DEPARTMENT OF ELECTRONIC AND COMPUTER ENGINEERING
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

ELEC 2400 ELECTRONIC CIRCUITS

Midterm Exam

20:00 – 21:30 28 Oct 2021 LTB

Name: ______________________________

Student No.: ______________________________

Department: ______________________________

Questions	Maximum Scores	Scores
1	11	
2	11	
3	11	
4	11	
5	11	
6	11	
7	11	
8	11	
9	12	
Total	100	

1. Answer **all** questions in the space provided.
2. This is a **closed book** examination. No additional sheet is allowed.
3. Show all your calculations clearly. No marks will be given for unjustified answers.

The HKUST Academic Honor Code

Honesty and integrity are central to the academic work of HKUST. Students of the University must observe and uphold the highest standards of academic integrity and honesty in all the work they do throughout their program of study.

As members of the University community, students have the responsibility to help maintain the academic reputation of HKUST in its academic endeavors.

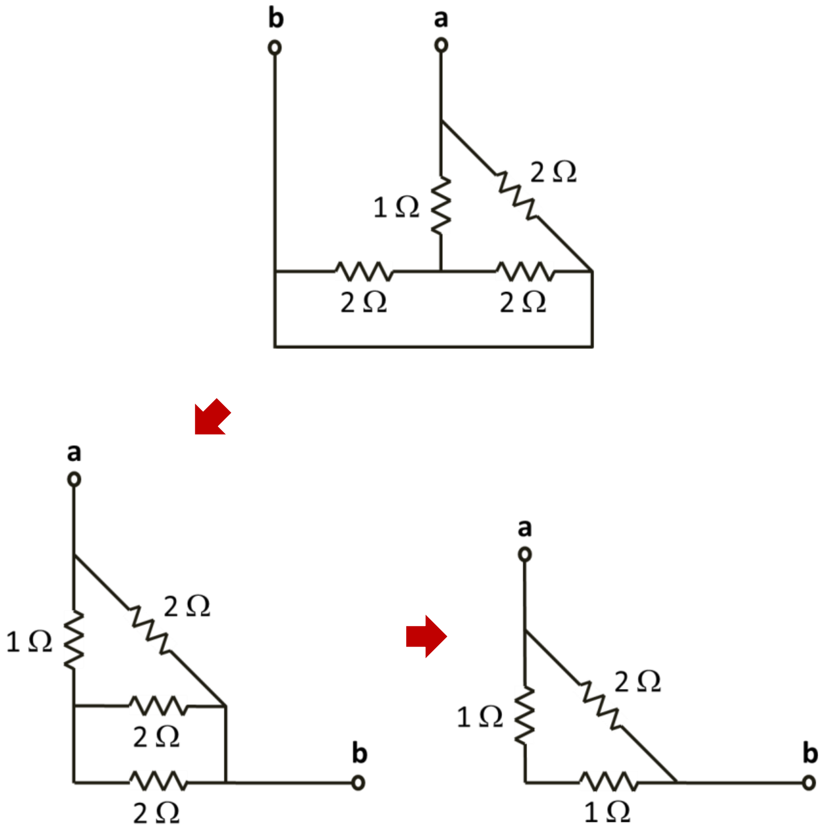
Sanctions will be imposed on students, if they are found to have violated the regulations governing academic integrity and honesty.

Declaration of Academic Integrity

I confirm that I have answered the questions using only materials specifically approved for use in this examination, that all the answers are my own work, and that I have not received any assistance during the examination.

