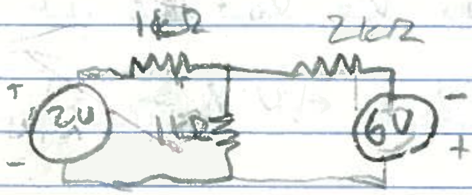
$2+2+2+1+2+2 = 11/12$

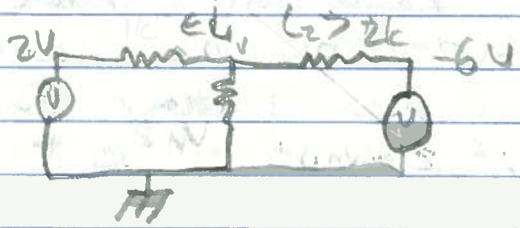
Dan Ports
6.002 PS3

1. The two networks are linear, so their Thevenin equivalents can be found from the graph.

$V_{TH_1} = V_{OC_1} = 2\,V$, $I_{N_1} = I_{SC_1} = 2\,mA$
$\Rightarrow R_{TH_1} = V_{TH_1}/I_{N_1} = 1\,k\Omega$

$V_{TH_2} = V_{OC_2} = -6\,V$, $I_{N_2} = I_{SC_2} = 3\,mA$
$\Rightarrow R_{TH_2} = V_{TH_2}/I_{N_2} = 2\,k\Omega$





$(V_1 - 2V)/1k\Omega + V_1/1k\Omega + (V_1 + 6V)/2k\Omega = 0$
$\Rightarrow 2(V_1 - 2V) + 2V_1 + V_1 + 6V = 0$
$\Rightarrow 2V_1 + 2V_1 + V_1 = 4V - 6V$
$\Rightarrow \boxed{V_1 = V_2 = -2/5\,V}$

$(-2/5\,V - 2V) = i_1 \cdot 1k\Omega \Rightarrow i_1 = -12/5\,V / 1k\Omega$ — 2 V

$(-2/5\,V - -6V) = i_2 \cdot 2k\Omega \Rightarrow i_2 = 28/5\,V / 2k\Omega = 2.8\,m$

2

2. a. W/ $V_s = 0$, the circuit is 3 parallel resistors w/ $R_{eq} = 2k\Omega \,//\, 1k\Omega \,//\, 2k\Omega = 500\,\Omega$, $V_A = I_s R_{eq} = 2mA \cdot 500\,\Omega = 1V$

W/ $I_s = 0$, the circuit is a series parallel combo

By the voltage-divider relation $V_B = -V_s/2 = -2V$
By superposition, $V = V_A + V_B = \boxed{1V - 2V = -1V}$

b. $P = 1V = V^2/R = 1V^2/2k\Omega = \boxed{1/2\ mW}$

2

Using the relation above, $P = V^2/R$, superposition cannot apply power is a non-linear function. $P = (V_A + V_B)^2/R$, not $V_A^2/R + V_B^2/R$

3a. $i_s = v_o/R + v_o^3 = v_o + v_o^3$
$\boxed{5mA = v_o + v_o^3}$ (v_o in Volts)

