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

ELEC 2400 ELECTRONIC CIRCUITS

Midterm Exam Solution

19:30 – 21:00 21 Mar 2019 LTJ

Name: ______________________________

Student No.: ______________________________

Department: ______________________________

Questions	Maximum Scores	Scores
1	6	
2	10	
3	13	
4	12	
5	12	
6	13	
7	10	
8	12	
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.

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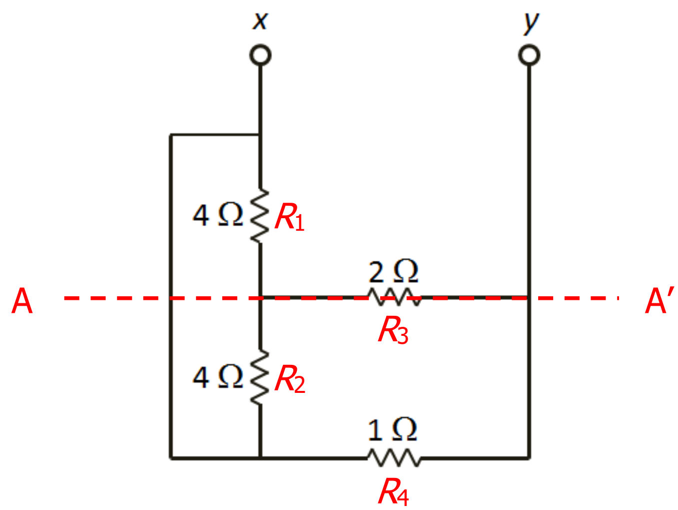
Declaration of Academic Integrity

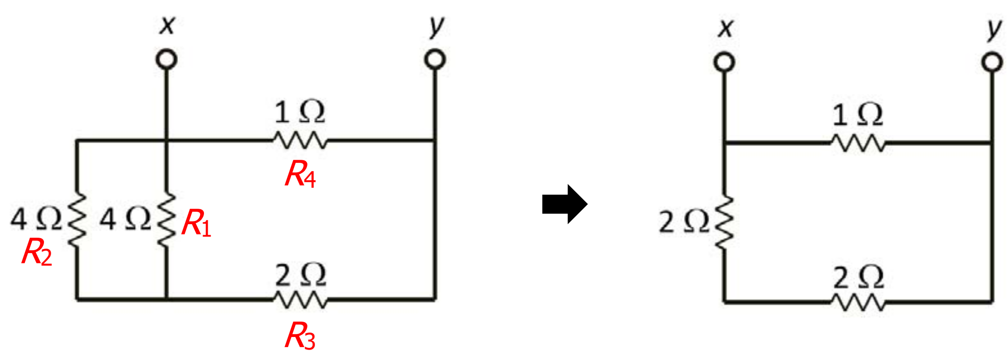
I confirm that I have answered the questions using only materials specifically approved for use in this examination, that all the answers are my own work, and that I have not received any assistance during the examination.

Student's Signature: ______________________________

1. Find the equivalent resistance between the terminals x and y of the below resistor network.



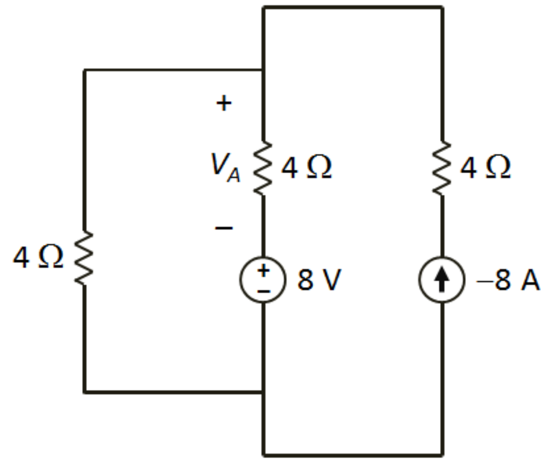
Solution:
A key observation is that we can flip resistors R_2 and R_4 about the line A-A′ and redraw the original circuit as follows:



The equivalent resistance is therefore

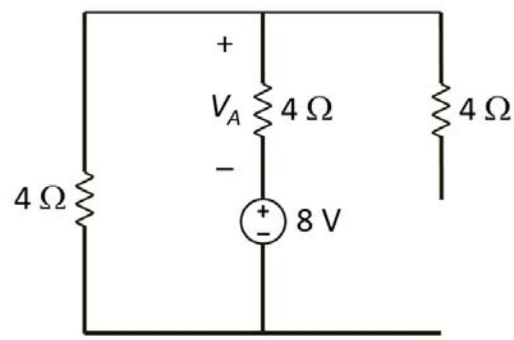
$$(2 + 2) \parallel 1 = 4 \parallel 1 = \frac{4}{5} = 0.8\ \Omega$$

2. Find the voltage V_A using superposition.



Solution:

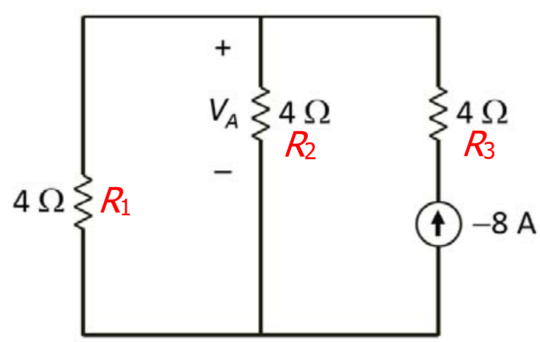
(1) V_A due to the 8-V source alone:
The reduced circuit is as shown on the right.
From which, $V_A = -4\ \mathrm{V}$.



(2) V_A due to the -8-A source alone:
The reduced circuit is as shown on the right.
R_1 and R_2 divide the -8-A current equally. The presence of R_3 doesn't matter.

Therefore

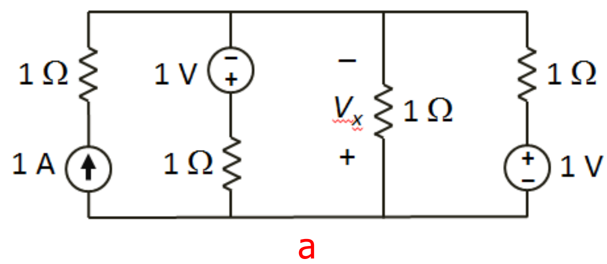
$$V_A = -4\ \mathrm{A} \times 4\ \Omega = -16\ \mathrm{V}$$



(3) By superposition

$$V_A = -4 - 16 = -20\ \mathrm{V}$$

3. Use nodal analysis to find the voltage V_x in the below circuit.

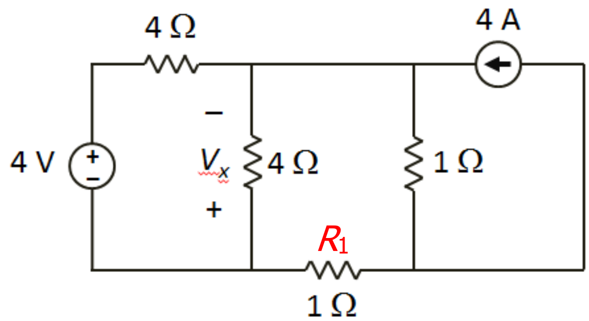


Solution:
Summing all the currents originating from node a:

$$1 + \frac{V_x - 1}{1} + \frac{V_x}{1} + \frac{V_x + 1}{1} = 0$$

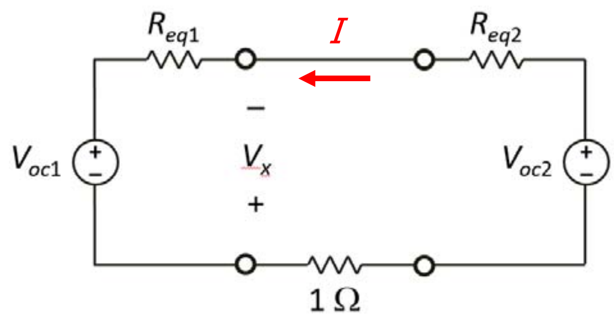
Solving to yield $V_x = -\frac{1}{3}$ V.

