Ryerson University
Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

ELE 202
Electric Circuit Analysis
LAB COVER PAGE for Part I submission.

Lab #:	3	Lab Title:	Resistive networks

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First Name:	
Student #:	
***Signature*:**	

Section #:	4
Submission date and time:	June 6 2022
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Document submission for Part I:

- A completed and signed "COVER PAGE – **Part I**" has to be included with your submission. The report will not be graded if the signed cover page is not included.
- Your completed handwritten pages of **Section 4.0** should be scanned (via a scanner or phone images), together with the required MultiSIM images. **Note:** *MultiSIM results must be generated using the Department's licensed version of MultiSIM, and the captured screenshots should show your name (at the center-top) and the timestamp (at the bottom-right corner of your screen).*
- Collate and create a ***.pdf*** or ***.docx*** file of the above, and upload it via D2L **any time prior to the start of your scheduled lab**. Upload instructions are provided on D2L.

Zero marks will be assigned for the entire lab if this Part I is not submitted prior to your scheduled lab.

**By signing above, you attest that you have contributed to this submission and confirm that all work you have contributed to this submission is your own work. Any suspicion of copying or plagiarism in this work will result in an investigation of Academic Misconduct and may result in a "0" on the work, an "F" in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at: www.ryerson.ca/senate/current/pol60.pdf.*

Ryerson University
Department of Electrical, Computer, & Biomedical Engineering
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ELE 202
Laboratory #3

Resistive Network Analysis Methods – *Nodal and Mesh*

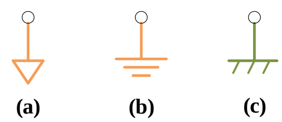
1.0 INTRODUCTION

Electric circuit analysis is the process of finding voltages across and currents through every component element in the network. Relatively simple resistive circuits can be analyzed by directly applying Kirchhoff's laws in combination with Ohm's law, as was done in the previous laboratory exercise. However, as the circuits become structurally more complicated and involve increasingly more component elements, this direct method becomes onerous. To aid in the analysis of such complex circuits, two powerful circuit analysis techniques – ***nodal*** analysis and ***mesh*** analysis – are commonly used.

Nodal analysis is a method of determining the voltage at the nodes in a circuit with respect to a "***reference***" node, using Kirchhoff's Current Law (**KCL**). *Mesh* analysis is a method that is used to solve for the current through any component element in a planar circuit, using Kirchhoff's Voltage Law (**KVL**). Either method used yields the same results; the choice often depends on a personal preference or on the intuitiveness of the analysis method better suited for a particular structural configuration of the circuit elements in a network.

As noted above, *nodal* analysis requires selecting a circuit node as the "***reference***". The *reference* node is commonly referred to as "***ground***" since it is assumed to have, or be at, **zero** potential. A *reference* node is indicated by any of the three symbols in **Figure 1.0**.

Figure 1.0: Common symbols for a *reference* node



The symbol in **Figure 1.0a** can be used to indicate a "*common ground*" reference node. When the potential of the earth is used as a reference, this common ground symbol can be interchanged with the symbol of an "*earth ground*" in **Figure 1.0b**. For most circuits, the symbol in **Figure 1.0b** often gets used to denote a common "***ground***" reference node even when not connected to the earth's potential. The type of ground in **Figure 1.0c** is referred to as a "*chassis ground*" and is used in devices where the case, enclosure, or chassis acts as the reference point for all circuits in the device.

Although *theoretically* the choice of a reference node for a circuit is arbitrary, *practically* the choice for the reference node is often obvious. For example, the node with the most *branches* is usually a good choice. For more practical circuits, the node that represents the **negative terminal** of an input power source to which most circuit branches connect is often an intuitive "***ground***" reference point to use. All *unreferenced* node voltages in a circuit are then defined in an absolute sense with respect to this "***ground***" reference node.

References: (i) Course Textbook: "*Fundamentals of Electric Circuits*" by C. K. Alexander and M. N. O. Sadiku; and (ii) "*Electric Circuits*" by J. W. Nilsson and S. A. Riedel

2.0 OBJECTIVES

- To understand the concept of circuit *reference* node.
- To experimentally verify *nodal* and *mesh* analysis techniques on a D.C. resistive circuit.

3.0 Required LAB EQUIPMENT & PARTS

- Digital Multimeter (DMM) and Power Supply
- ELE202 Lab Kit: various components, breadboard, wires and jumpers.

4.0 PRE-LAB: ASSIGNMENT

(a) *Circuit Reference Node*

(i) For the circuit shown in **Figure 2.0a**, the input D.C. source voltage, **E = 15 V** and node "**d**" is selected as the *reference node* connected to the circuit ground, $\mathbf{V_d = 0\ V}$. Calculate the current, **I** and the voltage at node "**a**" (=$\mathbf{V_a}$), node "**b**" (=$\mathbf{V_b}$), and node "**c**" (=$\mathbf{V_c}$) with respect to the ground *reference node*. From these node voltages, calculate the resistor voltages, $\mathbf{V_{ab}}$, $\mathbf{V_{bc}}$, and $\mathbf{V_{cd}}$ across resistors $\mathbf{R_1}$, $\mathbf{R_2}$ and $\mathbf{R_3}$, respectively. Record all the results in **Table 2.0**.