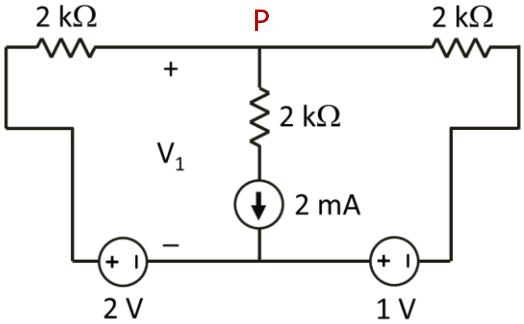
Student's Signature: ______________________________

1. Find the equivalent resistance between the terminals a and b of the below resistor network.



$$R_{\mathrm{EQ}} = (1 + 1)||2 = 1\ \Omega$$

2. Find the voltage V_1.



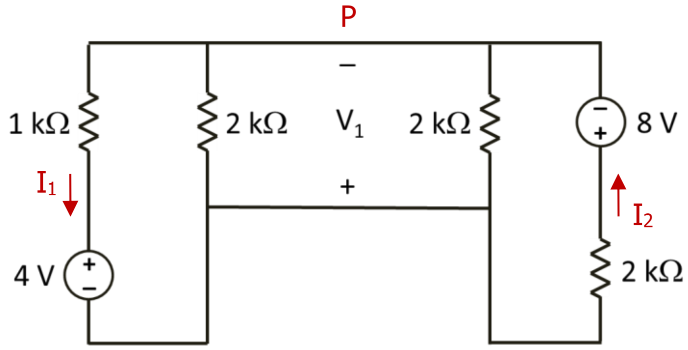
Apply KCL to node P:

$$\frac{V_1 - 2}{2\mathrm{k}} + \frac{V_1 + 1}{2\mathrm{k}} + 2\mathrm{m} = 0$$

$$V_1 - 2 + V_1 + 1 + 4 = 0$$

$$V_1 = -1.5\ \mathrm{V}$$

3. Consider the circuit below.



(a) Find the voltage V_1.
(b) Compute the power for the 4-V and 8-V voltage sources, and specify whether each is supplying power or absorbing power (dissipating power).

Apply KCL to node P:

$$\frac{V_1 + 4}{1\text{k}} + \frac{V_1}{2\text{k}} + \frac{V_1}{2\text{k}} + \frac{V_1 - 8}{2\text{k}} = 0$$

$$2V_1 + 8 + V_1 + V_1 + V_1 - 8 = 0$$

$$V_1 = 0 \text{ V}$$

Apply KVL to the left mesh:

$$4 + I_1 \times 1\text{k} = 0$$
$$I_1 = -4 \text{ mA}$$

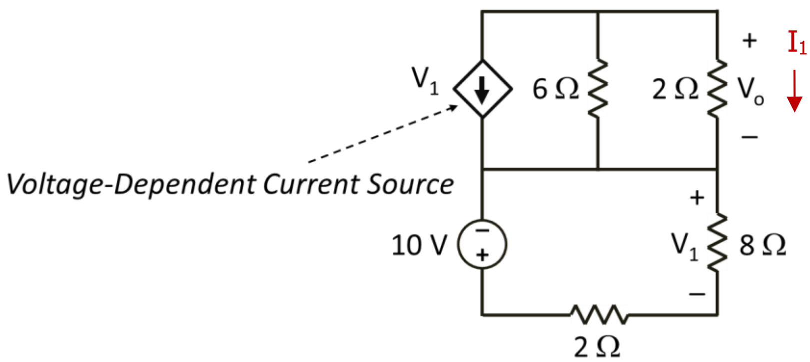
Hence, for the 4-V voltage source, DC power $= 4I_1 = -16$ mW, supplying.

Apply KVL to the right mesh:

$$I_2 \times 2\text{k} + 8 = 0$$
$$I_2 = -4 \text{ mA}$$

Hence, for the 8-V voltage source, DC power $= 8I_2 = -32$ mW, supplying.