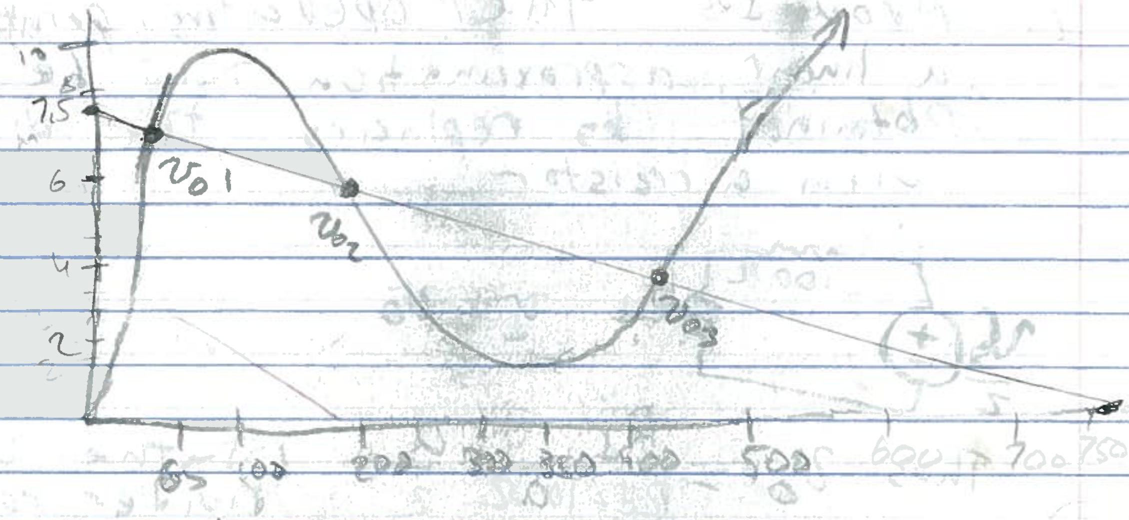
b. $\boxed{V_o \approx 1.516\ V}$

c. $i_D = V_o^3 + 3V_o^2 v_o$

1

$i_s - i_R - i_D = 0$
$\Rightarrow I_s + i_s - V_o/R - v_o/R - V_o^3 - 3V_o^2 v_o = 0$
$\Rightarrow (I_s - V_o/R - v_o/R)^? + i_s - v_o/R - 3V_o^2 v_o = 0$
$\Rightarrow 0 + i_s - v_o/R - 3V_o^2 v_o = 0$
$\Rightarrow i_s = v_o(1/R + 3V_o^2)$
$\Rightarrow i_s = v_o(1/R + 3(1.516V)^2)$
$\Rightarrow \boxed{v_o/i_s = \frac{1}{1 + 3(1.516)^2}} = 1/7.895$ $k\Omega$

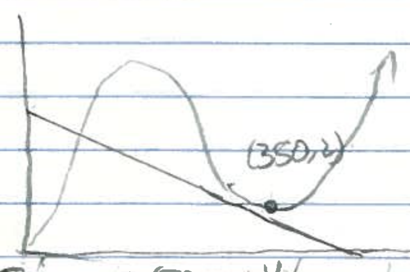
4a



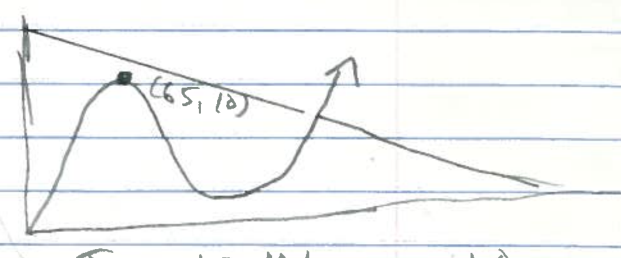
The Thevenin equivalent voltage (at the diode's terminals) $V_s/2 = 750$ mV, and the Thevenin resistance 100 Ω $\Rightarrow I_{sc} = 7.5$ mA

From the graph, operating values exist at about $V \approx 50$ mV, $i \approx 7$ mA, $V \approx 200$ mV, $i \approx 5.5$ mA, and $V \approx 450$ mV, $i \approx 3.5$ m

b. Multiple solutions exist when the load line intersects the nonlinear curve in more than one place. In addition to the graph drawn above, adjusting V_s can give curves that look like:



or



when $I_{sc} - 350\text{ mV}/100\,\Omega < 2$ mA … $I_{sc} - 65\text{ mV}/100\,\Omega > 10$ mA

$\Rightarrow \frac{V_s}{2}/100\,\Omega - 350\text{ mV}/100\,\Omega < 2$ mA $\quad \frac{V_s}{2}/100\,\Omega - \frac{65\text{ mV}}{100\,\Omega} > 10$ mA

$\Rightarrow V_s - 700\text{ mV} < 400$ mV $\quad V_s - 130\text{ mV} > 2$ V

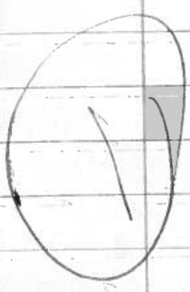
$V_s < 400\text{ mV} + 700$ mV $\quad V_s > 2\text{ V} + 130$ mV

$V_s < 1.1$ V $\quad V_s > 2.13$ V

$\boxed{\text{Thus there are multiple solutions for } 1.1\text{ V} < V_s < 2.13\text{ V (approximately)}}$

1. Around v_S, the operating points a linear approximation can be obtained by replacing the diode with a resistor

Thus $v_0 = \frac{R_d}{R_d + 100\Omega} \frac{v_s}{2}$ by the voltage divider relationship



$$\Rightarrow \frac{v_0}{v_s} = \frac{R_d}{2R_d + 100\Omega},$$

where R_d is the equivalent resistance for small signal components given by

$R_d = \left.\frac{dv_D}{di_D}\right|_{V_D}$ = the reciprocal of the slope of the curve at an operating point

5.

A	B	C	D	O_2	O_1	O_0
0	0	0	0	0	0	0
0	0	0	1	0	0	1
0	0	1	0	0	0	1
0	0	1	1	0	1	0
0	1	0	0	0	0	1
0	1	0	1	0	1	0
0	1	1	0	0	1	0
0	1	1	1	0	1	1
1	0	0	0	0	0	1
1	0	0	1	0	1	0
1	0	1	0	0	1	0
1	0	1	1	0	1	1
1	1	0	0	0	1	0
1	1	0	1	0	1	1
1	1	1	0	0	1	1
1	1	1	1	1	0	0

b.

