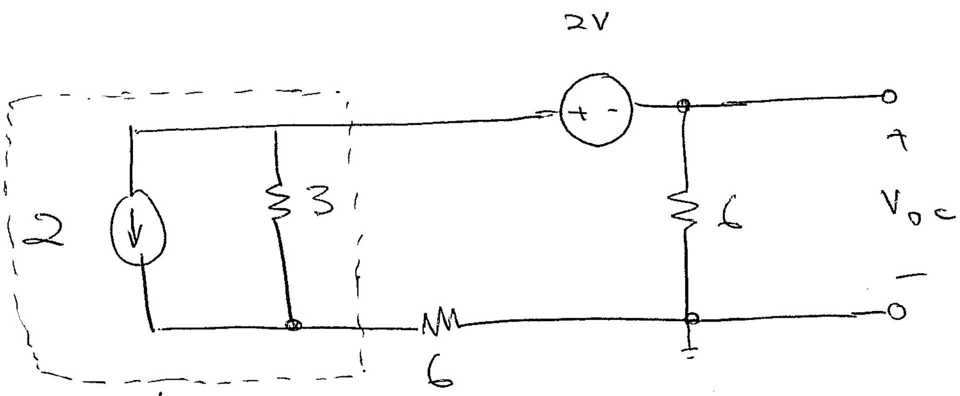
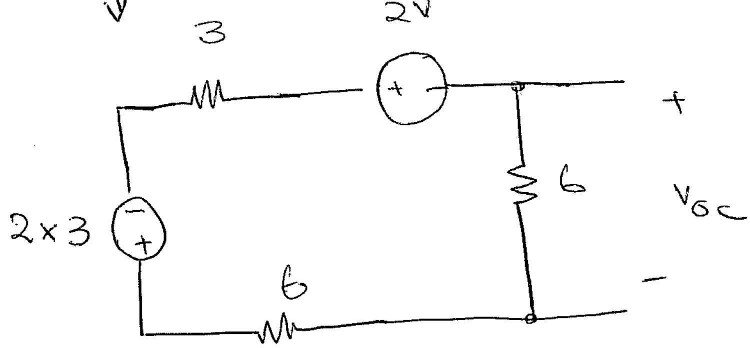
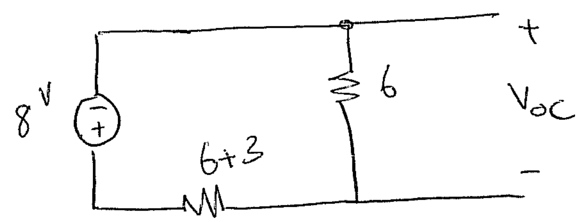
Q1a)



Source transformation



which simplifies to

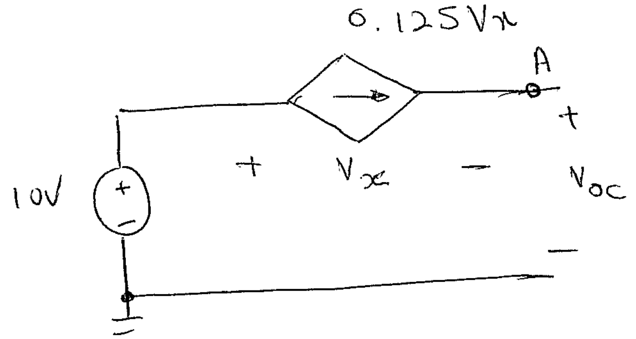


$$V_{oc} = \frac{6}{6+9} \times -8 = -3.2\,V$$

$$R_{th} = 6 \parallel 9 = 3.6\,\Omega = R_{No}$$

$$I_{short} = \frac{V_{oc}}{R_{th}} = -0.889\,A$$

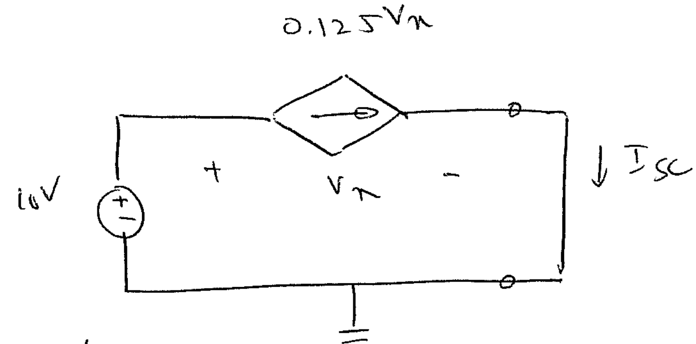
Q1b)



