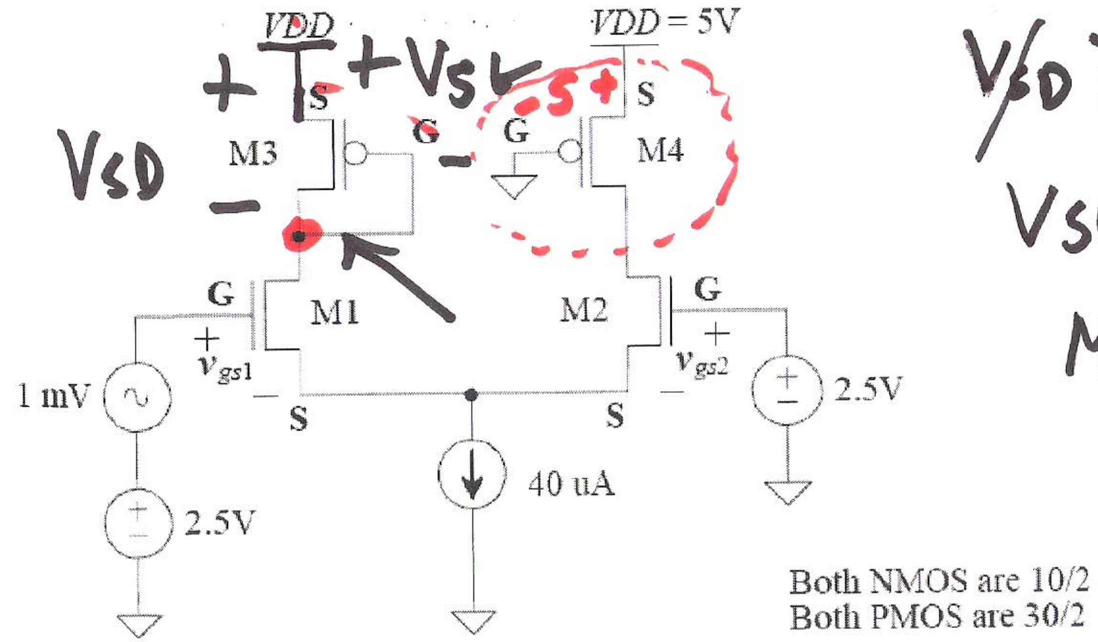

Figure 9.17 Circuit discussed in Ex. 9.5.

for saturation, PMOS

$$\cancel{V_{SD}} \geq \cancel{V_{SG}} - V_{THP} = V_{SD,SAT}$$

$$V_{SD} = V_{SG}, \quad 0 \geqq V_{THP}$$

M3 in saturation

$$V_{SG} = \sqrt{\frac{2 I_D \cdot L}{KP_p \cdot W_3}} + V_{THP}$$

$$= 1.158$$

$$V_{D1} = VDD - V_{SG}$$

$$V_{D1} = 5 - 1.158 = 3.842$$

for M1 to be in sat.

$$V_{DS1} > V_{GS1} - V_{THN}$$

$$3.842 - \cancel{1.442} > \underbrace{2.5 - \cancel{1.442} - .8}_{1.7}$$

Yes, M1 in saturation

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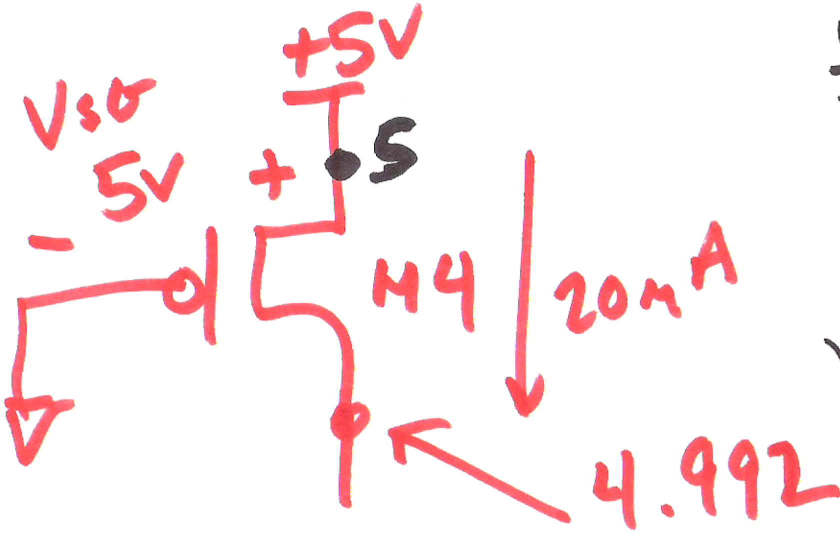
2)



