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 #:	2	Lab Title:	Basic Concepts

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Section #:	4
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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.*

ELE 202
Laboratory #2

Basic Concepts, Relationships and Laws of Electric Circuits

1.0 INTRODUCTION

The relationship between *current* (**I**) and *voltage* (**V**) across the terminals of a circuit element defines the behavior of that element within the circuit. The graphical means of representing the terminal characteristics of a circuit element is done by introducing the variable **I** to represent current flowing through the element, while voltage **V** is the *Potential Difference* (**P.D.**) or voltage across the element. If the voltage applied to the element were varied and the resulting current measured, it would be possible to construct a functional relationship between voltage and current known as the ***I-V*** characteristic. Depending on the electrical properties of a circuit element, this ***I-V*** relationship can be "*linear*" or "*non-linear*".
Electrical current, **I** (= $\mathrm{d}\mathbf{Q}/\mathrm{dt}$) is the rate at which *free* electrons (or charge, **Q**) is made to drift through a material in a particular direction, that is, moved around a circuit. In order to cause the *free* electrons to drift in a given direction, an Electro-Motive Force (**EMF**) must be applied, and which ends up being the driving force in an electrical circuit. The electrical symbol for an EMF is **E**, the unit of measurement is in **volts (V)**, and the typical voltage-sources of EMF are cells, batteries (or power-supplies), and generators.
When current flows through a metal wire or other circuit elements, it encounters a certain amount of *resistance*, the magnitude of which depends on the electrical properties of the material. Practically all circuit elements exhibit some resistance; as a consequence, the current flowing through an element will cause energy to be dissipated in the form of heat. An ideal resistor, **R,** is a circuit element that exhibits "*linear*" resistance properties according to **Ohm's Law**, whereby the voltage across the resistor element is directly proportional to the current flow through it. The unit of electrical resistance (R) is the **ohm (Ω)**. It should be noted that the EMF (the driving force, **E**) causes current to flow in a circuit, whereas a **P.D.** (Potential-Difference) is the result of current flowing through a resistor, **R**. Hence, EMF is a "*cause*" and P.D. is an "*effect*".
These basic concepts of current, voltage and power in an electric circuit are easy to grasp however, to actually determine the values and relationships of these variables in a given circuit requires a sound understanding of some "*fundamental laws*" that govern electric circuits. These laws, known as **Ohm's Law** and **Kirchhoff's Laws** (**KVL** and **KCL**) form the foundation upon which electric circuit analysis is built. So, for this particular lab, the student is urged to review Ohm's and Kirchhoff's laws, and related techniques commonly applied in circuit design and analysis.

References:- (i) Course Textbook: "*Fundamentals of Electric Circuits*" by C. K. Alexander and M. N. O. Sadiku; and (ii) "*Principles and Applications of Electrical Engineering*" by G. Rizzoni.

2.0 OBJECTIVES

- To enhance understanding of the basic electric circuit laws: Ohm's law, Kirchhoff's voltage law (**KVL**), and Kirchhoff's current law (**KCL**)
- To experimentally verify **KVL** and **KCL** in actual circuits.
- To investigate the current-voltage (***I-V***) characteristics of a linear circuit-element (e.g. Resistor) through the use of some simple D.C. circuits.
- To explore and verify the characteristics of ***series*** and ***parallel*** combinations of linear circuit-elements.

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) *I-V* Characteristics of Ohmic Resistor using a simple D.C. Circuit

(i) Assume varying values of the DC source-voltage, **E** applied as shown in **Figure 2.0**. For each source-voltage value, use Ohm's Law to determine the corresponding value of the current, I_R when the resistance, **R** is 2.2 kΩ and when it is 3.3 kΩ. Record your theoretical results in **Table 2.0.**