4. Use source transformation to find the voltage V_x in the below circuit.

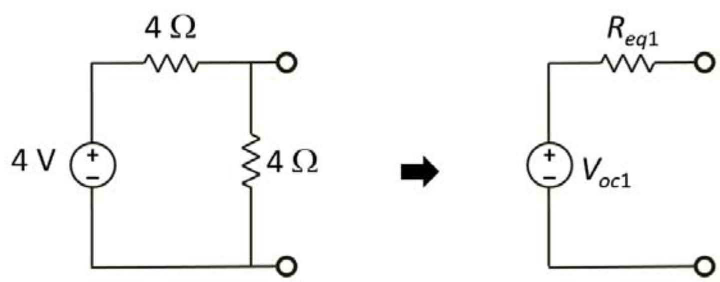


Solution:
Given the cross connection due to R_1, *one way* is to transform both the left and right sides of the circuit to their Thevenin's equivalents. This will lead to a readily solvable circuit as shown in below:

Fig. A



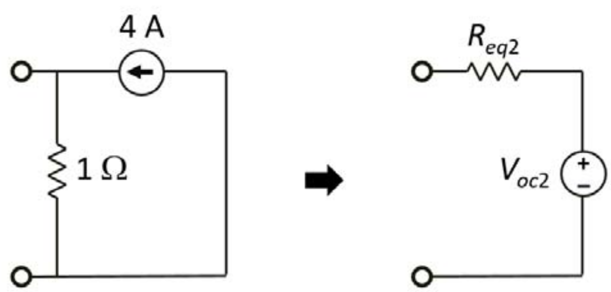
Left side:



for which:

$$V_{oc1} = 2\ \text{V}, \quad R_{eq1} = 4 \parallel 4 = 2\ \Omega$$

Right side:



for which:

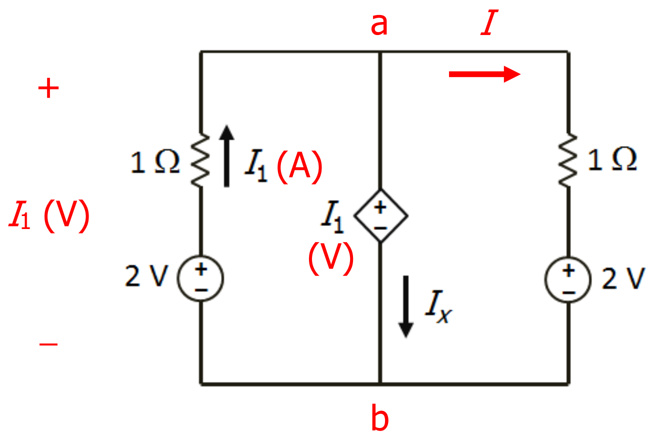
$$V_{oc2} = 4\ \text{A} \times 1\ \Omega = 4\ \text{V}, \quad R_{eq2} = 1\ \Omega$$

Now back to Fig. A,

$$I = \frac{V_{oc2} - V_{oc1}}{R_{eq1} + R_{eq2} + 1} = \frac{4-2}{2+1+1} = 0.5\ \text{A}$$

$$V_x = -V_{oc1} - IR_{eq1} = -2 - 0.5 \times 2 = -3\ \text{V}$$

5. The circuit below contains a current-dependent voltage source. Find the current I_x.



Solution:
The tricky part is that I_1 represents both a current and a voltage, as shown in above.

The middle branch of the circuit says $V_{ab} = I_1$ V.