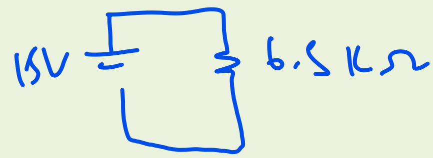
Pre-Lab workspace

$V_A = 15V$

$V_{AB} = 2.308V$

$V_{BC} = 5.07V$

$V_{CD} = 7.615V$



$I = 2.3\ mA$

$V_{AB} = V_A - V_B = 2.308V$

$15 - 2.3V = V_B$

$12.692 = V_B$

$V_{BC} = V_B - V_C = 5.07V = V_C$

$12.692 - 5.07 = V_C$

$7.622 = V_C$

$V_A = 15V$

$V_B = 12.692V$

$V_C = 7.622V$

(ii) Construct the circuit of **Figure 2.0a** in MultiSIM. With node "**d**" as the *reference node*, measure the current, **I**, the node voltages $\mathbf{V_a}$, $\mathbf{V_b}$ and $\mathbf{V_c}$, and the voltages across $\mathbf{R_1}$ (=$\mathbf{V_{ab}}$), $\mathbf{R_2}$ (=$\mathbf{V_{bc}}$), and $\mathbf{R_3}$ (=$\mathbf{V_{cd}}$), respectively. Record all the results in **Table 2.0**.

- Copy and paste a screenshot showing one MultiSIM readings on the circuit. Include the MultiSIM circuit file (**.ms14**) in your Pre-Lab submission.
- All screenshots should show your name printed on the center-top of the MultiSIM screen and the timestamp at the bottom-lower corner.

(iii) **Relocate** the circuit ground *reference node* at node "c" as shown in **Figure 2.0b**, thereby making $\mathbf{V_c}$ **= 0V**. Then repeat above steps **(i)** and **(ii)** but with calculations/measurements of node voltages $\mathbf{V_a}$**,** $\mathbf{V_b}$ and $\mathbf{V_d}$ with respect to reference node "c"; and circuit element voltages across $\mathbf{R_1}$ (=$\mathbf{V_{ab}}$), $\mathbf{R_2}$ (=$\mathbf{V_{bc}}$), and $\mathbf{R_3}$ (=$\mathbf{V_{cd}}$) as before.

(iv) Comment on the results in **Table 2.0** obtained for both cases (when *reference point* at "**d**" and *reference point* at "**c**"). State clearly which one of the currents, node voltages, or element voltages have changed or remain unchanged; and explain why.

Pre-Lab workspace

Only change present in individual node voltages
I, V_{AB}, V_{BC}, V_{CD} are unchanged.
This makes sense since only the ref node was changed, without a change to any element that would affect the total V/i in the circuit.

$i = \frac{15}{6.5k} = 2.308$ mA

$V_{CD} = 7.615V = V_c - V_D$

$-7.615 = V_D$

$V_{BC} = V_B - V_C = 5.07V$

$V_B = 5.07V$

$V_{AB} = V_A - V_B = 2.308V$

$V_A = 2.308 + 5.07$

$= 7.378$

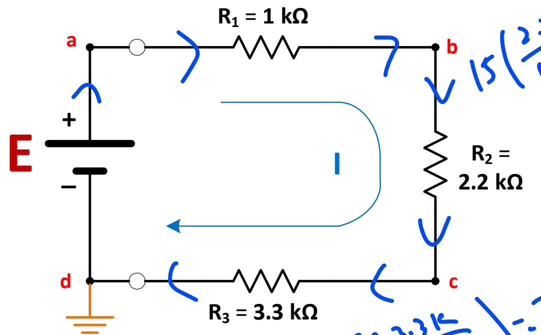
$15\left(\frac{1k}{6.5k}\right) = 2.308V$

$15\left(\frac{1k}{6.5k}\right) = 2.308V$

$15\left(\frac{2.2k}{6.5k}\right) = 5.07V$

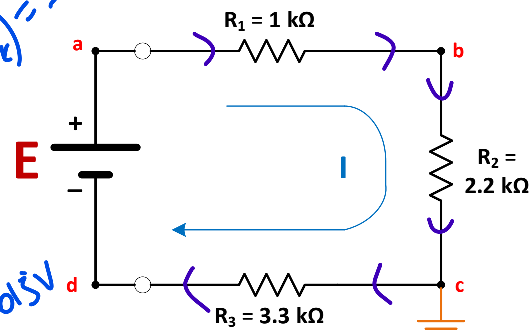
$15\left(\frac{2.2k}{6.5k}\right) = 5.07V$