Pre-Lab workspace

$V = iR$

$i = \frac{V}{R}$

$= \frac{3V}{2.2k\Omega}$ $= 1.36mA$

$= \frac{3V}{3.3k\Omega}$ $= 0.909mA$

$= \frac{6V}{2.2k\Omega}$ $= 2.72mA$

$= \frac{6}{3.3k\Omega}$ $= 1.818mA$

$= \frac{15V}{2.2k\Omega}$ $= 6.8mA$

$= \frac{15}{3.3k}$ $= 4.54$

$= \frac{9V}{2.2k\Omega}$ $= 4.09mA$

$= \frac{9V}{3.3k\Omega}$ $= 2.727mA$

$= \frac{12V}{2.2k\Omega}$ $= 5.45mA$

$= \frac{12V}{3.3k\Omega}$ $= 3.6mA$

$= \frac{12}{22k\Omega}$ $= 5.45mA$

(ii) Construct and simulate this circuit of **Figure 2.0a** on MultiSIM, and set it up as depicted in **Figure 2.0b** to measure the current, I_R and voltage, V_R when **R** = 2.2 kΩ. Vary the DC source-voltage, **E** such that the voltage, V_R across the resistor has the values listed in **Table 2.0**. For each listed source-voltage, measure the corresponding current, I_R and voltage, V_R. Record these simulation 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) Change the resistor to **R** = 3.3kΩ, and repeat above **step (ii)**.

(iv) Compare your Theory results with the MultiSIM results from **Table 2.0**, and comment on your observations.

Pre-Lab workspace

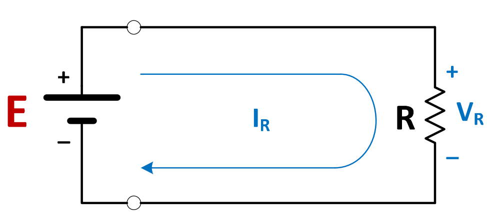


Figure 2.0a: Simple DC Circuit

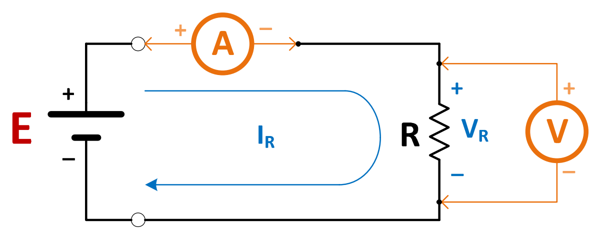


Figure 2.0b: Simple DC Circuit showing Voltmeter & Ammeter connections

	V_R =>	3V		6V		9V		12V		15V	
R		Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result
2.2 kΩ	I_R => (mA)	1.36	1.36	2.73	2.73	4.1	4.1	5.45	5.4	6.8	6.8
3.3 kΩ	I_R => (mA)	0.91	0.91	1.82	1.82	2.7	2.7	3.6	3.6	4.55	4.55

Table 2.0: Theoretical and MultiSIM results of the Simple DC Circuit in Figure 2.0

(b) Series Resistors Circuit - KVL

(i) For the circuit of **Figure 2.1a**, assume the source-voltage, **E = 15V**, $\mathbf{R_1}$ = 3.3 kΩ, $\mathbf{R_2}$ = 2.2 kΩ and $\mathbf{R_3}$ = 1.0 kΩ. Determine the expected current, **I** and the voltages across resistors $\mathbf{R_1}$ (=V_{ab}), $\mathbf{R_2}$ (= V_{bc}) and $\mathbf{R_3}$ (=V_{cd}) for the respective values of resistors shown. Record your theoretical results in **Table 2.1**. Determine the sum ΣV = (V_{ab} + V_{bc} + V_{cd}) to verify the KVL law.

Pre-Lab workspace

$R_{eq} = 3.3k + 2.2k + 1k$
$= 6.5k$

$V = iR$
$i = \frac{V}{R} = \frac{15V}{6.5k\Omega}$

$i = 2.3\ mA$

$V_1 = \frac{3.3k}{6.5k} 15$
$= 7.62\ V$
$V_2 = 5.08V$
$V_3 = 2.30\ V$

(ii) On MultiSIM, construct and simulate the circuit of **Figure 2.1a** using a DC source-voltage, **E = 15V,** $\mathbf{R_1}$ = 3.3 kΩ, $\mathbf{R_2}$ = 2.2 kΩ and $\mathbf{R_3}$ = 1.0 kΩ. The measurement setup for the simulator is depicted in **Figure 2.1b**. Record the measured current, **I** and the voltages across resistors $\mathbf{R_1}$ (=V_{ab}), $\mathbf{R_2}$ (= V_{bc}) and $\mathbf{R_3}$ (=V_{cd}) for the respective values of resistors shown. Record your simulation results in **Table 2.1**. Determine the sum ΣV = (V_{ab} + V_{bc} + V_{cd}) to verify the KVL law.