for sat

$$V_{SD} \overset{?}{\geq} V_{SG} - V_{THP}$$

$$V_S - V_D \overset{?}{\geq} 5 - .9$$

$$\overset{5}{\cancel{V_{DD}}} - V_D \geq 4.1$$

$$\underline{\underline{V_D \leq .9V}}$$

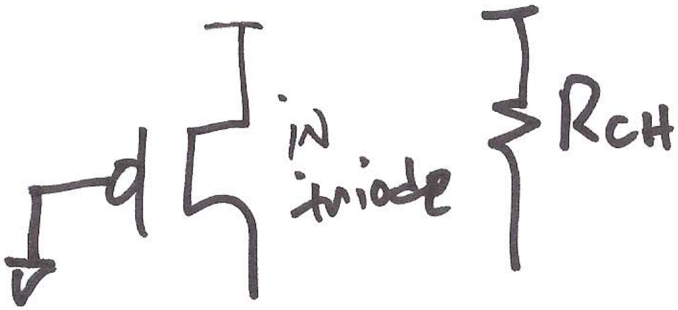
for triode operation

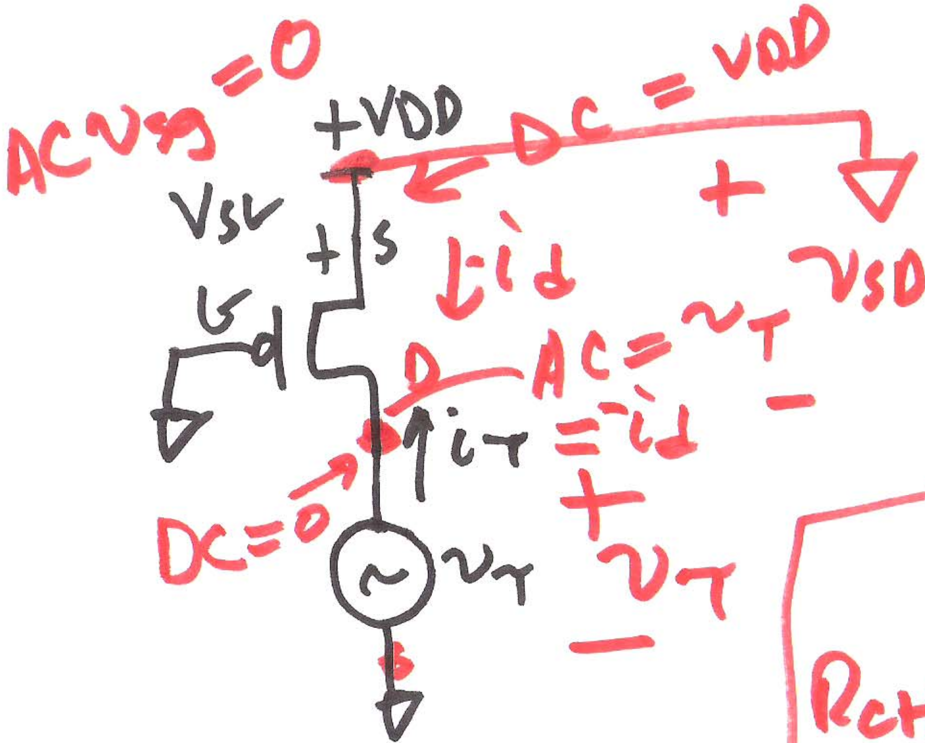
$$I_D = KP_p \cdot \frac{W}{L} \cdot \left(\left(V_{\cancel{GS}}^{SG} - V_{THP} \right) V_{SD} - \frac{V_{SD}^2}{2} \right)$$

$$20 = 40 \cdot \frac{30}{2} \left((5 - .9) V_{SD} - \frac{V_{SD}^2}{2} \right)$$ M4 is in triode!

$$\boxed{V_{SD} = 8.13\,mV}$$

3)





$$\frac{\delta(I_D+i_d)}{\delta v_{SD}} = \frac{\delta}{\delta v_{SD}}\left(\qquad \right)$$

$$I_D + i_d = KP_P\frac{W}{L}\left((V_{GS}+v_{gs}-V_{THN})\cdot V_{SD} + v_{SD} + \cancel{\frac{(V_{SD}+v_{SD})^2}{2}}\right)$$