4. The circuit below contains a voltage-dependent current source. Find the voltage V_o.



The 2-Ω and 8-Ω resistors at the bottom are connected in series. They form a voltage divider in which

$$V_1 = -10\left(\frac{8}{8+2}\right) = -8$$

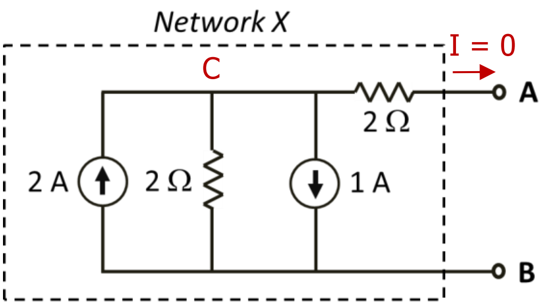
The 2-Ω and 6-Ω resistors at the top are connected in parallel. They form a current divider in which

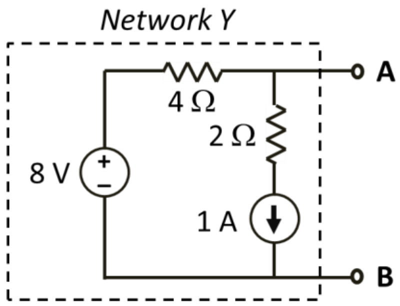
$$I_1 = -V_1\left(\frac{6}{6+2}\right) = 6$$

Hence

$$V_o = 2I_1 = 12 \text{ V}$$

5. Is the network X equivalent to the network Y? Present a proof or a disproof.





We seek to compare the Thevenin's equivalents of Network X and Network Y.

Open-circuit voltage V_{OC}:
For Network X, apply KCL to node C:

$$\frac{V_{CB}}{2} - 2 + 1 = 0$$

$$V_{CB} = 2$$

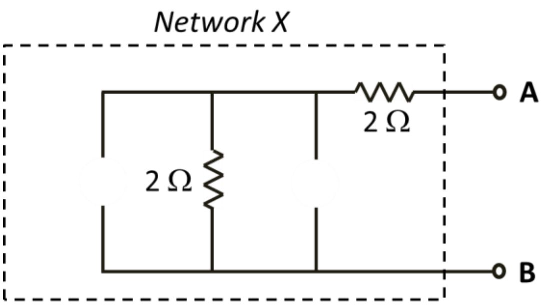
$$V_{OC} = V_{AB} = V_{AC} + V_{CB} = 0 + 2 = 2 \text{ V}$$

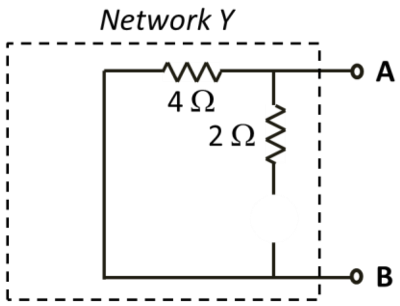
Network Y:

$$V_{OC} = V_{AB} = 8 - 1 \times 4 = 4 \text{ V}$$

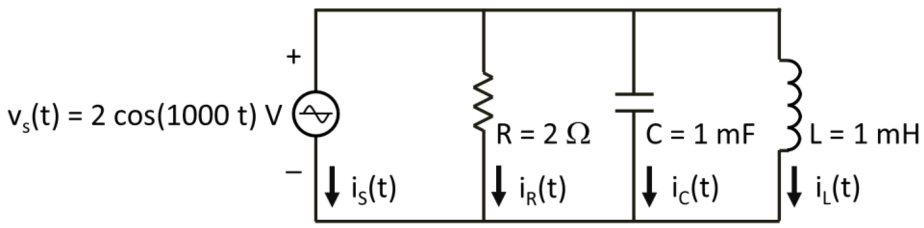
The two V_{OC}'s are different. Hence Network X is NOT equivalent to Network Y. This completes the disproof.

(On the other hand, the equivalent resistances of the two networks are the same. Specifically, $R_{AB} = 4\,\Omega$ for both networks. This is evident after the independent voltage and current sources are set to zero as shown below. However, this is not necessary for the disproof.)