- 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.

Pre-Lab workspace

(iii) Compare your Theory results with the MultiSIM results from **Table 2.1**, and comment on your observations.

Pre-Lab workspace

They're the same

(iv) **Design Problem:** Referring to the circuit of **Figure 2.1a**, a designer wishes to create three *equal* potential differences (i.e. V_{ab}= V_{bc}= V_{cd}) of **5V** each from a source-voltage, **E = 15V.** The **maximum** source-current, **I** available from the **E** battery-source is **5mA**, and so the designer must ensure the current value stays within this requirement, and **not exceed**. Using KVL concept, analyse and determine a set of values for **I**, R_1, R_2 and R_3 the designer can use to meet the above design specifications. ***Use standard resistor values available in your lab kit in your design.*** Record the results of your design analysis in **Table 2.2**.

Using your design values of R_1, R_2 and R_3 implement and simulate your circuit design on MultiSIM. Measure the current, **I** and the voltages across resistors R_1 (=V_{ab}), R_2 (= V_{bc}) and R_3 (=V_{cd}), and record the results in **Table 2.2**.

- Copy and paste a screenshot showing one MultiSIM readings on the circuit. Include the MultiSIM circuit file (**.ms14**) in your Pr-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.

Pre-Lab workspace

$5V = \frac{R_{eq}}{R_1} \cdot 15$

$\frac{1}{3} = \frac{R_{eq}}{R_1}$

$R_1 = R_2 = R_3$

$V = iR$

$\frac{15V}{5mA} = R$

$3k\Omega = R$

$R_1 = R_2 = R_3 = 1 k\Omega$

(v) Compare your Theory results with the MultiSIM results from **Table 2.2**, comment on your observations and explain any discrepancies in your design outcome.

Pre-Lab workspace

They're the same

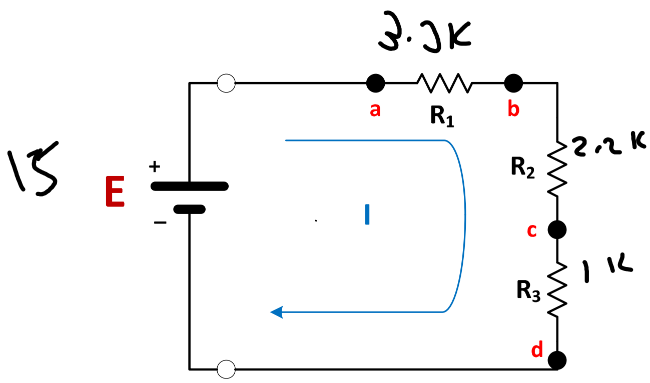


Figure 2.1a: KVL Series Circuit

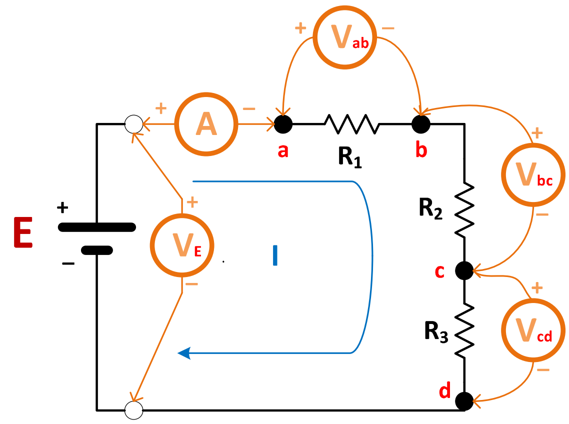


Figure 2.1b: KVL Series Circuit showing Voltmeter & Ammeter connections

V_E	I (mA)		V_{ab} (Volts)		V_{bc} (Volts)		V_{cd} (Volts)		$\Sigma V = (V_{ab} + V_{bc} + V_{cd})$	
	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result
15V	2.3	2.3	7.62	7.62	5.08	5.08	2.3	2.3	15V	15V

Table 2.1: Theoretical and MultiSIM results of the Series Circuit in Figure 2.1

Design values => R_1 = 1kΩ? R_2 = 1kΩ? R_3 = 1kΩ?