$$R_{CH} = \frac{v_{SD}}{i_d} = \frac{-v_T}{-i_T}$$

$$\boxed{R_{CH} = \frac{1}{KP_P\cdot\frac{W}{L}(V_{GS}-V_{THN})}}$$

$$R_{CH} = \frac{v_T}{i_T}$$

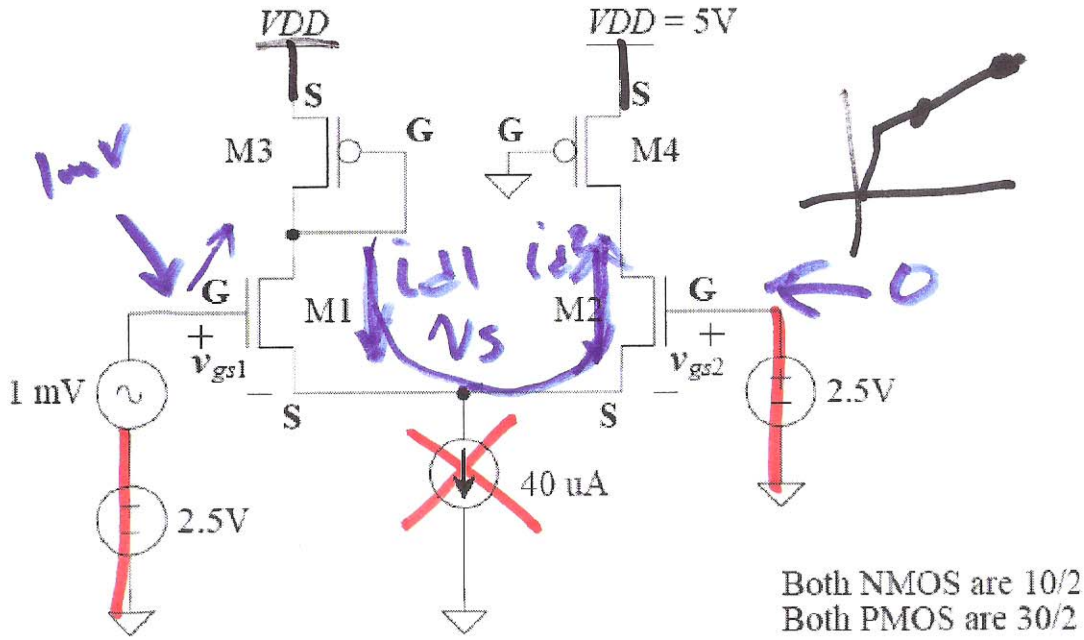


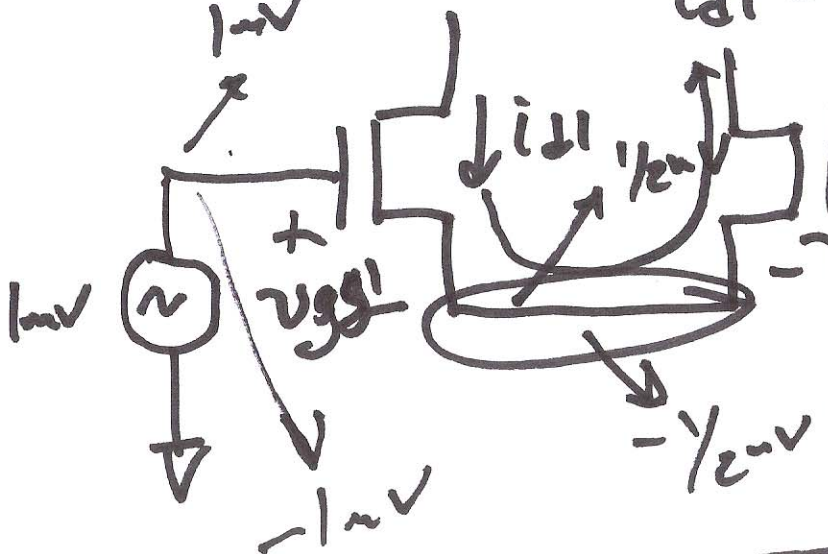
Figure 9.17 Circuit discussed in Ex. 9.5.

20uA → 20.1uA = i_{d1}

19.9uA = i_{d2}

5)

$i_{d1} = -i_{d2}$



$g_{m1} v_{gs1} = i_{d1}$

$g_{m2} v_{gs2} = i_{d2}$

$g_{mN} = g_{m1} = g_{m2}$

$V_{s1,2} = \frac{1}{2}\,mV$

$i_{d1} = -i_{d2}$

$v_{gs1} = -v_{gs2}$

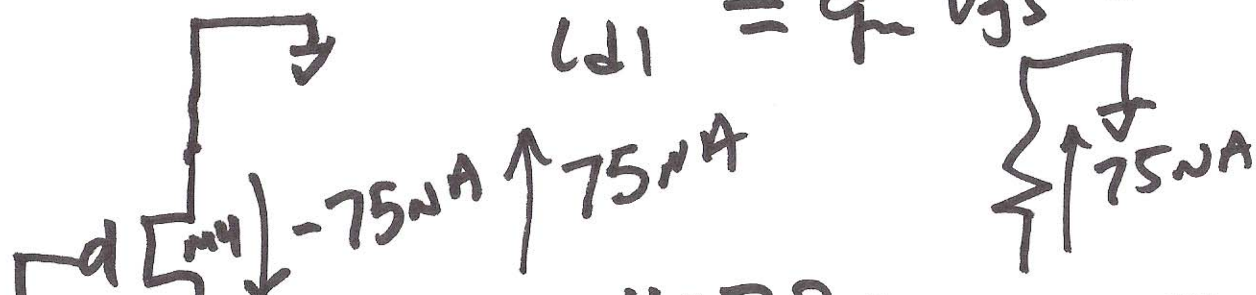
$\frac{1}{2}\,mV = -\left(-\frac{1}{2}\,mV\right)$