6. Consider the circuit below.



(a) Draw all the impedances (Z_R, Z_C and Z_L) in one impedance diagram.
(b) Draw all the phasor currents (I_S, I_R, I_C and I_L) in one phasor diagram.
(c) Evaluate $i_S(t)$, $i_R(t)$, $i_C(t)$ and $i_L(t)$ at t = 2 ms.

(a) $\omega = 1000$ rad/s. Hence

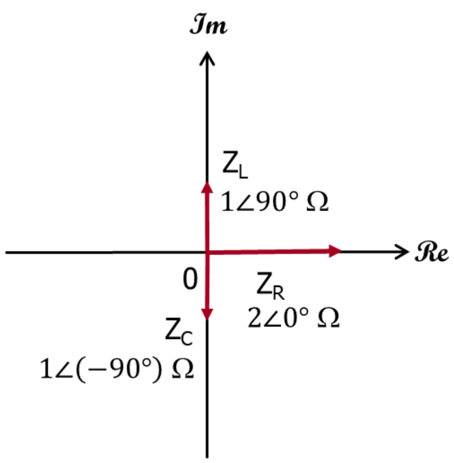
$$Z_R = 2\ \Omega$$
$$Z_C = 1/(j1000 \times 1\text{m}) = -j\ \Omega$$
$$Z_L = j1000 \times 1\text{m} = j\ \Omega$$

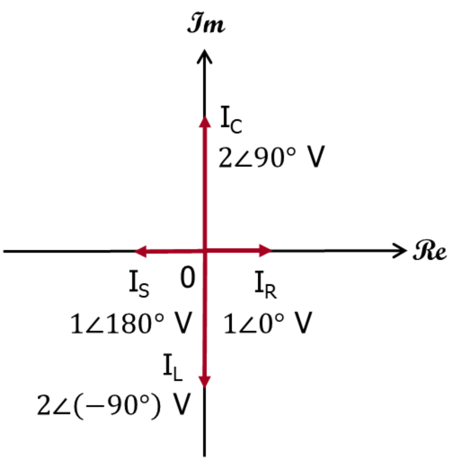
(b) $V_S = 2\angle 0° = 2$ V,

Hence
$$I_R = V_S/Z_R = 2/2 = 1\angle 0° \text{ A}$$
$$I_C = V_S/Z_C = 2/(-j) = j2 = 2\angle 90° \text{ A}$$
$$I_L = V_S/Z_L = 2/j = -j2 = 2\angle(-90°) \text{ A}$$
$$I_S = -I_R - I_C - I_L = -1\angle 0° = 1\angle 180° \text{ A}$$

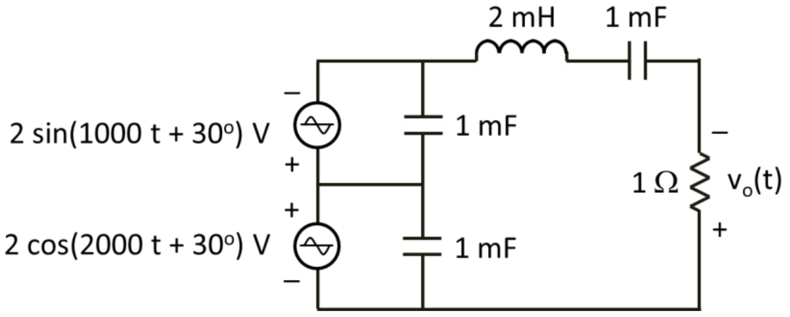
(c) At $t = 2$ ms,

$$i_S(t) = -\cos(1000t) = -\cos(2) = 0.416 \text{ A}$$
$$i_R(t) = \cos(1000t) = \cos(2) = -0.416 \text{ A}$$
$$i_C(t) = 2\cos(1000t + 90°) = 2\cos\left(2 + \frac{\pi}{2}\right) = -1.82 \text{ A}$$
$$i_L(t) = 2\cos(1000t - 90°) = 2\cos\left(2 - \frac{\pi}{2}\right) = 1.82 \text{ A}$$