15V



$15\left(\frac{3.3k}{6.5k}\right) = 7.615V$

Figure 2.0a: Circuit reference node at "**d**"



$15\left(\frac{3.3k}{6.5k}\right) = 7.615V$

Figure 2.0b: Circuit reference node at "**c**"

		Using *Reference* Node "**d**"	Using *Reference* Node "**c**"
I (mA)	Theoretical value =>	2.3 mA	2.308 mA
	MultiSIM value =>	2.308 mA	2.308 mA
V_a (Volts)	Theoretical value =>	15V	7.378V
	MultiSIM value =>	15 V	7.38 V
V_b (Volts)	Theoretical value =>	12.69 V	5.07V
	MultiSIM value =>	12.69V	5.077V
V_c (Volts)	Theoretical value =>	7.622 V	0
	MultiSIM value =>	7.01 V	0
V_d (Volts)	Theoretical value =>	0	-7.613 V
	MultiSIM value =>	0	-7.615 V
V_{ab} (Volts)	Theoretical value =>	2.308V	2.308V
	MultiSIM value =>	2.308V	2.308V
V_{bc} (Volts)	Theoretical value =>	5.07 V	5.077 V
	MultiSIM value =>	5.077V	5.077
V_{cd} (Volts)	Theoretical value =>	7.61V	7.613 V
	MultiSIM value =>	7.615V	7.615

Table 2.0: Theoretical and MultiSIM results of the Figure 2.0 circuits

(b) *Nodal and Mesh Analysis*

Consider the circuits in **Figure 3.0**, and assume input power supply, **E = 15V.**

(i) ***Nodal Analysis:*** Select node "**d**" as a *ground reference* node as shown in **Figure 3.0a**. Using the *nodal analysis* technique, calculate the node voltages **V_a**, **V_b** and **V_c** . Using theses calculated node voltages, determine the value of the branch current, **I_X** and the branch voltage, **V_X**. Record all your results in **Table 3.0.**

Pre-Lab workspace

$A = 15v$

B:

$0 = \frac{V_B - V_A}{2.2} + \frac{V_B - V_c}{5.1} + \frac{V_B}{3.3}$

$\frac{15}{2.2} = 0.9536 V_B - \frac{1}{5.1} V_c$

C:

$0 = \frac{V_c - V_A}{1.0} + \frac{V_c - V_B}{5.1} + \frac{V_c}{1.0}$

$15 = \left(\frac{1}{1} + \frac{1}{5.1} + \frac{1}{1}\right) V_c - \frac{V_B}{5.1}$

$V_B = 8.714\ V$

$V_c = 7.608V$

$I_X = \frac{V_{BD}}{3.3k} = \frac{8.714}{3.3k} = 2.64\ mA$

$V_X = V_A - V_c = 15 - 7.608 = 7.392$

(ii) ***Mesh Analysis:*** Using the *mesh analysis* technique on the circuit shown in **Figure 3.0b**, calculate the mesh currents I_A, I_B and I_C; and determine the branch currents, I_1, I_2, I_3 and I_X; and the branch voltage, V_X. Record all your results in **Table 3.0**.

Pre-Lab workspace

LA:

$0 = -15 + 2.2K(i_A - i_C) + 3.3K(i_A - i_B)$

$15 = 5.5K i_A - 2.2K i_C - 3.3K i_B$

LB:

$0 = 3.3K(i_B - i_A) + 5.1K(i_B - i_C) + 1K i_B$

$0 = 9.4K i_B - 3.3K i_A - 5.1K i_C$

$i_A = 10.249 mA$

$i_B = 7.608 mA$

$i_C = 7.39 mA$

$i_X = i_1 - i_2$
$= 2.641$

$V_X = 1K(i_3)$
$= 7.39V$

$i_3 = i_C$

$i_1 = i_A - i_B$
$= 2.611mA$

$i_2 = i_B - i_C$
$= 0.218mA$

(iii) Construct the circuit of **Figure 3.0** in MultiSIM. Set the input D.C. source, **E** to **15V**, and node "**d**" as the *ground reference* node. Measure the branch currents I_1, I_2, I_3 and I_X, the branch voltage, V_X and the node voltages, V_a, V_b and V_c. Use the measured branch currents to determine the values of the mesh currents I_A, I_B and I_C. Record all your results in **Table 3.0**.

- Copy and paste a screenshot showing one MultiSIM readings on the circuit. Include the MultiSIM circuit file (**.ms14**) in your Pre-Lab submission.
- All screenshots should show your name printed on the center-top of the MultiSIM screen

Compare these MutliSIM simulation results in **Table 3.0** with the calculated theoretical values for the node voltages, mesh currents, branch current I_X, and branch voltage V_X. State if the *Nodal* and *Mesh* analysis methods yield the same results for the branch current, I_X and the branch voltage, V_X. Why?

Pre-Lab workspace

They yield the same result since they apply the same basic circuit laws on the same circuit.