V_E	I (mA)		V_{ab} (Volts)		V_{bc} (Volts)		V_{cd} (Volts)	
	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result
15V	5	5	5	5	5	5	5	5

Table 2.2: Theoretical and MultiSIM results of the ***re-designed*** Series Circuit in Figure 2.1

(c) Parallel Resistors Circuit - KCL

(i) For the circuit of **Figure 2.2a**, assume the source-voltage, **E = 15V**, $\mathbf{R_1}$ = 3.3 kΩ, $\mathbf{R_2}$ = 2.2 kΩ and $\mathbf{R_3}$ = 1.0 kΩ. Determine the expected currents **I**, $\mathbf{I_1}$, $\mathbf{I_2}$ and $\mathbf{I_3}$ as shown in **Figure 2.2a.** Record your theoretical results in **Table 2.3**. Determine the sum ΣI = ($\mathbf{I_1}$ + $\mathbf{I_2}$ + $\mathbf{I_3}$) to verify the KCL law.

Pre-Lab workspace

$$R_{eq} = \frac{1}{\frac{1}{2.2k} + \frac{1}{1.0k} + \frac{1}{3.3k}}$$

$$= 568.96\,\Omega$$

$$i = \frac{15V}{568.96\,\Omega}$$

$$= 26.36\ mA$$

$$i_1 = \frac{0.57k}{3.3k}\ 26.36mA$$

$$= 4.55mA$$

$$i_2 = \frac{0.57k}{2.2k}\ 26.36mA$$

$$= 6.83\ mA$$

$$i_3 = \frac{0.57k}{1.0k}\ 26.36mA = 15.02mA$$

(ii) On MultiSIM, construct and simulate the circuit of **Figure 2.2a** using a DC source-voltage, **E = 15V,** $\mathbf{R_1}$ = 3.3 kΩ, $\mathbf{R_2}$ = 2.2 kΩ and $\mathbf{R_3}$ = 1.0 kΩ. The measurement setup for the simulator is depicted in **Figure 2.2b**. Record the measured currents **I**, $\mathbf{I_1}$, $\mathbf{I_2}$ **and** $\mathbf{I_3}$ as shown in **Figure 2.2a.** Record your simulation results in **Table 2.3**. Determine the sum ΣI = ($\mathbf{I_1}$ + $\mathbf{I_2}$ + $\mathbf{I_3}$) to verify the KCL law.

- 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.

Pre-Lab workspace

(iii) Compare your Theory results with the MultiSIM results from **Table 2.3**, and comment.

