LAB 9: OHM'S LAW

During this laboratory session, students will

✔1 learn how to build simple electrical circuits,

✔2 use multimeters as voltmeter and ammeter,

✔3 use a direct current (DC) power supply,

✔4 verify Ohm's law,

✔5 establish the resistance addition rules in series and in parallel.

Student Learning Outcome: Successful students will

✔1 be acquainted to electrical circuits,

✔2 know how to use a voltmeter,

✔3 know all the precaution to take when using an ammeter,

✔4 master Ohm's law.

INTRODUCTION

The main goal of this lab and the next one is to verify laws that rules the motion of charges in what we generally call electrical circuits. We will start with the so-called Ohm's law that could be easily used for simple electrical circuits. Then we will consider more complicated electric circuits in the next lab and apply the so-called Kirchhoff's rules. The secondary goal is to find the resistance addition rules —similar to when mounting springs in series and in parallel.

The following definitions are very simplified for a quick reading. But you can dig more using your textbooks.

Electrical circuits are combinations of electrical devices that can potentially enable charges to move. An electric circuit should have a battery or batteries and may have one or more of the following: resistor, capacitor, and inductor. For this lab, you will have resistors only.

Electric current is a flow of charged particles, such as electrons, protons, and ions. But mathematically, it is defined as the rate of charge flow and is given by

$$I = \frac{q}{t} \tag{1}$$

where q is the amount of flowing charges. The unit of I is coulomb per second, which is simply called ampere (from Ampère) and symbolized by A.

Batteries are electric devices that are mandatory in order to have electric currents. They, potentially, can impart kinetic energy to charges and play the role of charge pumps. For this lab, we will use the so-called direct current (DC) batteries only. DC batteries move charges in one direction only. They have two plates, which have different signs and are symbolized by two vertical lines of different length. The element between “a” and “d” in FIGURE 1 is an example. The positive side of the battery is indicated by the longer line. On the device itself, the positive plate is usually red.

Electric potential energy, when released, is an energy that can move charges. Electric potential is the energy per charge and is measured in units of volts—thus, volts is equivalent to J/C. Positively charged particles will move from higher electric potential (positive plate) to lower electric potential (like-charges repel each other). And, by convention, the electric current direction is the same as the direction of the motions of the positively charged particles. However, the moving charges could be negatively charged particles as well—indeed, the moving charges are electrons in most cases. Thus, an alias of the convention is needed: the direction of I is the opposite of the direction of the motions of the negatively charged particles. Apply the convention and its alias to find the overall current if both positive and negative charges contribute.

Electric conductors are materials that allow charged particles to flow across them.

Electric insulator is the antonym of electric conductor.

Resistors are electric conductors, which simply decrease the flow of charges by dissipating the energy in the form of heat. Their ability to slow down charges are characterized by their resistance, R, that is measured in units of ohms (Ω). Electric insulators have infinite resistance, whereas superconductors have no resistance at all. The conventional symbol for a resistor is used for each resistor R_1, R_2, R_3, and R_4 in FIGURE 1.

The loss of energy per charge, or potential difference, V, is determined by Ohm’s law:

$$V = IR \tag{2}$$

Equation (2) states that a resistance R, of which the two ends are under the electric potential difference V, will drive an electric current I given by V/R.

