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

ELEC 2400 ELECTRONIC CIRCUITS

Midterm Exam

20:00 – 21:45 29 Oct 2020 Online

Name: ______________________________

Student No.: ______________________________

Department: ______________________________

Questions	Maximum Scores	Scores
1	10	
2	10	
3	10	
4	10	
5	10	
6	12	
7	13	
8	12	
9	13	
Total	100	

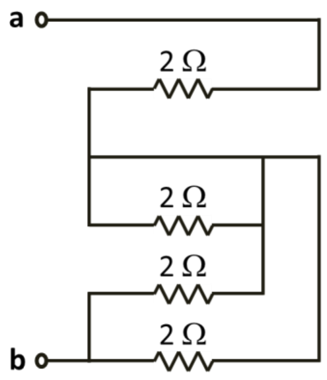
1. Answer **all** questions.
2. This is an **open book** examination.
3. Calculators are allowed.
4. Write down your answers on **clean** A4 paper. Show all your steps and calculations clearly. No marks will be given for unjustified answers.
5. Arrange all answer sheets in the correct order. Write down the correct page number at the upper right corner of the answer sheets. Your name and student number should be written on each answer sheet.
6. Scan or take a photo of all your answer sheets.
7. Upload a softcopy (PDF) of your answer sheets to CANVAS (Midterm Exam Paper).
8. Send one copy to Ricky CHOI at eericky@ust.hk as backup. You should use your ZOOM display name as the name of the PDF file.

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.

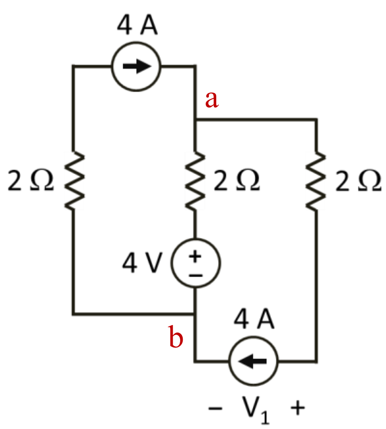
Student's Signature: ______________________________

Q1. [10 points] Find the equivalent resistance between terminals a and b of the resistor network below.



$$R_{eq} = 2 + 0||2 + 2||2 = 2 + 0 + 1 = 3\ \Omega$$

Q2. [10 points] Find the voltage V_1 in the circuit below.

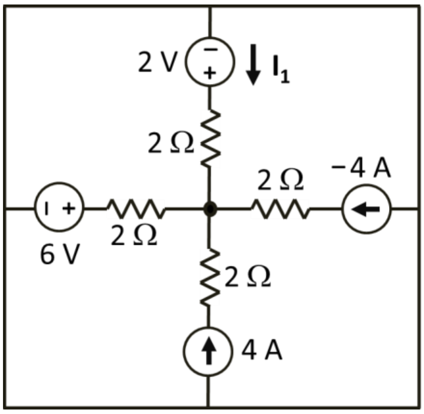


A key observation is that there is no current coming down the middle branch. You can verify this by applying KCL to node b. Then applying KVL to the right mesh,

$$V_{ab} = 4 = 4 \times 2 + V_1$$

$$V_1 = -4\text{ V}$$

Q3. [10 points] Find the current I_1 in the circuit below.



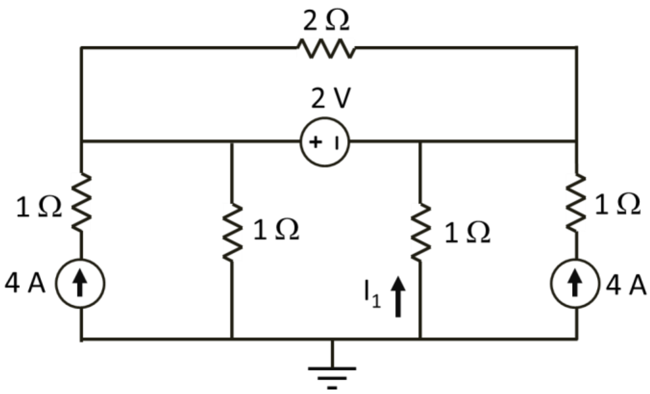
By applying KCL to the center node, we can see that the 4 A current coming from below completely flows out to the right. Hence the current I_1 coming from above completely flows out to the left.

