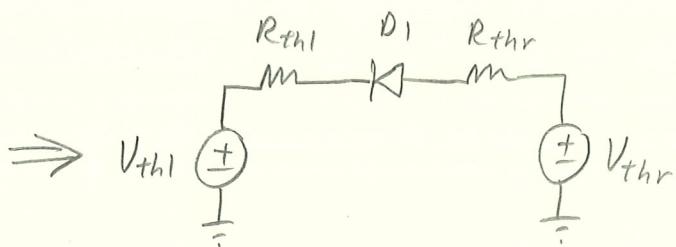
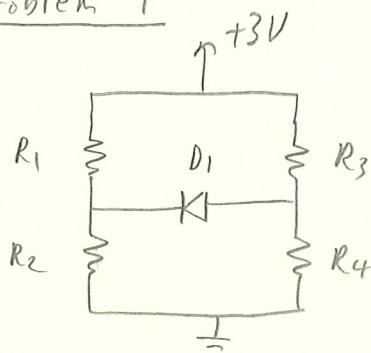


Problem 1

$$R_1 = 3k\Omega, R_2 = R_3 = R_4 = 2k\Omega$$

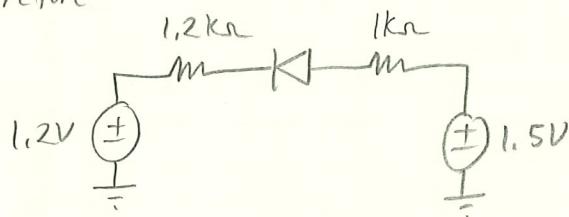
$$V_{th1} = \frac{3R_2}{R_1 + R_2} = \frac{3(2k)}{3k + 2k} = 1.2V$$

$$R_{th1} = R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2} = \frac{(3k)(2k)}{3k + 2k} = 1.2k\Omega$$

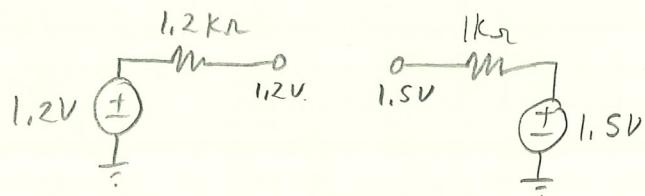
$$V_{thr} = \frac{3R_4}{R_3 + R_4} = \frac{3(2k)}{2k + 2k} = 1.5V$$

$$R_{thr} = R_3 // R_4 = \frac{(2k)(2k)}{2k + 2k} = 1k\Omega$$

Therefore:

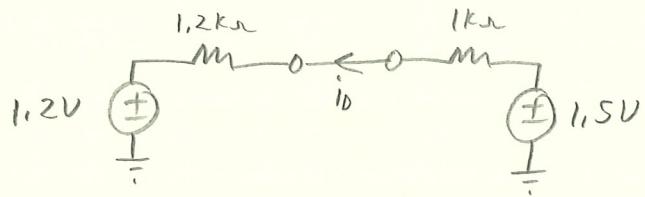


a. Ideal Diode \rightarrow assume off



D1 if forward biased \rightarrow probably on

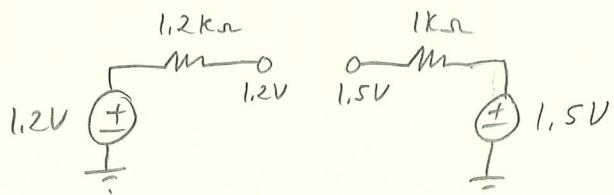
check with diode on:



$$i_D = \frac{1.5 - 1.2}{1.2k + 1k} = 0.136 \text{ mA}$$

Q-point: (0.136mA, 0V)

b. CVD Diode \rightarrow assume off



$$V_D = 1.5 - 1.2 = 0.3V$$

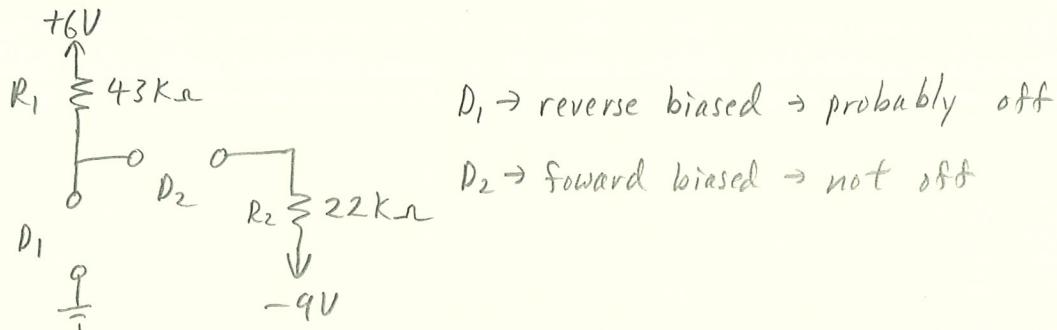
$$0.3V < V_{on} = 0.6V$$

\therefore diode is off

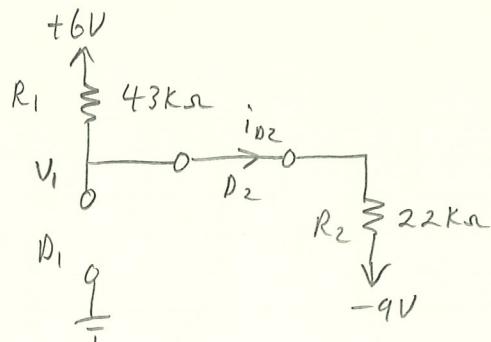
Q-point: (0A, 0.3V)

