Mid-Term Exam

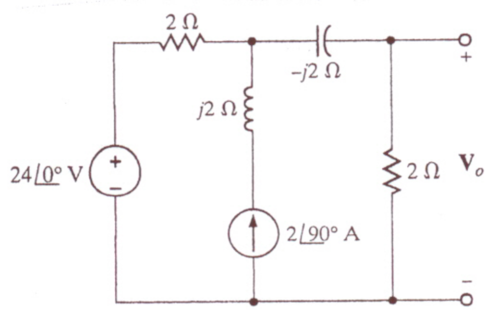
E246 Electronics and Instrumentation (Fall 2005)

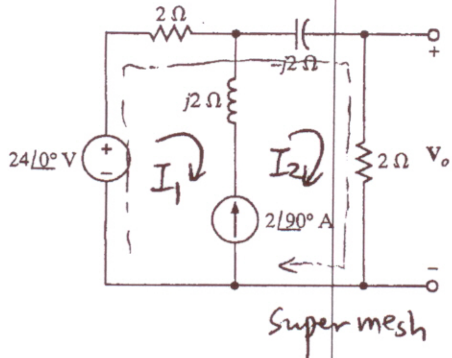
Name: Solutions

SID: ____________

Choose 3 (and only 3) out of 4 problems to solve. Each chosen problem carries equal weight. 100 points total. Do all work in the spaces provided. Show all work and organize it for partial credit. Include units in your answer. Open book, open notes.

Problem 1. Given the circuit shown below, find its Thevenin equivalent circuit in the frequency domain.





Solution: ① Find Vo:

KVL along supermesh:

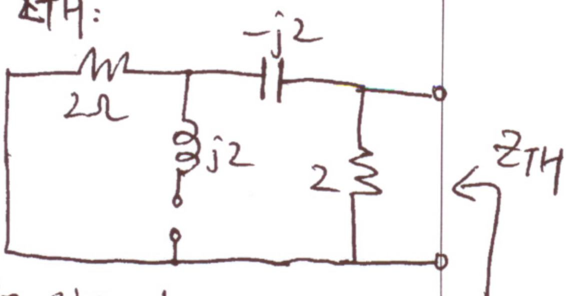
$$\begin{cases} -24\angle 0^\circ + 2I_1 - j2I_2 + 2I_2 = 0 \\ I_2 - I_1 = 2\angle 90^\circ \end{cases}$$

$$\Rightarrow \begin{cases} 2I_1 + (2-j2)I_2 = 24 \\ I_1 = I_2 - j2 \end{cases}$$

$$\Rightarrow I_2 = 4.4 + j3.2 = 5.44\angle 36^\circ$$

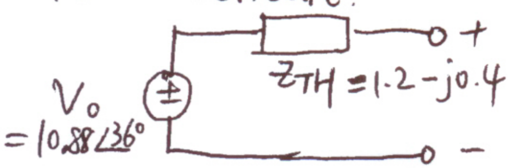
$$\Rightarrow V_o = 2 \cdot I_2 = 10.88\angle 36^\circ$$

②. Find Z_{TH}:



$$Z_{TH} = 2 \,||\, (2-j2) = \frac{2\times(2-j2)}{2+(2-j2)} = \frac{6}{5} - j\frac{2}{5} = 1.2 - j0.4 = 1.26\angle -18.43$$

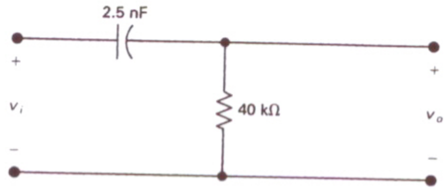
③. Thevenin circuit:



Problem 2. For the high-pass filter shown below,

1) find its transfer function $H(jw)=\frac{V_0}{V_1}$;
2) find its break frequency w_c;
3) find the magnitude and angle of H(jw) at w_c, 0.1 w_c, and 10 w_c;
4) If v_i=800cos(wt) mV, write the steady-state expression for V_0 when w= w_c.