For the left branch:

$$I_1 \text{ V} = 2 \text{ V} - I_1 \text{ A} \times 1 \text{ }\Omega$$

$$\text{or } \; I_1 = 2 - I_1 \; \text{ yielding } \; I_1 = 1$$

For the right branch:

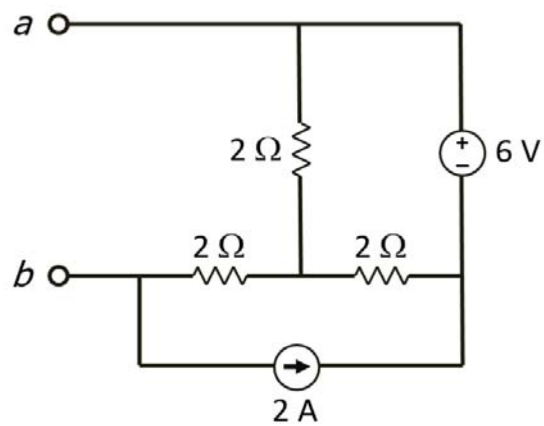
$$I_1 \text{ V} = 2 \text{ V} + I \text{ A} \times 1 \text{ }\Omega$$

$$\text{or } \; I_1 = 2 + I \; \text{ yielding } \; I = I_1 - 2 = -1 \text{ A}$$

Finally,

$$I_x = I_1 - I = 1 - (-1) = 2 \text{ A}$$

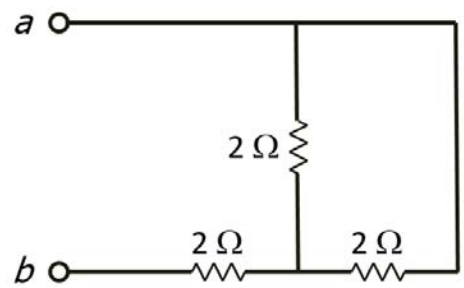
6. (a) Find the Norton's equivalent circuit with respect to the terminals *a*, *b* for the below circuit.



Solution:

(1) R_{eq}:

With all the independent sources zeroed out, the remaining circuit looks like this:

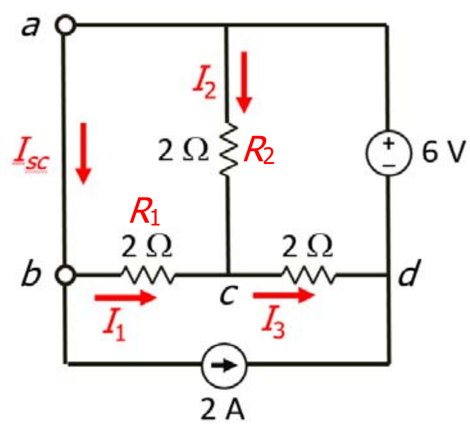


From which,

$$R_{eq} = 2 + (2 \parallel 2) = 3\ \Omega$$

(2) I_{sc}:

The circuit for I_{sc} calculation looks like this:



Here we label a few currents, resistors, and additional nodes as shown on the right.

A key observation is that $I_1 = I_2$ because $R_1 = R_2$ and their voltage drops are also the same. (In fact, the two resistors are connected in parallel).

Now

$$I_3 = I_1 + I_2 = 2I_1$$

From $V_{bd} = V_{ad} = 6\ \mathrm{V}$, we get

$$V_{bd} = 6\ V = I_1 \times 2\ \Omega + I_3 \times 2\ \Omega = 3I_1 \times 2\ \Omega$$

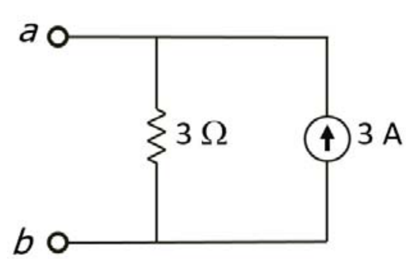
This yields $I_1 = 1\ \mathrm{A}$.