$0 : 1k\,i_3 + 5.1k(i_3 - i_2) + 2.2(i_3 - i_1)$
$= 8.3\,k\,i_3 - 5.1k\,i_2 - 2.2k\,i_1$

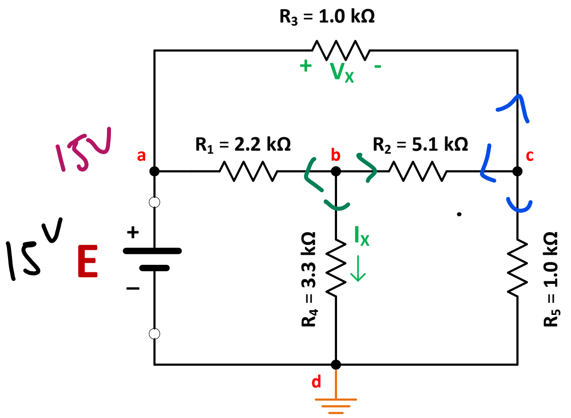


Figure 3.0a: Circuit for *Nodal* Analysis

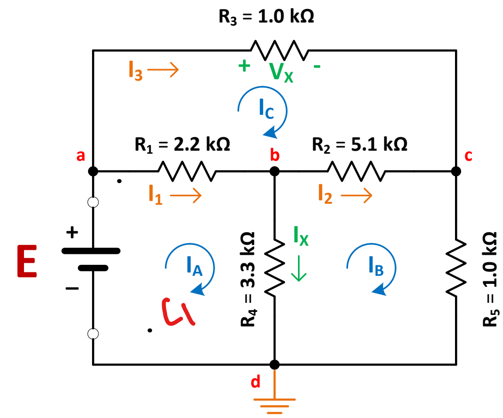


Figure 3.0b: Circuit for *Mesh* Analysis

$i_1 = i_A - i_C$

$i_X = i_A - i_B$

		Nodal Analysis	***Mesh*** Analysis
V_a (Volts)	Theoretical value =>	15V	
	MultiSIM value =>	15 V	
V_b (Volts)	Theoretical value =>	8.714 V	
	MultiSIM value =>	8.713 V	
V_c (Volts)	Theoretical value =>	7.608 V	
	MultiSIM value =>	7.60 V	
I_A (mA)	Theoretical value =>		10.249 mA
	MultiSIM derived =>		10.24 mA
I_B (mA)	Theoretical value =>		7.608 mA
	MultiSIM derived =>		7.608 mA
I_C (mA)	Theoretical value =>		7.3916 mA
	MultiSIM derived =>		7.39 mA
I_X (mA)	Theoretical value =>	2.64 mA	2.641 mA
	MultiSIM value =>	2.641 mA	2.641 mA
V_X (Volts)	Theoretical value =>	7.392 V	7.392 V
	MultiSIM value =>	7.392 V	7.392 V
I_1 (mA)	Theoretical value =>		2.641 mA
	MultiSIM value =>		2.837 mA
I_2 (mA)	Theoretical value =>		6.218 mA
	MultiSIM value =>		0.216 mA
I_3 (mA)	Theoretical value =>		7.3916 mA
	MultiSIM value =>		7.392 mA

Table 3.0: Theoretical and MultiSIM results of the Figure 3.0 circuits

5.0 IN-LAB Experiment: IMPEMENTATION & MEASUREMENTS

(a) *Circuit Reference Node*

1. Implement the circuit in **Figure 2.0a** on your breadboard using the resistor values as shown. Set the input D.C. source, **E** = **15V** on the power-supply and select node "**d**" as a *reference* node to which "COM" terminal of the DMM in the Voltmeter setting is connected to allow for direct measurement of the *unreferenced* voltage nodes.

2. With the "**-**" (or the reference) terminal of the DMM Voltmeter connected to the selected *reference* node, directly measure the voltages at nodes "**a**", "**b**", "**c**" and "**d**" (i.e. $\mathbf{V_a}$, $\mathbf{V_b}$, $\mathbf{V_c}$ and $\mathbf{V_d}$, respectively). Use the DMM Voltmeter to directly measure the voltage across resistors, $\mathbf{R_1}$ (=$\mathbf{V_{ab}}$), $\mathbf{R_2}$ (=$\mathbf{V_{bc}}$) and $\mathbf{R_3}$ (=$\mathbf{V_{cd}}$). Measure the current, **I** using the DMM set up as an Ammeter. From the above measured node voltages ($\mathbf{V_a}$, $\mathbf{V_b}$, $\mathbf{V_c}$ and $\mathbf{V_d}$), calculate the voltages $\mathbf{V_{ab}}$, $\mathbf{V_{bc}}$ and $\mathbf{V_{cd}}$. Record all your results in the below **Table 4.0**.

3. **Relocate** the circuit reference ground at node "**c**" shown in **Figure 2.0b**. Repeat **steps 1** and **2** above.