Since no current can flow through the open circuit, $0.125V_x = 0 \Rightarrow V_x = 0$

KVL $-10 + V_x + V_{oc} = 0 \Rightarrow \underline{V_{oc} = 10\text{ V}}$

To find I_{sc}:

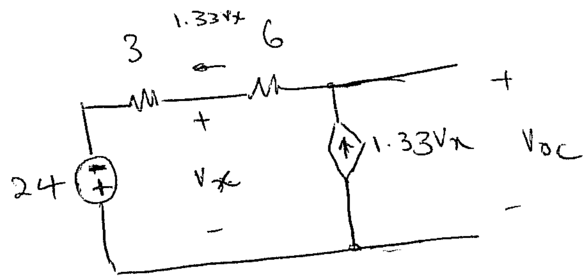


KVL: $-10 + V_x = 0 \Rightarrow V_x = 10V$

$I_{sc} = 0.125V_x = \underline{1.25\text{ A}}$

$R_{th} = R_{No} = \dfrac{V_{oc}}{I_{sc}} = \underline{8\Omega}$

Q1c)

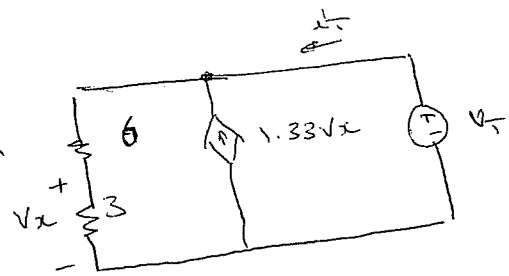


KVL $-24 - V_x + 3.99V_x = 0$

$\Rightarrow V_x = 8.02V$

KVL $-24 - V_{oc} + 9 \times 1.33 \times 8.02 = 0$

$\Rightarrow \underline{V_{oc} = 72V}$



$V_x = \frac{1}{3}V_T$

KCL: $i_T + 1.33V_x = \dfrac{V_T}{9} \Rightarrow \dfrac{V_T}{i_T} = \underline{-3.01\Omega} = R_{th}$

Q.5.4

With V_{DS} small compared to V_{OV}, eq. 5.13a applies:

$$r_{DS} = \frac{1}{\mu_n C_{ox} \left(\frac{W}{L}\right) V_{OV}}$$

(a) V_{OV} is doubled $\Rightarrow$ r_{DS} is halved. factor = 0.5

(b) W is doubled $\Rightarrow$ r_{DS} is halved. factor = 0.5

(c) W and L are doubled $\Rightarrow$ r_{ds} is unchanged. factor = 1.

(d) If oxide thickness t_{ox} is halved and $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$, C_{ox} is doubled. If W and L are also halved, r_{ds} is halved. factor = 0.5.

Q.5.9

$V_{DSsat} = V_{OV} = V_{GS} - V_t = 2.5 - 1 = 1.5\,V$

in saturation:

$$i_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right) V_{OV}^2 = \frac{1}{2} k_n V_{OV}^2$$

$$= \frac{1}{2} \times 1 \frac{mA}{V^2} \times (1.5\,V)^2 = 1.125\ mA$$

Q. 5.12

$$i_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_{th})^2, \quad \text{where } k_n' = \mu_n C_{ox}$$

for equal drain currents:

$$\mu_n C_{ox} \frac{W_n}{l} = \mu_p C_{ox} \frac{W_p}{l} \Rightarrow \mu_n W_n = \mu_p W_p$$

$$\Rightarrow \frac{W_p}{W_n} = \frac{\mu_n}{\mu_p} = \frac{1}{0.4} = 2.5$$

Q. 5.34

$$V_A = V_A' L = 20 \times 1.6 = 32V$$

$$\lambda = \frac{1}{V_A} = 0.031 \; V^{-1}$$

$$V_{DS} = 2^V > (V_{GS} - V_t) = 0.5 \Rightarrow \text{Saturation}$$

$$i_D = \frac{1}{2} k_n' \frac{W}{L} V_{ov}^2 = \frac{1}{2} \times 130 \times \frac{16}{1.6} \times 0.5^2 = 162.5 \mu A$$

$$r_o = \frac{V_A}{i_D} = \frac{32}{162.5\mu} = 197 \, k\Omega = \frac{\Delta V_{DS}}{\Delta i_D} = \frac{1}{\Delta i_D} \Rightarrow \Delta i_D = 5.1 \mu A$$