Pre-Lab workspace

They're the same

15

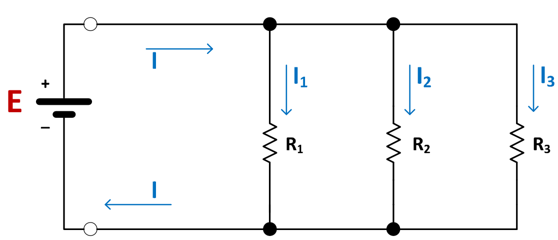


Figure 2.2a: KCL Parallel Circuit

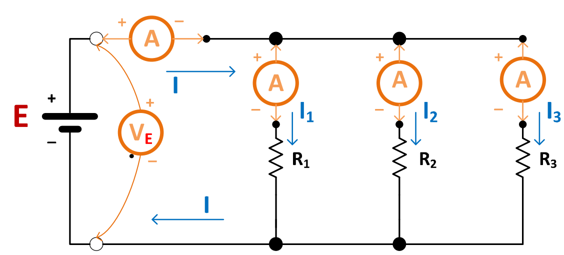
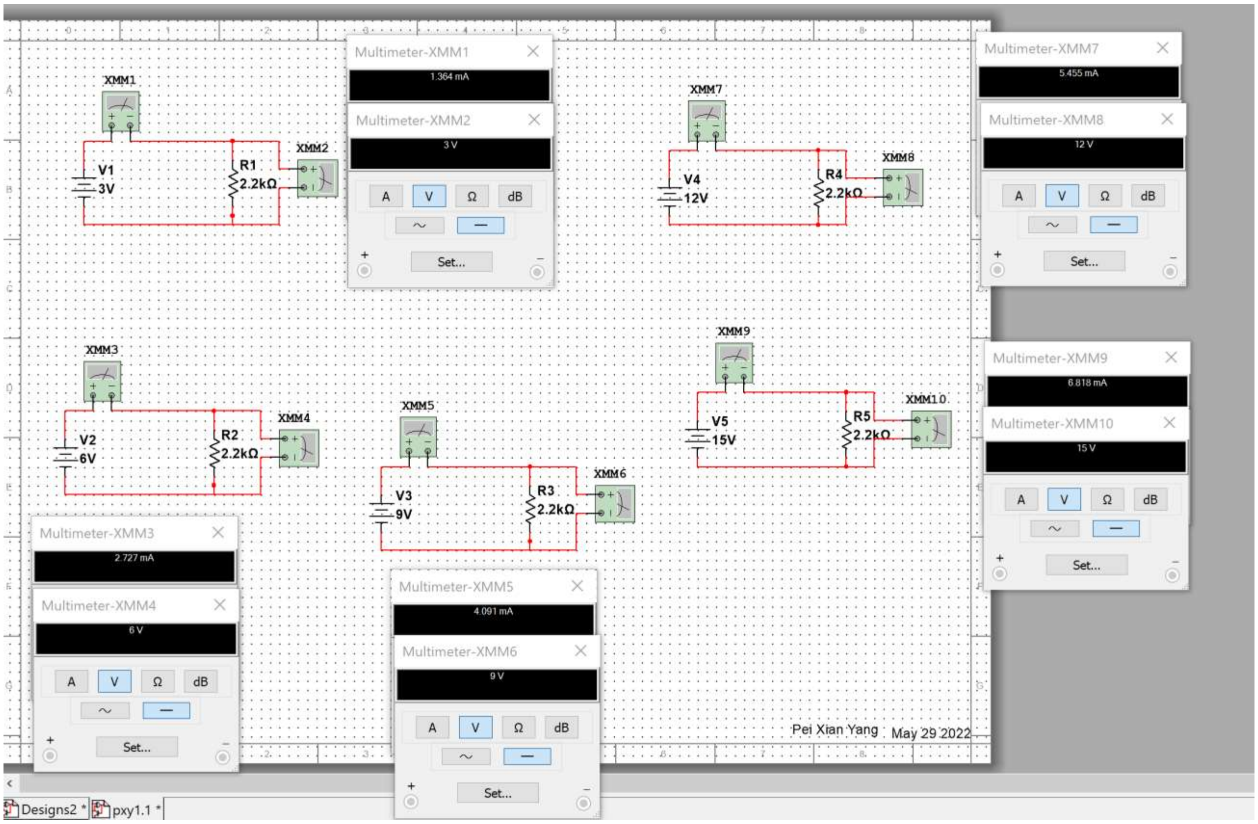
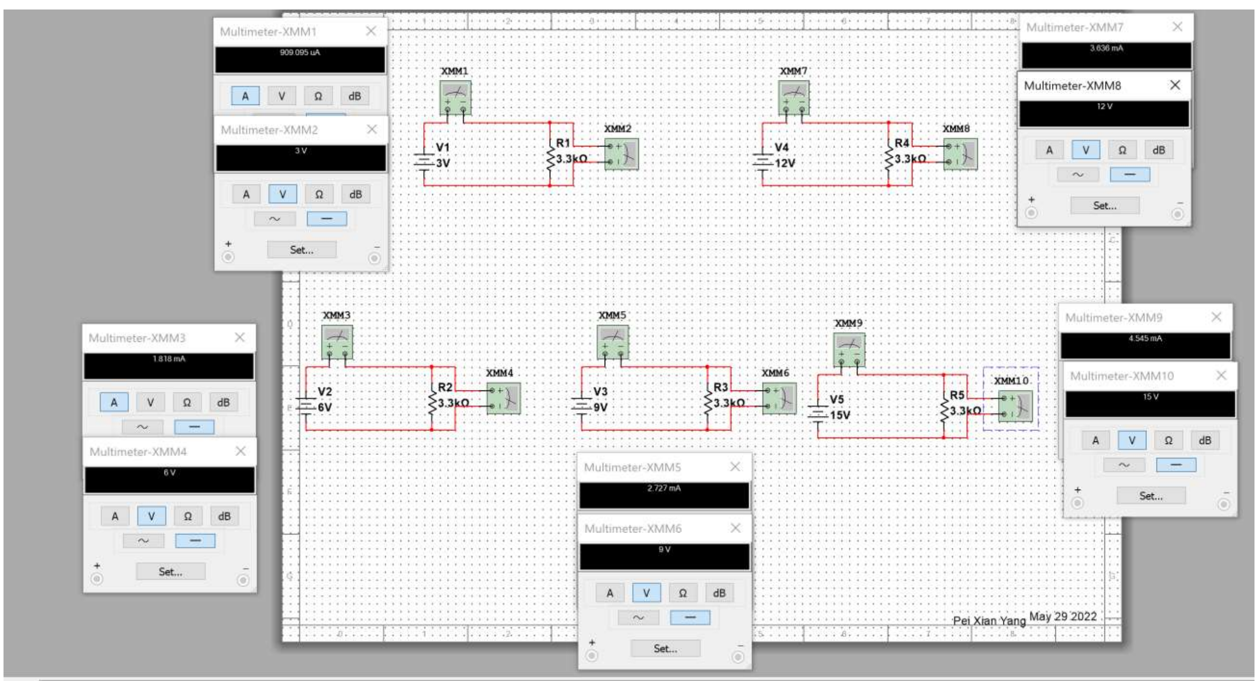