4. Turn OFF the Power Supply.

		Using *Reference* Node "**d**"	Using *Reference* Node "**c**"
I (mA)	Measured value =>	2.36 mA	2.36 mA
$\mathbf{V_a}$ (Volts)	Measured value =>	14.992 V	7.41 V
$\mathbf{V_b}$ (Volts)	Measured value =>	12.668 V	5.08 V
$\mathbf{V_c}$ (Volts)	Measured value =>	7.57 V	0
$\mathbf{V_d}$ (Volts)	Measured value =>	0	-7.59 V
$\mathbf{V_{ab}}$ (Volts)	Measured value =>	2.32 V	2.32 V
	Calculated value =>	2.308 V	2.308 V
$\mathbf{V_{bc}}$ (Volts)	Measured value =>	5.08 V	5.08 V
	Calculated value =>	5.077 V	5.077 V
$\mathbf{V_{cd}}$ (Volts)	Measured value =>	7.56 V	7.56 V
	MultiSIM value =>	7.615 V	7.615 V

Table 4.0: Experimental results of the Figure 2.0 circuits

(b) *Nodal and Mesh Analysis*

1. Implement the circuit in **Figure 3.0** on your breadboard using the resistor values as shown. Set the input D.C. source, **E** = **15V** on the power-supply.

2. ***Nodal Analysis***: Refer to the circuit of **Figure 3.0a**. Use node "**d**" as the ground *reference* node, and measure the node voltages $\mathbf{V_a}$, $\mathbf{V_b}$ and $\mathbf{V_c}$ with respect to this reference ground. Then measure the branch voltage, $\mathbf{V_X}$ across resistor, $\mathbf{R_3}$ and the branch current, $\mathbf{I_X}$ through resistor, $\mathbf{R_2}$.

3. ***Mesh Analysis***: Measure the branch currents $\mathbf{I_1}$, $\mathbf{I_2}$, $\mathbf{I_3}$ and $\mathbf{I_X}$, and then use these measured branch currents to determine the values of the mesh currents, $\mathbf{I_A}$, $\mathbf{I_B}$ and $\mathbf{I_C}$ and the branch voltage, $\mathbf{V_X}$. Record all your results in below **Table 5.0**.

4. Turn OFF the Power Supply

		Nodal Analysis	***Mesh*** Analysis
$\mathbf{V_a}$ (Volts)	Measured value =>	14.998 V	
$\mathbf{V_b}$ (Volts)	Measured value =>	8.707 V	
$\mathbf{V_c}$ (Volts)	Measured value =>	7.62 V	
$\mathbf{I_A}$ (mA)	Calculated value =>		10.43 mA
$\mathbf{I_B}$ (mA)	Calculated value =>		7.73 mA
$\mathbf{I_C}$ (mA)	Calculated value =>		7.513 mA
$\mathbf{I_X}$ (mA)	Measured value =>	2.713 mA	2.714 mA
$\mathbf{V_X}$ (Volts)	Measured value =>	7.38 V	7.39 V
$\mathbf{I_1}$ (mA)	Measured value =>		2.92 mA
$\mathbf{I_2}$ (mA)	Measured value =>		0.22 mA
$\mathbf{I_3}$ (mA)	Measured value =>		7.513 mA

$I_x = i_A - i_B$

$i_x + i_B = i_A$

$=$

$2.7 + 7.73 = 10.43$

$i_B - i_c = 7.73 - 7.51 = 0.22$

Table 5.0: Experimental results of the Figure 3.0 circuits

$i_1 = i_A - i_c = 10.43 - 7.51 = 2.92$

6.0 POST-LAB: OBSERVATIONS AND ANALYSIS OF RESULTS

1. From observing the results in **Table 4.0** of "***Circuit Reference Node***" experiment for both cases (when *reference point* at "**d**" and *reference point* at "**c**"): -

- **a.** State clearly which one of the currents, node voltages, or resistor voltages have changed or remain unchanged, and explain why. How do these experimental results compare to your Pre-Lab results in **Table 2.0**?
- **b.** Which of the two *reference points* would be your preferred choice? Explain.
- **c.** List, and comment on, the possible causes for any discrepancies from what you would expect theoretically or from the simulations?

workspace

a) Unchanged: $I, V_{AB}, V_{BC}, V_{CD}$. Since the only changing element was the location of GND, only nodal voltages were affected by the change.

Changed: V_A, V_B, V_C, V_D

These results match table 2.0

b) Ref point D is my preferred choice. It doesn't create any negative voltage values

c)

2. For the "***Nodal and Mesh Analysis***" experiment, compare your results in **Table 5.0** with the theoretical values and MultiSIM simulation measurements in **Table 3.0**, and explain.