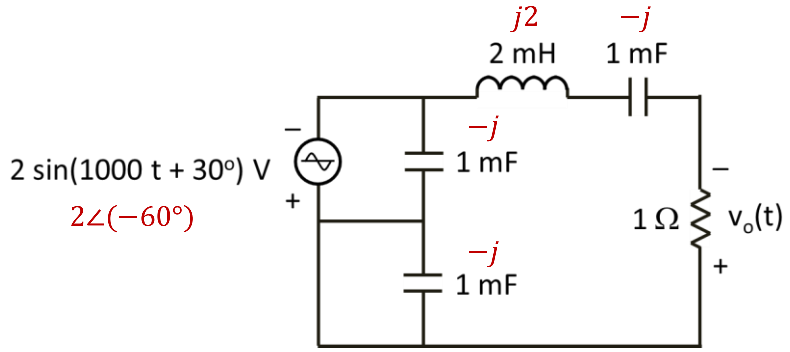


7. Find the output voltage $v_o(t)$.



Note that the two voltage and sources are at different frequencies. We have no option but to use superposition.

Part 1: with only the top voltage source, the circuit looks like this:



The impedances are as marked and the $\sin(1000t + 30°)$ function is replaced by $\cos(1000t - 60°)$ before converting to a phasor.

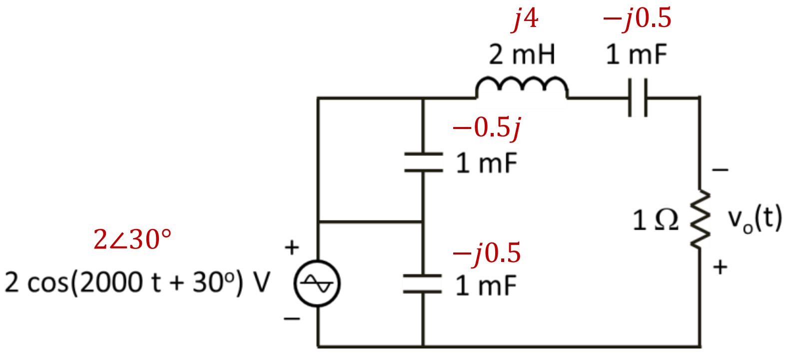
The inductor, capacitor and resistor are connected in series. They form a voltage divider in which

$$V_o = 2\angle(-60°)\left(\frac{1}{j2 - j + 1}\right) = \frac{2\angle(-60°)}{1 + j} = \frac{2\angle(-60°)}{\sqrt{2}\angle 45°} = \sqrt{2}\angle(-105°) = 1.41\angle(-105°)$$

Hence

$$v_o(t) = 1.41\cos(1000t - 105°)$$

Part 2: with only the bottom voltage source, the circuit looks like this:



The inductor, capacitor and resistor are connected in series. They form a voltage divider in which

$$V_o = -2\angle 30° \left(\frac{1}{j4 - j0.5 + 1}\right) = \frac{-2\angle 30°}{1 + j3.5} = \frac{2\angle 210°}{3.640\angle 74.05°} = 0.549\angle 136°$$