Figure 2.2b: KCL Parallel Circuit with Ammeter & Voltmeter connections

V_E	I (mA)		I_1 (mA)		I_2 (mA)		I_3 (mA)		$\Sigma I = (I_1 + I_2 + I_3)$	
	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result	Theory result	MultiSIM result
15V	26 3	26.3	4.5	4.5	6.8	6.8	15	15.0	26.3	26.3

Table 2.3: Theoretical and MultiSIM results of the Parallel Circuit in Figure 2.2


XMM1
V1
3V
R1
2.2kΩ
XMM2
Multimeter-XMM1
1.364 mA
Multimeter-XMM2
3 V
XMM7
V4
12V
R4
2.2kΩ
XMM8
Multimeter-XMM7
5.455 mA
Multimeter-XMM8
12 V
XMM3
V2
6V
R2
2.2kΩ
XMM4
XMM5
V3
9V
R3
2.2kΩ
XMM6
XMM9
V5
15V
R5
2.2kΩ
XMM10
Multimeter-XMM9
6.818 mA
Multimeter-XMM10
15 V
Multimeter-XMM3
2.727 mA
Multimeter-XMM4
6 V
Multimeter-XMM5
4.091 mA
Multimeter-XMM6
9 V
Pei Xian Yang
May 29 2022
Designs2 *
pxy1.1 *