$$g_{mN} = \sqrt{2 \cdot KP_N \cdot \frac{W}{L} \cdot 20\mu}$$

$$= 150\,\mu A$$

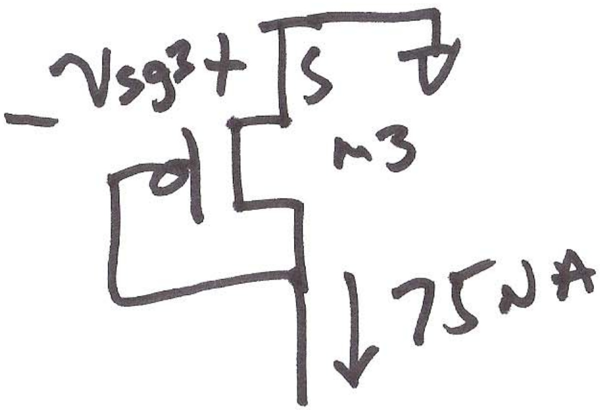
$i_{d1} = g_m v_{gs} = 150\,\mu A \cdot \frac{1}{2}\,mV = \boxed{75\,nA}$

$i_{d2} = \boxed{-75\,nA}$



$R_{ch4} = 407\,\Omega$

$75n \cdot 407 = \boxed{0.03\,mV = \text{drain } m3/m2}$



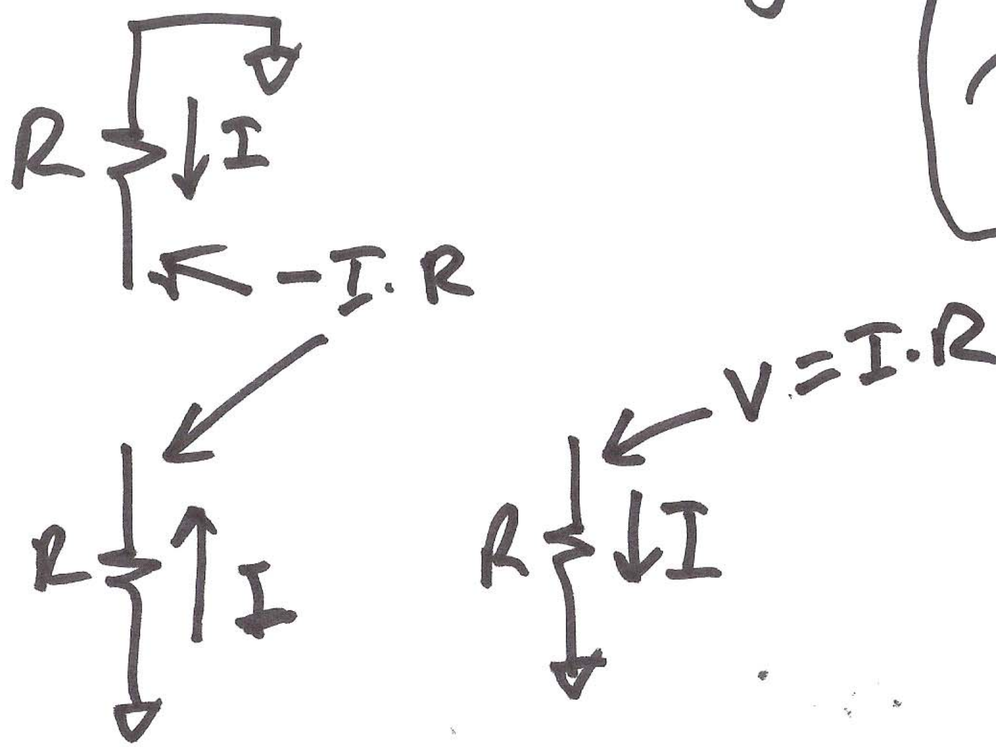
$$i_d = g_m v_{sg}$$

$$v_{sg} = -\frac{1}{g_{mp}} \cdot i_d$$

$$g_{mp} = 150\mu A$$

$$\boxed{v_{sg} = -\frac{1}{2} mV}$$

drains, M1 or M3



7)