Q. 5.39

$V_{GS} = -3^V$,

$V_{SG} = 3^V$,

$V_{DS} = -4^V$,

$V_{SD} = 4^V$,

$V_t = -1^V$,

$$i_D = \frac{1}{2} k_p' \frac{W}{L} (V_{GS} - V_t)^2 (1 + \lambda V_{DS})$$

$$\Rightarrow 3 = \frac{1}{2} k_p' \frac{W}{l} (-3 - (-1))^2 (1 - 0.02 \times (-4))$$

$$= 2.16 \, k_p' \frac{W}{l}$$

$$\Rightarrow k_p' \frac{W}{l} = 1.39 \, \frac{mA}{V^2}$$

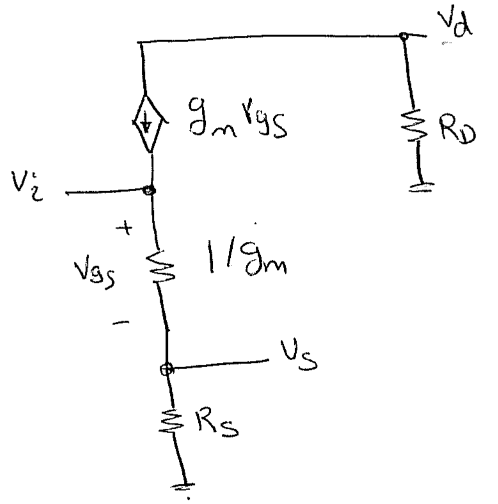
Q. 5.76

$\lambda = 0 \Rightarrow r_o = \infty$

$V_i = g_m V_{gs} \left(\frac{1}{g_m} + R_S \right)$

$V_d = - g_m V_{gs} R_D$

$V_s = g_m V_{gs} R_s$

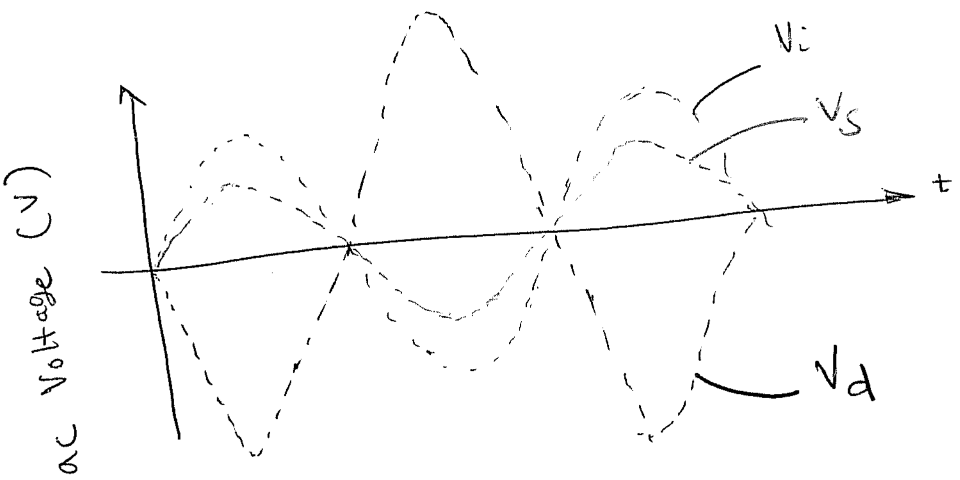


$$\frac{V_s}{V_i} = \frac{R_s}{\frac{1}{g_m} + R_s}$$ (Note. Voltage divider)

$$= \frac{g_m R_s}{1 + g_m R_s}$$

$$\frac{V_d}{V_i} = \frac{-R_D}{\frac{1}{g_m} + R_s} = \frac{-g_m R_D}{1 + g_m R_s}$$

for example:



* Remember that the actual nodes have DC components to, i.e. $V_{TOT} = V_{DC} + V_{AC}$