Multimeter-XMM1
909.095 uA
Multimeter-XMM2
3 V
XMM1
V1
3V
R1
3.3kΩ
XMM2
XMM7
V4
12V
R4
3.3kΩ
XMM8
Multimeter-XMM7
3.636 mA
Multimeter-XMM8
12 V
Multimeter-XMM3
1.818 mA
Multimeter-XMM4
6 V
XMM3
V2
6V
R2
3.3kΩ
XMM4
XMM5
V3
9V
R3
3.3kΩ
XMM6
XMM9
V5
15V
R5
3.3kΩ
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15 V
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2.727 mA
Multimeter-XMM6
9 V
Pei Xian Yang
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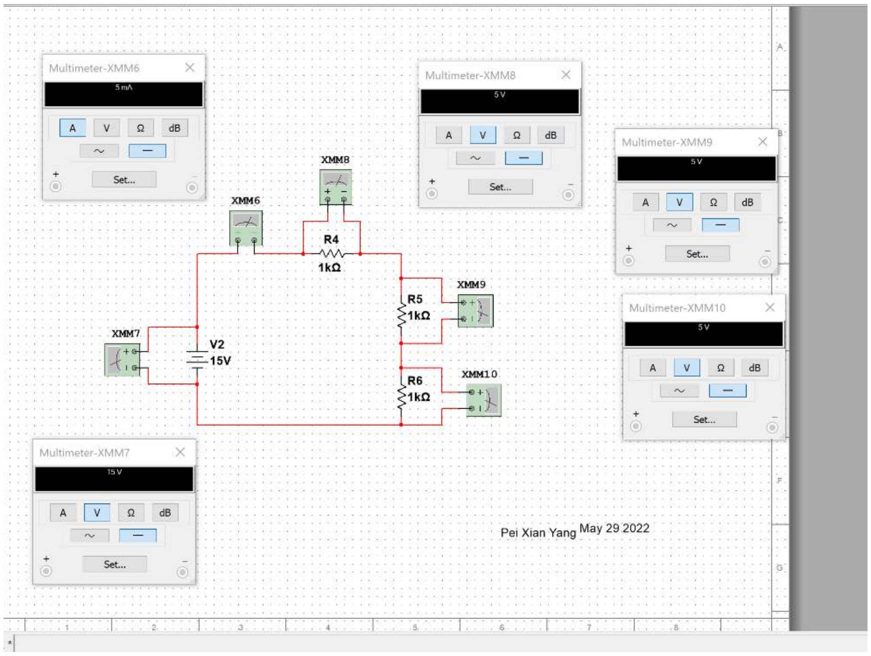
Multimeter-XMM6
5 mA
Multimeter-XMM8
5 V
Multimeter-XMM9
5 V
Multimeter-XMM10
5 V
Multimeter-XMM7