Problem 2a

assume diodes off:



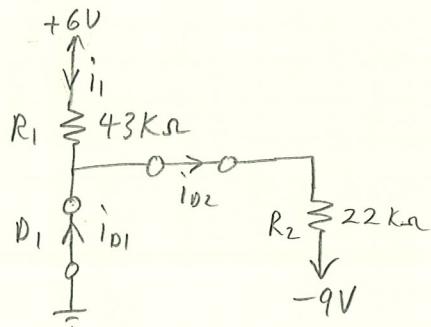
Test with D_1 off and D_2 on:



$$V_1 = -9 + (6 - -9) \frac{R_2}{R_1 + R_2} = -9 + \frac{15(22\text{k})}{43\text{k} + 22\text{k}} = -3.92\text{V}$$

D_1 is now forward biased and may be on

Test with D_1 and D_2 on:



$$i_1 = \frac{6}{43\text{k}} = 0.1395 \text{ mA}$$

$$i_{D2} = \frac{0 - -9}{22\text{k}} = 0.409 \text{ mA} \rightarrow D_2 \text{ is on}$$

$$i_1 + i_{D1} - i_{D2} = 0$$

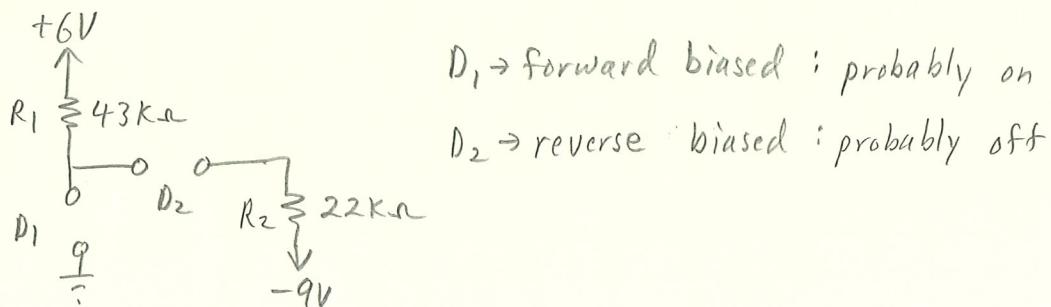
$$i_{D1} = i_{D2} - i_1 = 0.409mA - 0.1395mA = 0.27mA \rightarrow D_1 \text{ is on}$$

Q-point $D_1 : (0.27mA, 0V)$

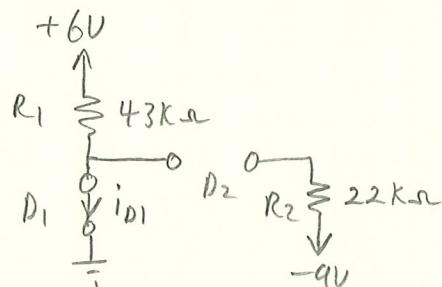
Q-point $D_2 : (0, 409mA, 0V)$

Problem 2b

assume D_1 and D_2 off:



Test with D_1 on and D_2 off:



$$i_{D1} = \frac{6}{43k} = 0.14mA \rightarrow D_1 \text{ is on}$$

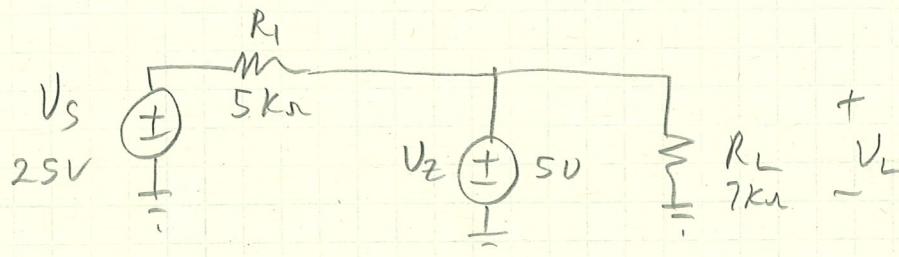
$D_2 \rightarrow$ reverse biased $\rightarrow D_2$ is off : $V_{D2} = -9V$