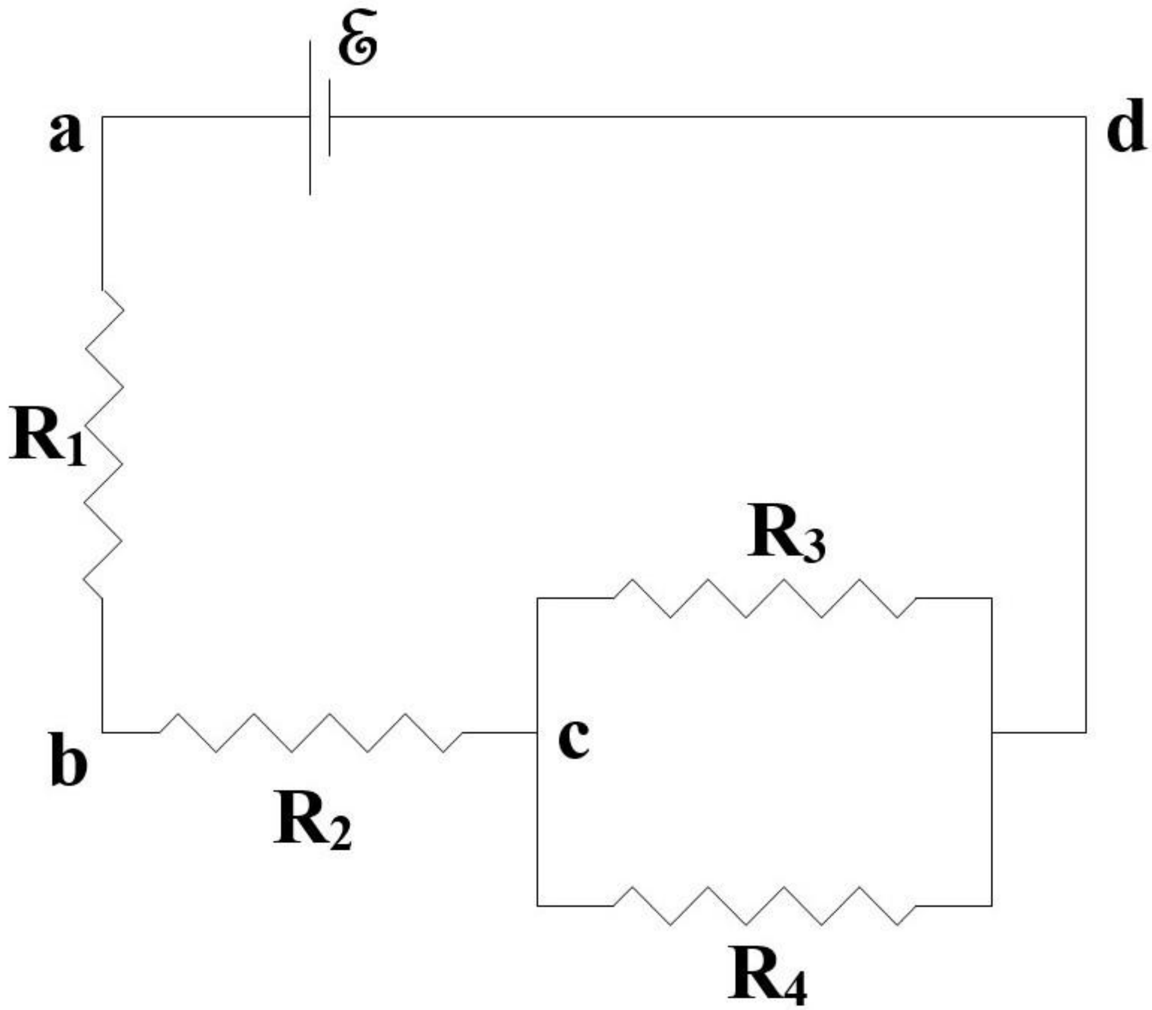

Figure 1: The simple electric circuit that we will use for this lab has one DC battery, four resistors, and a switch. The first two resistances are mounted in series, the two others are mounted in parallel.

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The cables used to connect the different elements of the circuits have hypothetically no resistance and that is why they are symbolized with simple straight lines. They form equipotential lines meaning that all points of a cable have the same electric potential.

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LAB 9: PRELIMINARY WORK

A 3 Ω resistor is driving 0.5 A. What is the electric potential difference between its two ends?

V = I * R

V = 0.5 * 3

V = 1.5 V

A 1.5 V AAA battery is feeding an electrical circuit, where a 3 Ω resistance drives 0.4 A. Do the givens support Ohm's law? Why or why not.

V = I * R

V = 0.4 * 3

V = 1.2

No, there is additional resistance in the circuit.