Apply KVL to the top-left mesh,

$$2 - 2I_1 - 2I_1 - 6 = 0$$

$$I_1 = -1\ A$$

Q4. [10 points] Find the current I_1 in the circuit below.



One way to solve the problem is by superposition.

1) Left 4 A source alone. The voltage source is short-circuited:
   There is no current going through the 2 Ω resistor because it is shorted. The remaining current divider divides the 4 A current in two halves. Hence

$$I_1 = -2\ \mathrm{A}$$

2) Right 4 A source alone:
   Same as 1) above since the circuit is left and right symmetric. Hence

$$I_1 = -2\ \mathrm{A}$$

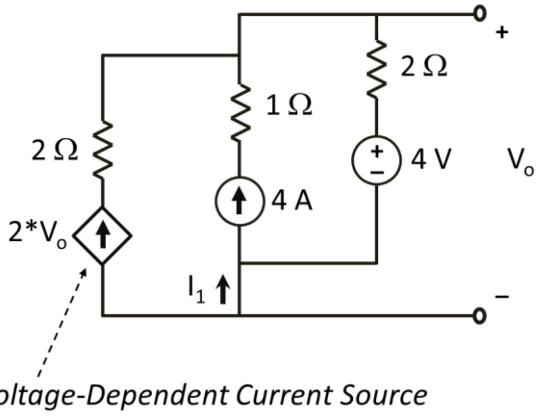
3) 2 V source alone. The two current sources are open-circuited:

$$I_1 = \frac{2}{1+1} = 1\ \mathrm{A}$$

By superposition,

$$I_1 = -2 - 2 + 1 = -3 \text{ A}$$

Q5. [10 points] Find the voltage V_o and the current I_1 in the circuit below.



Apply KCL to the bottom node,

$$2V_o + 4 - \frac{V_o - 4}{2} = 0$$

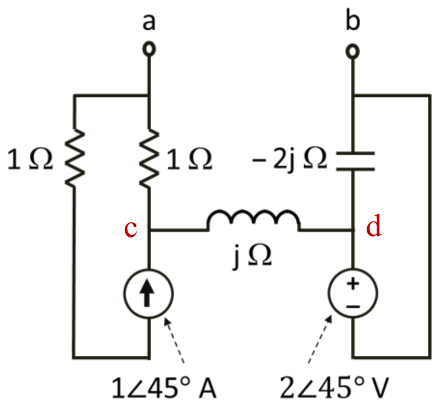
$$4V_o + 8 - V_o + 4 = 0$$

$$V_o = -4 \text{ V}$$

On the other hand,

$$I_1 = -2V_o = 8 \text{ A}$$

Q6. [12 points] Find the Norton's equivalent circuit with respect to terminals a and b, and write the answers in polar form. Draw the Norton's equivalent circuit. (Hint: you could find the Thevenin's open-circuit voltage first but this is optional.)



Equivalent impedance:

$$Z_{eq} = 1 + j + (-2j)||0 = \sqrt{2}\angle 45° \ \Omega$$

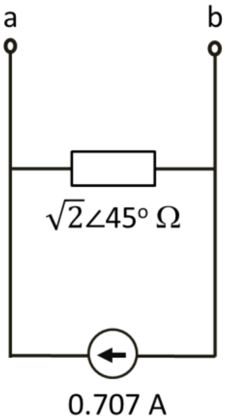
Open-circuit voltage:
The 1∠45° A current only flows around the left mesh. There is no current going through the inductor.

$$V_{oc} = V_{ab} = V_{ac} + V_{cd} + V_{db} = -1\angle 45° + 0 + 2\angle 45° = \angle 45° \text{ V}$$