Hence

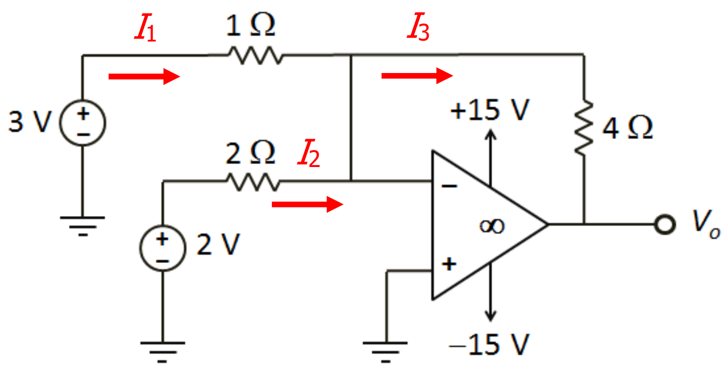
$$I_{sc} = I_1 + 2\ \mathrm{A} = 3\ \mathrm{A}$$

(continue)

(b) Draw the Norton's equivalent circuit found in part (a).



7. Assuming the op amp in the below circuit is ideal, find the output voltage V_o.



Solution:
Assuming that the op amp is not saturated, $V_- = V_+ = 0\text{ V}$.

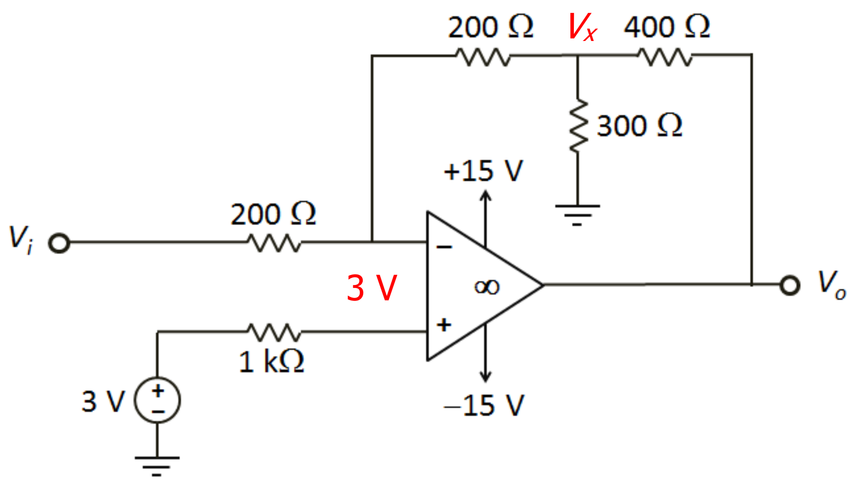
Then $I_1 = \frac{3\,V}{1\,\Omega} = 3\text{ A}$, $I_2 = \frac{2\,V}{2\,\Omega} = 1\text{ A}$.

Since $I_3 = I_1 + I_2 = 4\text{ A}$,

$$V_o = -I_3 \times 4\,\Omega = -16\text{ V}$$

However, this will be below the –15-V supply. So V_o will saturate just above –15 V.

8. Assume the op amp is ideal. Find the output voltage V_o of the amplifier structure in terms of the input voltage V_i shown below.



Solution:
There is no input current entering V_+. Assuming that the op amp is not saturated, $V_+ = V_- = 3\text{ V}$.