In order to accurately measure the electric current, an ammeter should drive that current. How should be the resistance of the ammeter compared to the resistance of the overall circuit, very big or very small? Explain.

An ammeter is connected in series with the circuit, meaning the same current that flows through the circuit also flows through the ammeter.

If the ammeter had a large resistance add extra resistance to the circuit.

If two resistors are mounted head-to-tail (in series), what would they share in common: the electric current or the electric potential difference? Explain (you may use drawings).

Two resistors connected in series share the same electric current, but the electric potential difference is divided between them.

If two resistances are mounted in parallel, what would they share in common: the electric current or the electric potential difference? Explain (you may use drawings).

Two resistors connected in parallel share the same electric potential difference, but the current divides between them depending on their resistances.

According to your answer to #4, which one of the two resistors would experience the higher potential drop?

In a series circuit, the resistor with the greater resistance experiences the higher potential drop.

According to your answer to #5, which one of the resistors would drive more electric current?

In a parallel circuit, the resistor with the smaller resistance drives (carries) the greater electric current.

0 words

Warning: Follow the instruction given to you during the introduction part of the lab session when you use an ammeter. Replacing a fuse may delay the lab for more than 15 min.

ACTIVITY #1: CARBON RESISTORS

1. Identifying a carbon resistor using the color code:
   Carbon resistors have a color code that could be used to determine or estimate their resistance (see the following table). The first two bands—but how do I know which ones are the first two? Gold is not part of it—give the first two digits of the resistance, the third band indicates how many zeros are to follow these, and the fourth band indicates the uncertainty. For example, blue-red-brown-gold is 620 Ω ± 5%. This may be written as

$$R = 620 \pm 60k\Omega$$

   Find four resistances: one of few hundred ohms, a second with few thousand ohms, a third between 10,000 and 20,000 ohms, and the fourth more than 20,000 ohms. Read the values using the color codes, then measure each one of them using an ohmmeter. Compare and discuss (include percent difference).

COLOR	NUMBER	MULTIPLIER	TOLERANCE
Black	0	10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5%
Silver		10^{-2}	10%
No color			20%

2. Resistances mounted in series:
   Mount the first and second resistors in #1) in series (head-to-tail) and measure the resistance using an ohmmeter. Compare with the previously measured resistances and infer a simple rule for resistors in series. What is then the expected value of the resistance of the four resistors all mounted in series? Mount all four resistors in series and measure the resistance.

Compare with the expected one.

3. Resistances in parallel:
   Mount the third and fourth resistors in parallel and measure the new resistance with an ohmmeter. How is the new resistance related to the measured values for the third and fourth resistances? Using that relationship, predict the resistance of the first and second resistors mounted in parallel. Compare with the actual measurement.

ACTIVITY #2: OHM'S LAW

General instruction: To protect your multimeter and circuit elements, do not plug the battery or power supply until all the rest is connected and your TA or instructor checked everything. After you are finished with the circuit, unplug the battery or power supply before you take the circuit apart.

1. Choose four other resistors between 100 W and 1000 W that all are different one from each other. Label the resistors (i.e., R_1, etc.). Use your multimeter to measure the actual resistance of each resistor (like in the previous activity) and record all in a chart, including the color codes and resulting specified resistances.
2. Place the resistor, **one at a time**, in series with the power supply (direct connection). Use Ohm's law to find their resistances by first measuring the voltage across them and the current through them—once again, follow instructions when using the multimeter as an ammeter. Compare with the color code and ohmmeter values from step #1 (use percent differences).
3. Using the multimeter, determine the current through each of the resistors and the voltage across each of the resistors—be careful to follow instructions when using the multimeter as an ammeter. Create an Excel chart to record the measurements. FIGURE 2 shows how to mount the ammeter if one has to measure the electric current in the first two

resistances. FIGURE 3 shows how to mount the voltmeter if one has to measure the electric potential difference between the two ends of either R_3 or R_4.