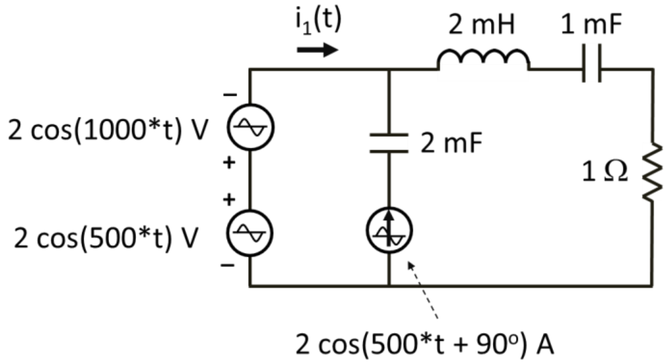
Short-circuit current:

$$I_{sc} = \frac{V_{oc}}{Z_{eq}} = \frac{\angle 45°}{\sqrt{2}\angle 45°} = \frac{1}{\sqrt{2}}\angle 0° = 0.707 \text{ A}$$

The Norton's equivalent circuit is as shown below. Note the correct direction of the short-circuit current.



Q7. [13 points] Find the current $i_1(t)$ in the circuit below.



The excitations are of different frequencies. We can't combine them together. Superposition is the only way to go.

At ω = 500 rad/s, the impedances of the 1 mF capacitor, 2 mF capacitor, and 1 mH inductor are 1/(j*0.5k*1m) = –2j Ω, 1/(j*0.5k*2m) = –j Ω, and j*0.5k*2m = j Ω, respectively.

At ω = 1000 rad/s, the impedances of the 1 mF capacitor, 2mF capacitor, and 1 mH inductor are 1/(j*1k*1m) = –j Ω, 1/(j*1k*2m) = –0.5j Ω, and j*1k*2m = 2j Ω, respectively.

1) For the $2\cos(1000t)$ V source alone:

$$I_1 = \frac{-2}{2j - j + 1} = \frac{-2}{1+j} = -1 + j = \sqrt{2}\angle 135°$$

2) For the $2\cos(500t)$ V source alone:

$$I_1 = \frac{2}{j - 2j + 1} = \frac{2}{1-j} = 1 + j$$

3) For the $2\cos(500t + 90°)$ A source alone:

$$I_1 = -2\angle 90° = -2j$$

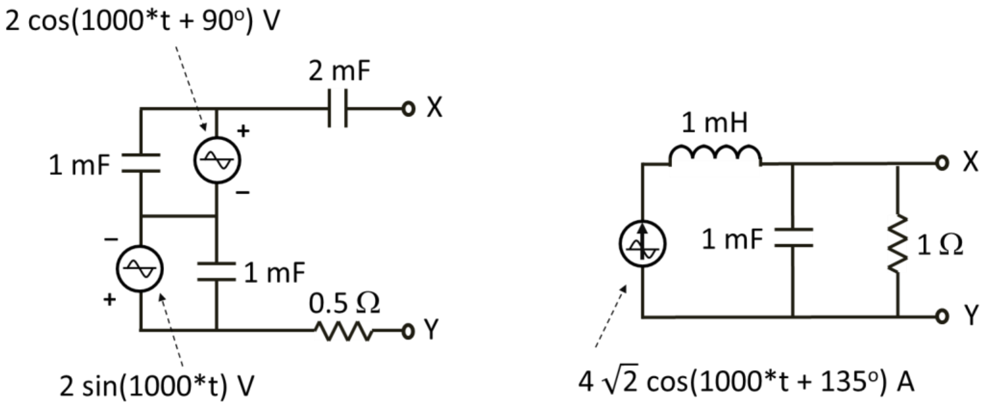
Since 2) and 3) are at the same frequency, we can combine the results to give

$$I_1 = 1 - j = \sqrt{2}\angle(-45°)$$

Combining the result from 1),

$$i_1(t) = \sqrt{2}\cos(1000t + 135°) + \sqrt{2}\cos(500t - 45°)$$

Q8. [12 points] Is the network A equivalent to the network B? Present a proof or a disproof.



Network A

Network B

We seek to find the Thevenin's equivalent circuits for both networks.