- **a.** Specifically, did the *Nodal* and *Mesh* analysis methods yield the same results for the branch current, I_X and the branch voltage, V_X? Why?
- **b.** Do your results in **Table 3.0** and **Table 5.0** verify the *Nodal* and *Mesh* analysis techniques? Explain.
- **c.** List, and comment on, the possible causes for any discrepancies from what you would expect theoretically or from the simulations?

workspace

a) Yes they yielded the same V_X & I_X values. This makes sense because the 2 circuit analyses were performed on the same circuit.

b) Yes, table 3.0 & 5.0 verify the nodal & mesh techniques, since the values found through node & mesh calculations are close to the values found through experimentation

c) The values found in experimentation differed from those found in calculations by ~ thousandth. This likely occurred due to flaws in the physical elements that don't allow each element to be 100% efficient (as assumed in calculations)

7.0 LAB REPORT REQUIREMENTS & GUIDELINES

Lab reporting is to be completed and submitted separately as **Part I** and **Part II**, noted below:

<u>Part I</u> (**Pre-Lab Work**) => represents **40%** of the pre-assigned Lab weight.

Pre-Lab Work (assignment) of **Section 4.0** that includes handwritten calculations, MultiSIM results, and analysis is to be completed and <u>submitted **prior to the start** of your scheduled lab</u>. *The grading is commensurate with completeness and accuracy of your handwritten calculations, analysis and MultiSIM simulation circuits/plots.*

Note the following requirements for the document submission for Part I:

- A completed and signed "COVER PAGE – **Part I**" has to be included with your submission, a copy of which is available on D2L. The report will not be graded if the signed cover page is not included.
- Your completed handwritten pages of **Section 4.0** should be scanned (via a scanner or phone images), together with the required MultiSIM images. **<u>Note:</u>** *MultiSIM results must be generated using the Department's licensed version of MultiSIM, and the captured screenshots should show your name (at the center-top) and the timestamp (at the bottom-right corner of your screen).*
- Collate and create a .pdf or .docx file of the above, and upload it via D2L **any time prior to the start of your scheduled lab**. Upload instructions are provided on D2L.

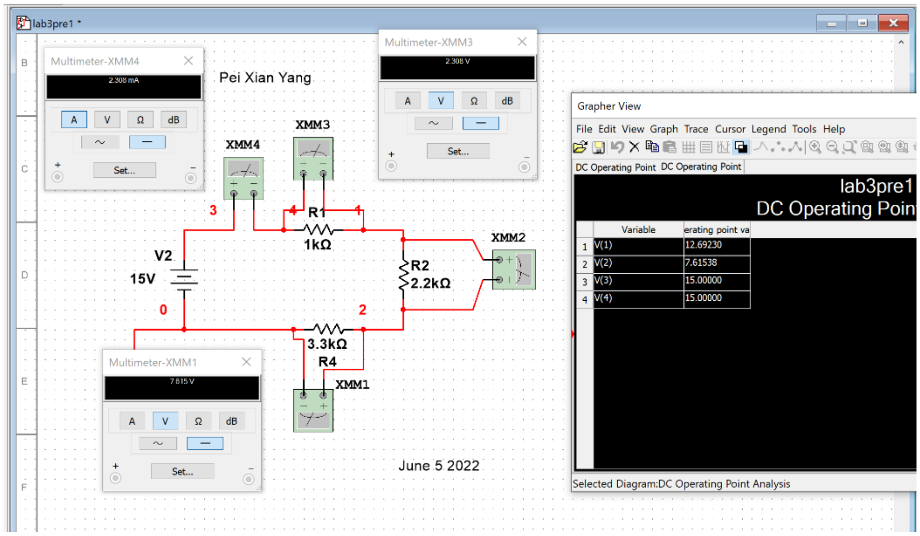
Zero marks will be assigned for the entire lab if this Part I is not submitted prior to your scheduled lab.