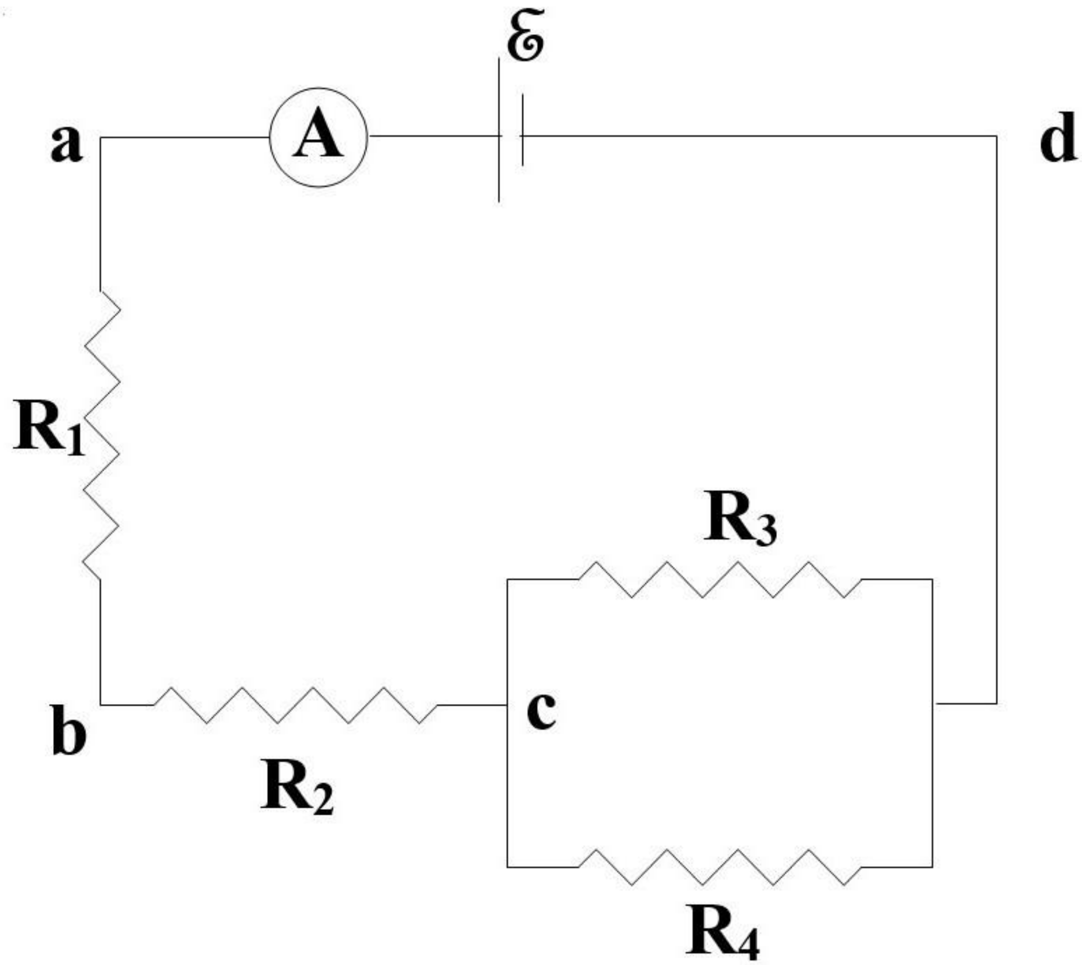

Figure 2: In an electrical circuit, the ammeter should be mounted in series with the element(s) you want to measure the electric current of. The internal resistance of the ammeter is so weak that it will not affect your measurement. In any case, avoid mounting the ammeter in parallel.