Network A:
The two voltage sources are at the same frequency, with ω = 1k rad/s.
The phasor representations for the top and bottom voltage sources are $2\angle 90°$ V and $2\angle(-90°)$ V, respectively.
The 1 mF capacitor impedance is 1/(j*1k*1m) = –j Ω.
The 2 mF capacitor impedance is 1/(j*1k*2m) = –0.5j Ω.

$$Z_{eq} = 0.5 - 0.5j\ \Omega$$

$$V_{oc} = V_{XY} = 2\angle 90° - 2\angle(-90°) = 2j - (-2j) = 4j = 4\angle 90°\ \text{V}$$

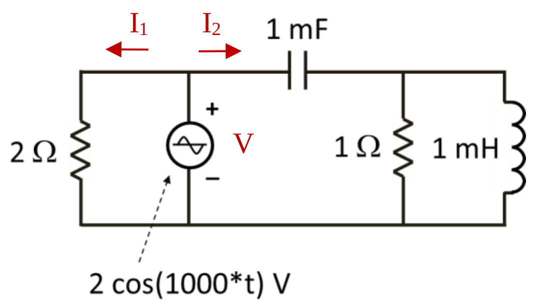
Network B:
The current source is at the same frequency as that in Network A, with ω = 1k rad/s.
The 1 mF capacitor impedance is 1/(j*1k*1m) = –j Ω.
The 1 mH inductor impedance is j*1k*1m = j Ω.

$$Z_{eq} = 1||(-j) = \frac{-j}{1-j} = \frac{-j(1+j)}{2} = 0.5 - 0.5j = \frac{\angle(-45°)}{\sqrt{2}}\ \Omega$$

$$V_{oc} = V_{XY} = 4\sqrt{2}\angle 135° \times 1||(-j) = 4\sqrt{2}\angle 135° \times \frac{\angle(-45°)}{\sqrt{2}} = 4\angle 90°\ \text{V}$$

Network A and B have the same Thevenin's equivalent circuit as evident by identical Z_{eq} and V_{oc}. Hence Network A is equivalent to Network B.

Q9. [13 points] Consider the circuit below. Compute the average AC power for each circuit element and specify whether each circuit element is supplying AC power, absorbing AC power (dissipating power) or neither.



With ω = 1k rad/s:
The 1 mF capacitor impedance is 1/(j*1k*1m) = –j Ω.
The 1 mH inductor impedance is j*1k*1m = j Ω.

1) The capacitor and inductor consume zero average AC power. They are neither supplying nor absorbing power.

2) For the R = 2 Ω resistor,

$$\text{Average AC power} = \frac{1}{2}\frac{|V|^2}{R} = \frac{2^2}{2 \times 2} = 1\ \text{W, absorbing}$$

$$I_1 = \frac{V}{R} = \frac{2\angle 0°}{2} = 1\ \text{A}$$

3) For the 1 Ω resistor, we can determine the average AC power for the entire right branch consisting of the capacitor, inductor and resistor, and attribute 100% of the power to the 1 Ω resistor since the capacitor and inductor consume zero power. Let Z be the impedance of the right branch.

   The current going into the branch

$$I_2 = \frac{V}{Z} = \frac{2}{-j + (1||j)} = \frac{2}{-j + \frac{j}{1+j}} = \frac{2(1+j)}{-j(1+j)+j} = 2 + 2j = 2\sqrt{2}\angle 45°\ \text{A}$$

$$\text{Average AC power of right branch} = \frac{1}{2} \times 2 \times 2\sqrt{2}\cos(0° - 45°) = \frac{2^2\sqrt{2}}{2\sqrt{2}} = 2\ \text{W, absorbing}$$

   This must be the average AC power absorbed by the 1 Ω resistor.

4) For the voltage source, the total current coming down is

$$-I_1 - I_2 = -1 - (2 + 2j) = 3.606\angle(-146.3°)$$

$$\text{Average AC power} = \frac{1}{2} \times 2 \times 3.606\cos(0° + 146.3°) = -3\ \text{W, generating}$$

As a final check, the net average AC power for the entire circuit is zero. Hence the AC power balance is satisfied.

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