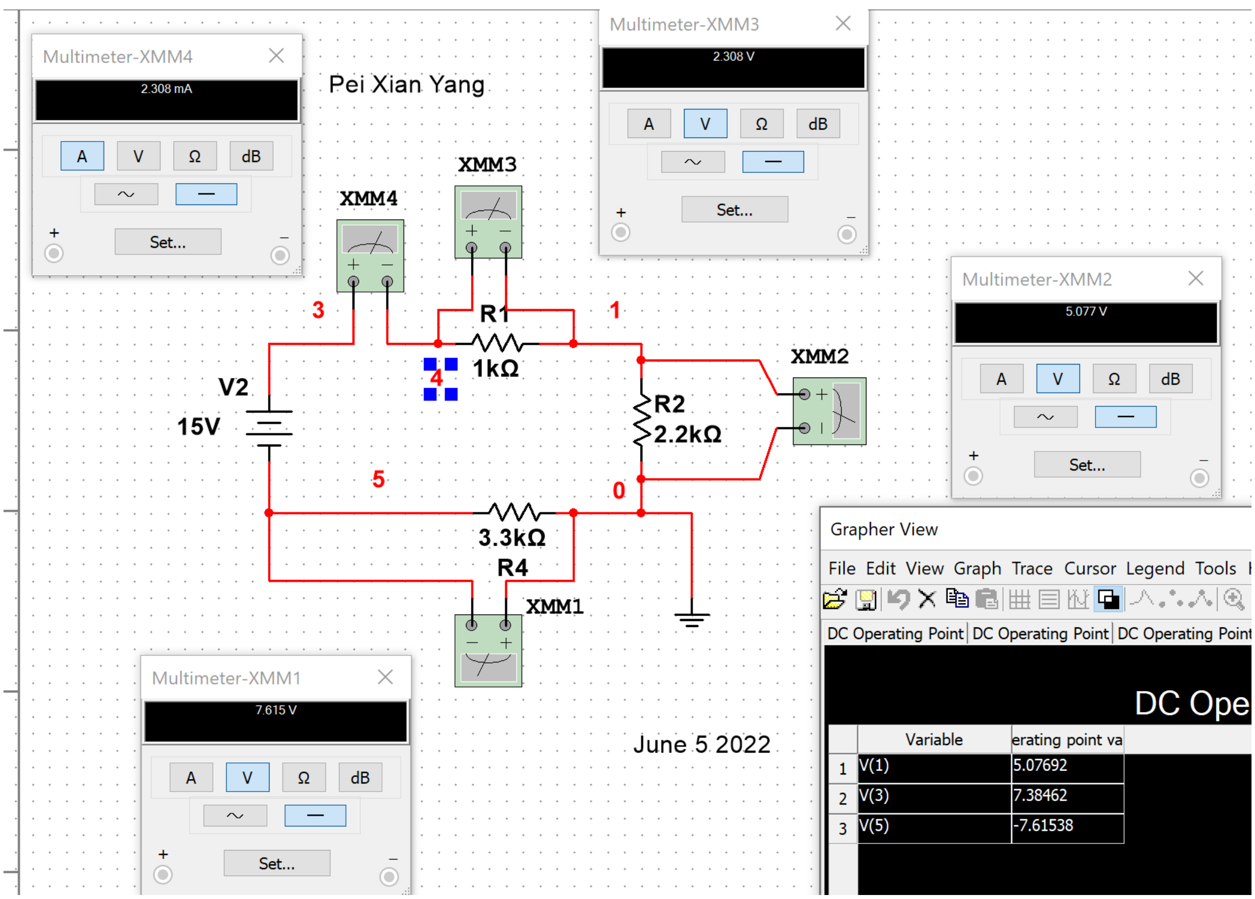
<u>Part II</u> (**In-Lab Work** and **Post-Lab Work**) => represents **60%** of the pre-assigned Lab weight.

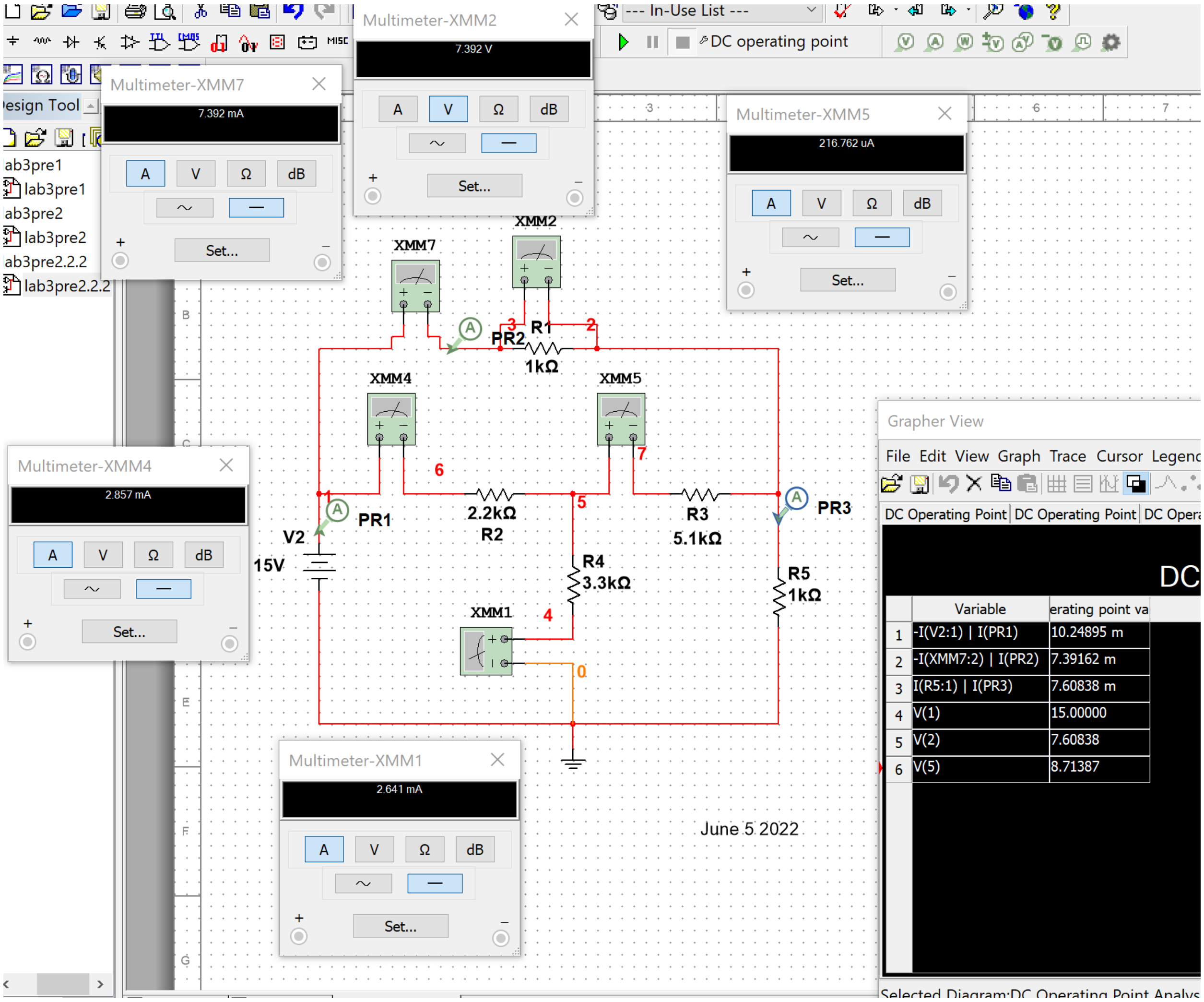
In-Lab Work (**Section 5.0**) and **Post-Lab Work** (**Section 6.0**) that include in-lab results, handwritten analysis and observations are to be completed and submitted <u>**by 11.59 p.m.** of the same day as your scheduled lab</u>. *The grading is commensurate with: - completeness, correctness and collection of all experimental results (data and waveforms); merits of observation of the correlations between the experimental and pre-lab assignment results; and reasonableness of the answers to questions posed.*