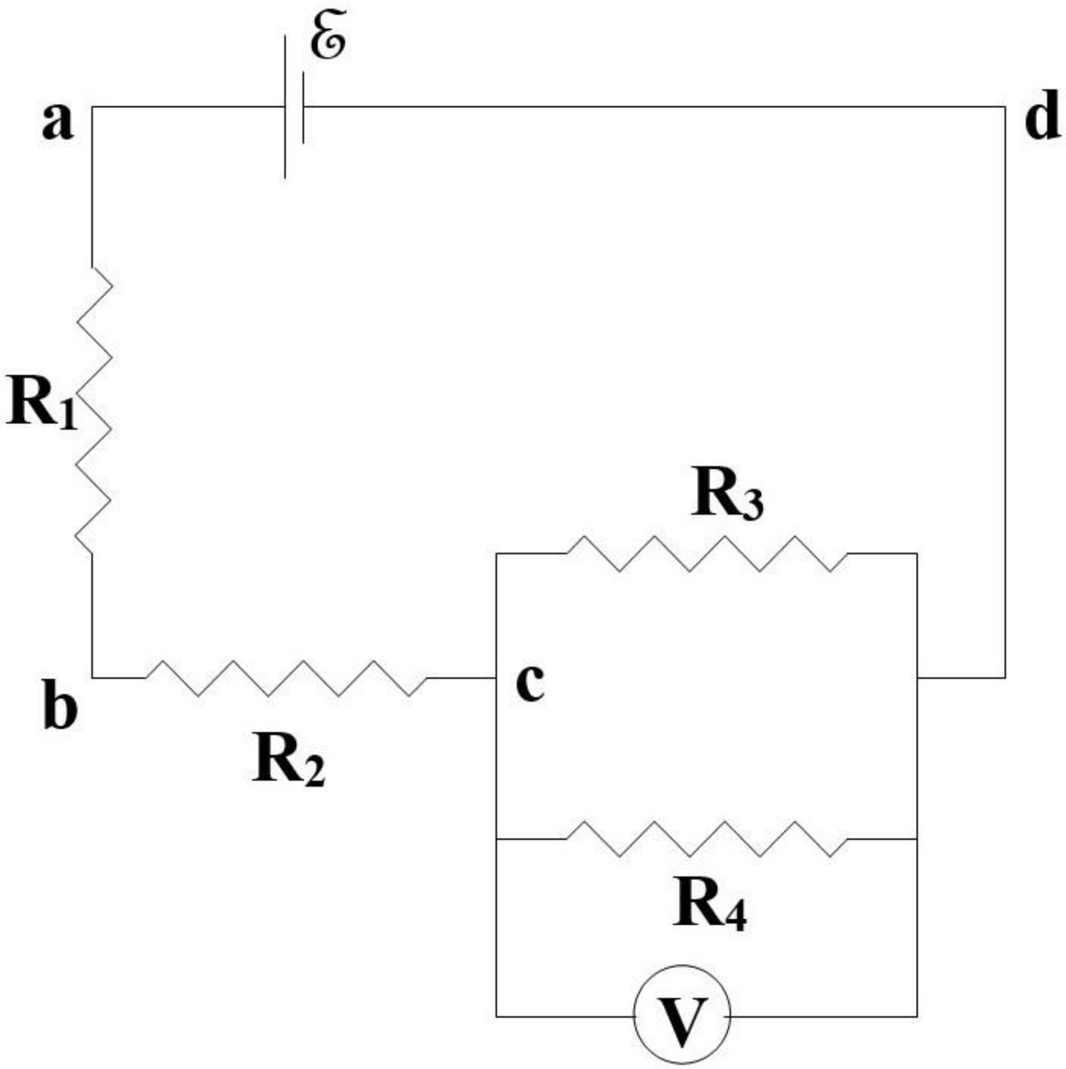

Figure 3: In an electrical circuit, the voltmeter should be mounted in parallel. To measure both V3 and I3, the ammeter should be mounted in series with R3 (ammeter slightly different than in FIGURE 2).

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4. From your results, infer four general rules about voltages and currents in series and parallel (two rules for each).
5. Using Ohm's law, measure the total resistance between "a" and "d." Explain your method.
6. Using a multimeter, measure the resistance between "a" and "d." Compare to your results in #5.
7. Using the rules that you establish in Activity #1, find the expected equivalent resistance between "a" and "d." Compare with your results in #6 and #7.