$O_2 = ABCD$

$O_1 = \bar{A}\bar{B}CD + \bar{A}B\bar{C}D + \bar{A}BC\bar{D} + \bar{A}BCD + A\bar{B}\bar{C}D$
$+ A\bar{B}C\bar{D} + \overline{AB}CD + AB\bar{C}\bar{D} + AB\bar{C}D + ABC\bar{D}$

$O_0 = \bar{A}\bar{B}\bar{C}D + \bar{A}\bar{B}C\bar{D} + \bar{A}B\bar{C}\bar{D} + \bar{A}BCD$
$+ A\bar{B}\bar{C}\bar{D} + A\bar{B}CD + AB\bar{C}D + ABC\bar{D}$

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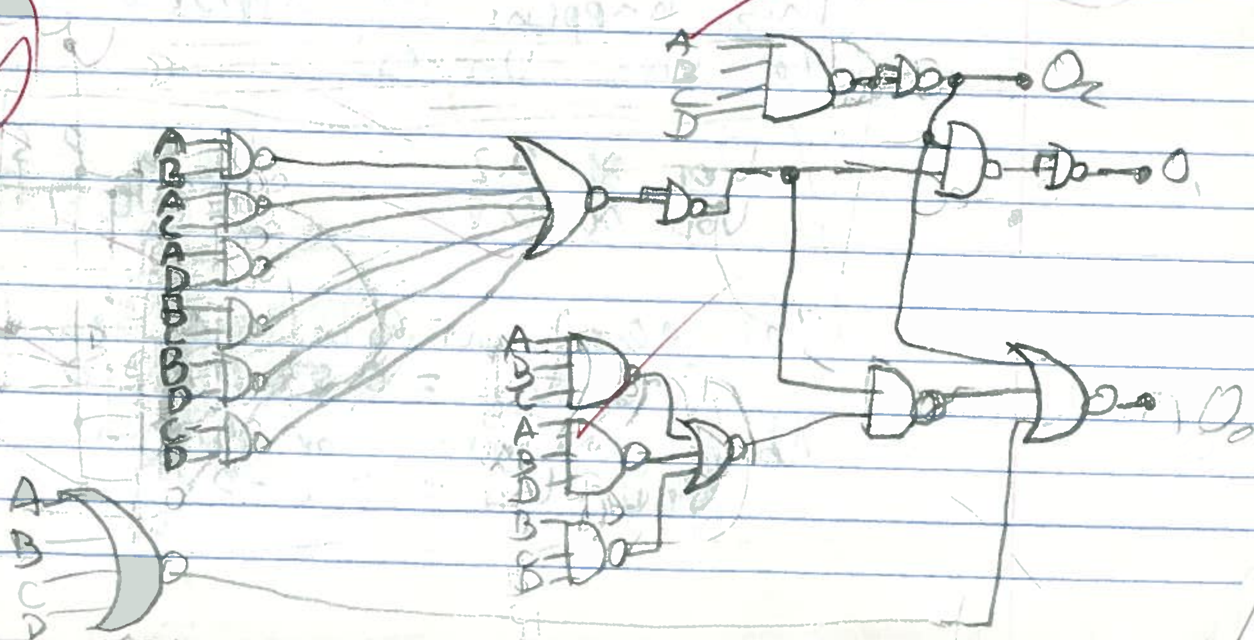
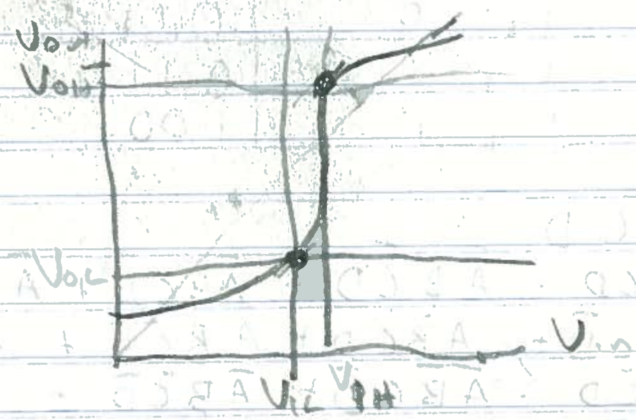


6 a. To have no noise margin, $V_{OL} = V_{IL} = V_{IH} = V_{OH}$. This can only work when the curve intersects the $V_{out} = V_{IN}$ line. This happens at about $V_{in} = V_{out} = 0.65V$

Thus,

$\boxed{V_{OL} = V_{IL} = V_{IH} = V_{OH} = 0.65\ V}$

b. The noise margin is $V_{IL} - V_{OL}$ or $V_{OH} - V_{OL}$. This is maximized when the curve is as far away from the $V_{out} = V_{IN}$ line as possible, i.e. when the slope of the curve is 1



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This happens at approximately the following values:

units?

$V_{OL} \approx 0.2$ $\quad$ $V_{IL} \approx 0.5$

$V_{OH} \approx 0.8$ $\quad$ $V_{IH} \approx 0.7$

The noise margin for low value

$V_{IL} - V_{OL} = 0.5 - 0.2 = 0.3$

Noise margin for high value

$V_{OH} - V_{IH} = 0.8 - 0.7 = 0.1$