15 V
XMM8
XMM6
R4
1kΩ
R5
1kΩ
XMM9
XMM7
V2
15V
R6
1kΩ
XMM10
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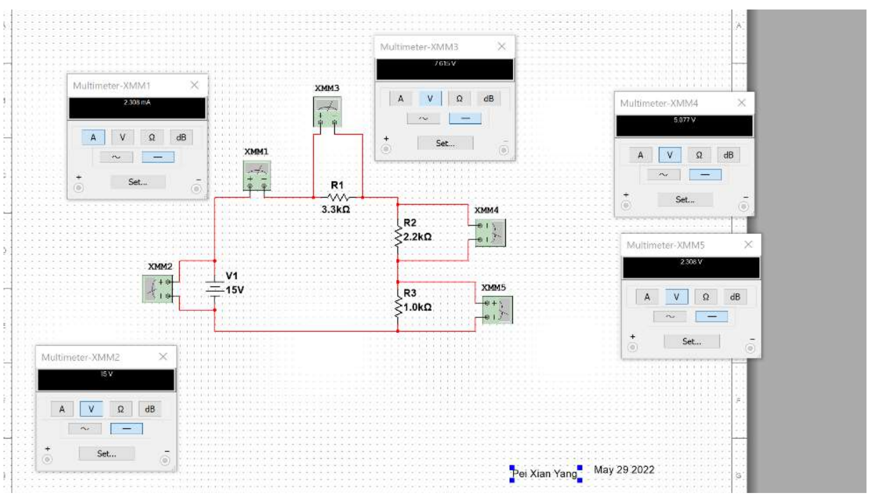
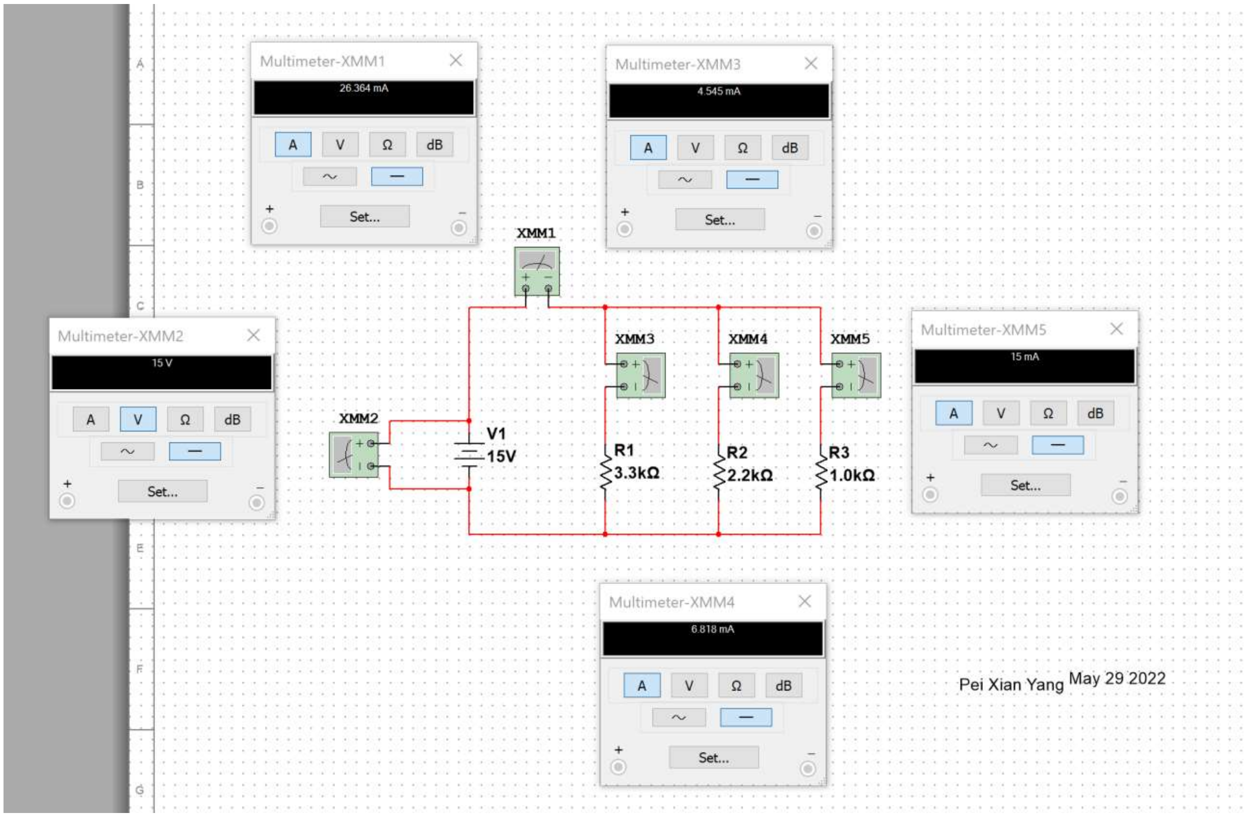

Multimeter-XMM1
Multimeter-XMM3
Multimeter-XMM4
Multimeter-XMM5
Multimeter-XMM2
15 V
XMM3
XMM1
R1
3.3kΩ
R2
2.2kΩ
XMM4
XMM2
V1
15V
R3
1.0kΩ
XMM5
Pei Xian Yang May 29 2022

3.



Multimeter-XMM1
26.364 mA
Multimeter-XMM3
4.545 mA
Multimeter-XMM2
15 V
Multimeter-XMM5
15 mA
Multimeter-XMM4
6.818 mA
XMM1
XMM2
XMM3
XMM4
XMM5
V1
15V
R1
3.3kΩ
R2
2.2kΩ
R3
1.0kΩ
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