Note that 1 nF=10^{-9} F.



$V_1 = V_i$

1). $H(jw) = \frac{V_0}{V_1} = \frac{R}{R+\frac{1}{jwC}} = \frac{jRwC}{jwRC+1} = \frac{jw\times 40\times10^3\times2.5\times10^{-9}}{jw\times40\times10^3\times2.5\times10^{-9}+1}$

$= \frac{jw}{jw+10^4}$

2). $H(jw) = \frac{jw}{jw+10^4} = \frac{w}{\sqrt{w^2+10^8}} \angle (90^\circ - \tan^{-1}\frac{w}{10^4})$

Let $\frac{w}{\sqrt{w^2+10^8}} = \frac{1}{\sqrt{2}}$, $\Rightarrow w = 10^4$ this is the break frequency

3). $H(jw)\big|_{w=10^4} = \frac{j10,000}{j10,000+10,000} = 0.7071\angle 45^\circ$

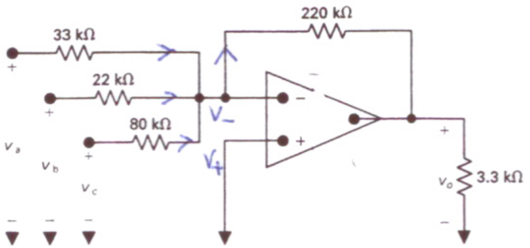
$H(jw)\big|_{w=0.1\times10^4} = \frac{j1,000}{j1,000+10,000} = 0.0995\angle 84.29^\circ$

$H(jw)\big|_{w=10\times10^4} = \frac{j100,000}{j100,000+10,000} = 0.9950\angle 5.71^\circ$

4). $V_0 = V_1 \cdot H(jw_c) = 800\angle 0^\circ \times \frac{j\times10,000}{j10,000+10,000} = 565.69\angle 45^\circ$

So $V_0(t) = 565.69\cos(10,000t+45^\circ)$ mV.

Problem 3. An op amp circuit is shown below. The bottom of the circuit is connected to the ground. Find v_0 if v_a=1.2V, v_b=-1.5v, and v_c=4V.



$$\frac{-V_- + V_a}{33K} + \frac{-V_- + V_b}{22K} + \frac{-V_- + V_c}{80K} = \frac{V_- - V_o}{220K}$$

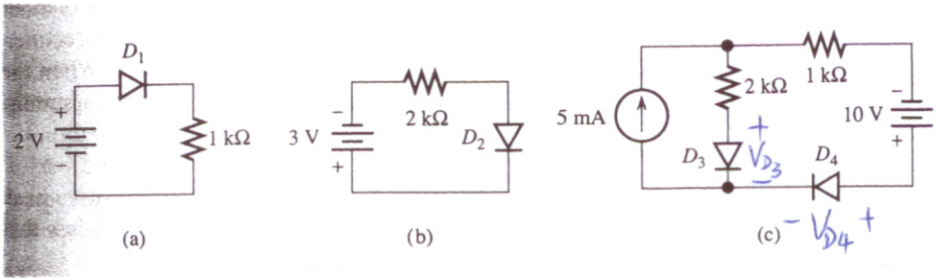
$$V_- = V_+ = 0$$

$$\Rightarrow \quad V_o = -\left(\frac{220}{33} V_a + \frac{220}{22} V_b + \frac{220}{80} V_c\right)$$

$$= -\left(\frac{220}{33} \times 1.2 + \frac{220}{22} \times (-1.5) + \frac{220}{80} \times 4\right.$$

$$= -4V.$$

Problem 4. Determine the diode states (i.e., on or off) for the circuits shown below. Assume ideal diodes.



...ution:

a). D_1 is on.

b). D_2 is off.

c). D_3 is off and D_4 is on.

This can be seen by replacing [D_3] and D_4 with very small resistance δD_3, δD_4, and working out $V_{D_3} <$ [0], $V_{D_4} > 0$.