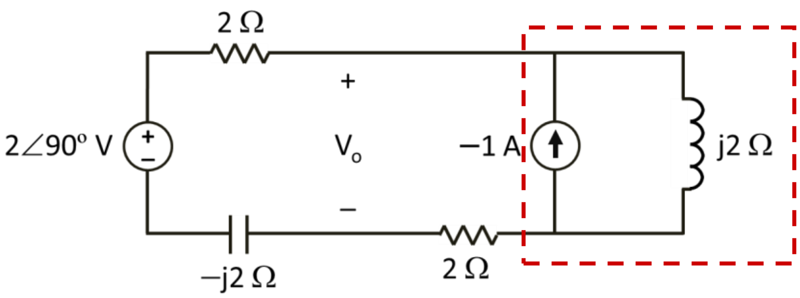
Hence

$$v_o(t) = 0.549\cos(2000t + 136°)$$

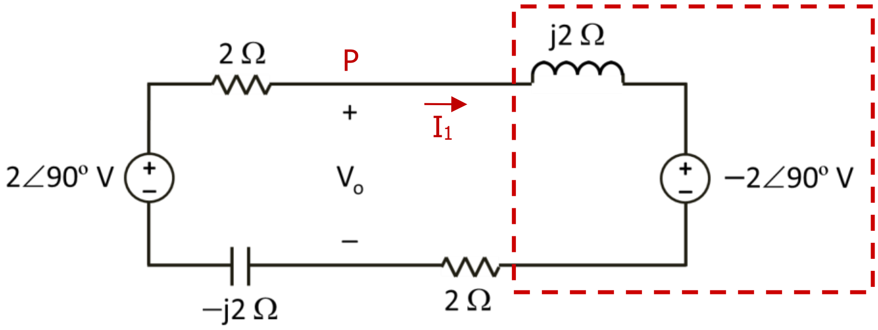
Finally, by superposition:

$$v_o(t) = 1.41\cos(1000t - 105°) + 0.549\cos(2000t + 136°) \text{ V}$$

8. Find the voltage V_o and write the answer in polar form.



By converting the sub-circuit inside the red box to its Thevenin's equivalent, the circuit is simplified to the one below having only a single mesh.



Method 1 – Apply KVL to the mesh:

$$I_1 = \frac{2\angle 90° + 2\angle 90°}{2 + 2 + j2 - j2} = \frac{j2 + j2}{4} = j$$

Hence

$$V_o = I_1 \times j2 - 2\angle 90° + I_1 \times 2 = -2 - j2 + j2 = -2 = 2\angle 180° \text{ V}$$

Method 2 – Apply KCL to node P:

$$\frac{V_o - 2\angle 90°}{2 - j2} + \frac{V_o + 2\angle 90°}{2 + j2} = 0$$

$$\frac{V_o - j2}{1 - j} + \frac{V_o + j2}{1 + j} = 0$$

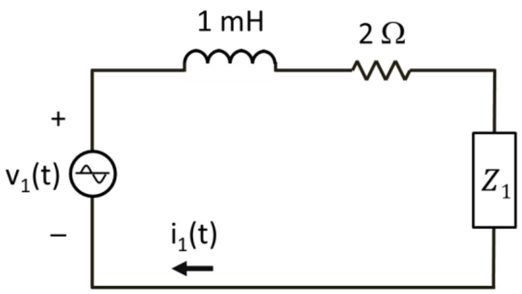
$$(V_o - j2)(1 + j) + (V_o + j2)(1 - j) = 0$$

$$V_o(1+j+1-j)+j2(1-j-1-j)=0$$

$$2V_o+j2(-j2)=0$$

$$V_o=-2=2\angle 180°\ \text{V}$$

9. In the following circuit, find the unknown element Z_1 (either a resistor, inductor or capacitor), and its resistance, inductance or capacitance value.



Given:
$v_1(t) = V_p \sin(2000\,t + 20°)$ V
$i_1(t) = I_p \sin(2000\,t + 20°)$ A

V_p and I_p are both unknown.

Notice that $v_1(t)$ and $i_1(t)$ are in phase. The total impedance formed by the inductor, resistor, and Z_1 connected in series must therefore be real, i.e.,

$$Z_L+Z_R+Z_1=\frac{V_1}{I_1}=\frac{V_p\angle(20°-90°)}{I_p\angle(20°-90°)}=\frac{V_p}{I_p}=\mathcal{R}eal$$

Since Z_R is real,

$$Z_L+Z_1=\mathcal{R}eal$$

The impedance of the inductor, $Z_L = j2000 \times 1\text{m} = j2\ \Omega$. Hence Z_1 can only be a capacitor of capacitance C, where

$$Z_1=\frac{1}{j2000C}=-j2$$

$$C=0.25\ \text{mF}$$

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< Rough work paper >

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