Applying KCL at node V_-:

$$\frac{V_i - 3}{200} = \frac{3 - V_x}{200}$$

giving

$$V_x = 6 - V_i \qquad (1)$$

Applying KCL at node V_x:

$$\frac{V_x - 3}{200} + \frac{V_x}{300} + \frac{V_x - V_o}{400} = 0$$

$$6V_x - 18 + 4V_x + 3V_x - 3V_o = 0$$

giving

$$V_o = \tfrac{13}{3}V_x - 6 \qquad (2)$$

Combining (1) and (2)

$$V_o = \tfrac{13}{3}(6 - V_i) - 6 = -\tfrac{13}{3}V_i + 20\text{ V} \qquad (3)$$

(a) When $V_o = 15\text{ V}$, $V_i = \frac{15}{13}\text{ V}$. When $V_o = -15\text{ V}$, $V_i = \frac{105}{13}\text{ V}$.

So as long as

$$\tfrac{15}{13}\text{ V} \le V_i \le \tfrac{105}{13}\text{ V}$$

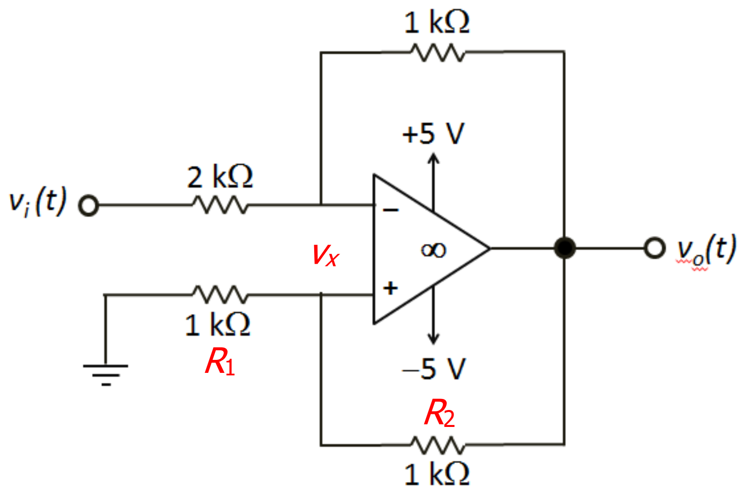
the op amp is not saturated and V_o will be given by (3).

However,

(b) For $V_i < \frac{15}{13}\text{ V}, V_o$ will saturate at just below 15 V.

(c) For $V_i > \frac{105}{13}\text{ V}, V_o$ will saturate at just above –15 V.

9. Assuming the op amp in the below circuit is ideal,
   (a) find the output voltage $v_o(t)$ in terms of the input voltage $v_i(t)$.
   (b) Plot $v_o(t)$ when $v_i(t) = t$, for $0 \le t \le 4$.



Solution:
Assuming that the op amp is not saturated, let $v_+ = v_- = v_x$.

Notice that R_1 and R_2 form a voltage divider, resulting in $v_x = \frac{v_o}{2}$.

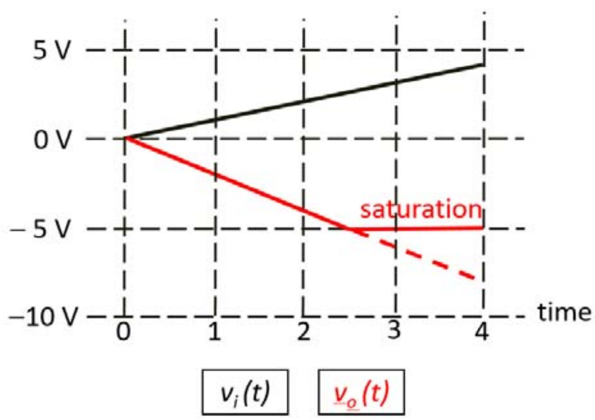
Applying KCL at V_-:

$$\frac{v_i - v_x}{2\text{k}} = \frac{v_x - v_o}{1\text{k}}$$

$$v_i = 3v_x - 2v_o = 3\left(\frac{v_o}{2}\right) - 2v_o = -\frac{v_o}{2}$$

(a) Therefore $$v_o(t) = -2v_i(t)$$

(b) Below is a plot of $v_o(t)$ vs. $v_i(t)$. Notice the saturation of $v_o(t)$ due to the lower supply voltage at −5 V.



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