Q-point $D_1 : (0.14mA, 0V)$

Q-point $D_2 : (0mA, -9V)$

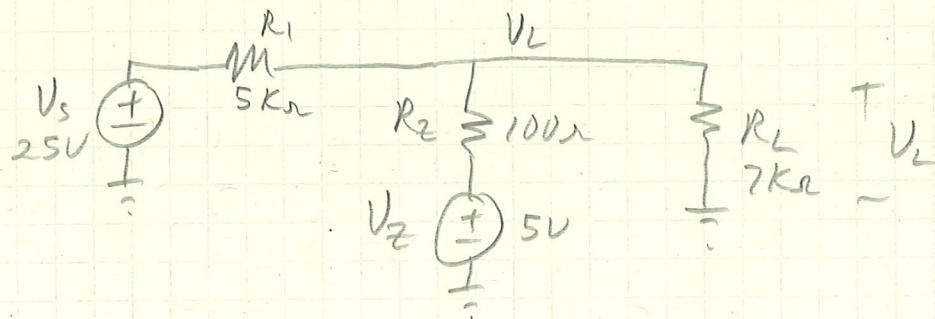
Problem 3

a. Find V_L for $V_Z = 5V$ and $R_Z = 0\Omega$



$$V_L = 5V$$

b. Find V_L for $V_Z = 5V$ and $R_Z = 100\Omega$



From lecture notes:

$$V_L = \frac{\frac{V_s}{R_1} + \frac{V_Z}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_L}} = \frac{\frac{25}{5000} + \frac{5}{100}}{\frac{1}{5000} + \frac{1}{100} + \frac{1}{7000}} = 5.32V$$

$$V_L = 5.32V$$

c. Find $R_{L\min}$ for $V_Z = 5V$ and $R_Z = 0\Omega$

From lecture notes:

$$R_{L\min} = \frac{R_1}{\left(\frac{V_s}{V_Z} - 1\right)} = \frac{5000}{\left(\frac{25}{5} - 1\right)} = 1250\Omega$$

$$R_{L\min} = 1250\Omega$$

Problem 4

Find f_T for NMOS with $L = 1\mu m$, $\mu_n = 1000 \text{ cm}^2/\text{V}\cdot\text{s}$, $V_{GS} = 3.3V$, and $V_{TN} = 1V$

$$L = 1\mu m = 1 \times 10^{-6} \text{ m} = 1 \times 10^{-4} \text{ cm}$$

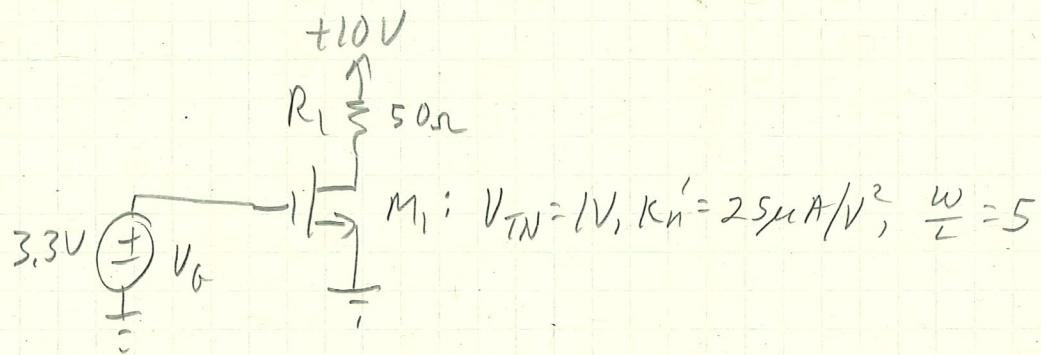
$$f_T = \left(\frac{1}{2\pi}\right) \frac{\mu_n}{(L^2)} (V_{GS} - V_{TN})$$

$$= \left(\frac{1}{2\pi}\right) \left(\frac{1000}{(1 \times 10^{-4})^2}\right) (3.3 - 1)$$

$$= 36.6 \text{ GHz}$$

Problem 5

Find the Q-Point for M_1



$$V_{GS} - V_{TN} = 3.3 - 1 = 2.3V > 0 \therefore M_1 \text{ is on}$$

Assume Saturation mode with $\lambda = 0V^{-1}$

$$\begin{aligned} i_D &= \frac{1}{2} k'_n \left(\frac{W}{L}\right) (V_{GS} - V_{TN})^2 \\ &= \frac{1}{2} (25 \times 10^{-6})(5)(3.3 - 1)^2 \\ &= 330.625 \mu A \end{aligned}$$

$$\begin{aligned} \therefore V_D &= 10 - i_D R_L \\ &= 10 - (330.625 \times 10^{-6})(50) \\ &= 9.983V \end{aligned}$$

$$V_{DS} = 9.983V$$

$$V_{GS} - V_{TN} = 2.3V$$

$\therefore V_{DS} > V_{GS} - V_T \rightarrow m_i$ is in saturation mode

Q-Point: $V_{GS} = 3.3V$, $V_{DS} = 9.983V$, $i_o = 330.625\mu A$