Note the following requirements for the document submission for Part II:

- A completed and signed "COVER PAGE – **Part II**" has to be included with your submission, a copy of which is available on D2L. The report will not be graded if the signed cover page is not included.
- Scan your completed pages of **Section 5.0** and **Section 6.0** (via a scanner or phone images), together with any required In-Lab Oscilloscope screen-shot images.
- Collate and create a .pdf or .docx file of the above, and upload it via D2L **by 11.59 p.m. on the same day** your lab is scheduled. <u>Late submissions will not be graded</u>.


lab3pre1 *
Multimeter-XMM4
2.308 mA
Pei Xian Yang
Multimeter-XMM3
2.308 V
XMM3
XMM4
R1
1kΩ
V2
15V
R2
2.2kΩ
XMM2
3.3kΩ
R4
XMM1
Multimeter-XMM1
7.615 V
June 5 2022
Grapher View
File Edit View Graph Trace Cursor Legend Tools Help
DC Operating Point DC Operating Point
lab3pre1
DC Operating Poin
Variable
erating point va
V(1) 12.69230
V(2) 7.61538
V(3) 15.00000
V(4) 15.00000
Selected Diagram:DC Operating Point Analysis


Multimeter-XMM4
2.308 mA
A V Ω dB
Set...
Pei Xian Yang
Multimeter-XMM3
2.308 V
A V Ω dB
Set...
XMM3
XMM4
3
R1
1
1kΩ
4
V2
15V
R2
2.2kΩ
XMM2
Multimeter-XMM2
5.077 V
A V Ω dB
Set...
5
0
3.3kΩ
R4
XMM1
Multimeter-XMM1
7.615 V
A V Ω dB
Set...
June 5 2022
Grapher View
File Edit View Graph Trace Cursor Legend Tools
DC Operating Point DC Operating Point DC Operating Point
DC Ope
Variable
erating point va
1 V(1) 5.07692
2 V(3) 7.38462
3 V(5) -7.61538


Multimeter-XMM7
7.392 mA
Multimeter-XMM2
7.392 V
Multimeter-XMM5
216.762 uA
Multimeter-XMM4
2.857 mA
Multimeter-XMM1
2.641 mA
DC operating point
--- In-Use List ---
XMM7
XMM2
XMM4
XMM5
XMM1
PR1
PR2
PR3
R1
1kΩ
R2
2.2kΩ
R3
5.1kΩ
R4
3.3kΩ
R5
1kΩ
V2
15V
June 5 2022
Grapher View
File Edit View Graph Trace Cursor Legend
DC Operating Point
Variable
1 -I(V2:1) | I(PR1) 10.24895 m
2 -I(XMM7:2) | I(PR2) 7.39162 m
3 I(R5:1) | I(PR3) 7.60838 m
4 V(1) 15.00000
5 V(2) 7.60838
6 V(5) 8.71387
Selected Diagram:DC Operating Point Analys