

# Ohm's Law and Resistivity

## (Multimeter / PASCO Sensors)

Your Name \_\_\_\_\_

Partners' Names \_\_\_\_\_

TA's signature allowing you to take the quiz or leave \_\_\_\_\_

Obtained reasonable experimental results?	yes	<input type="checkbox"/>
Answered questions?	yes	<input type="checkbox"/>
Cleaned your table?	yes	<input type="checkbox"/>

**When you measure a current, you have to be careful more about the connections. Wrong connections and measurement may break the device.**

### Introduction

Ohm's law is a fundamental rule to analyze circuits when a circuit involves voltage, current, and resistance in a simplest case. The other complicated circuits can also be based on this theory. Georg Simon Ohm proposed the relationship:

$$V = IR$$

where  $V$  is voltage;  $I$  is current; and  $R$  is resistance. The resistance can be defined as how large the current flows in a circuit with a fixed voltage. The units of voltage, current, and resistance are volts (V), amps (A), and ohms ( $\Omega$ ), respectively.

From this idea, we can extend the theory to find the correspondent resistance when the circuit contains multiple resistors. Let us think of two-resistor case. What is the equivalent resistance to be derived from Ohm's law? It depends on how you connect them. If they are connected in series, the equivalent resistance is simply  $R_1 + R_2$ . On the other hand, if they are connected as parallel, the equivalent resistance has to be  $R_1R_2/(R_1+R_2)$ . This is because the current is the equal in a series connection and voltage is different in accordance with the value of each resistance.

Speaking of resistance, every material has resistance. To quantify the value, we need to know the material dependent value called resistivity,  $\rho$ . The length,  $\ell$ , and cross-sectional area,  $A$  of the material gives the resistance of it:

$$R = \rho \frac{\ell}{A}$$

From the dimension analysis, the resistivity has units,  $\Omega \cdot \text{m}$ .

### Objectives:

- To test Ohm's law
- To experimentally verify the theoretical formulas of equivalent resistance
- To find resistivity of carbon

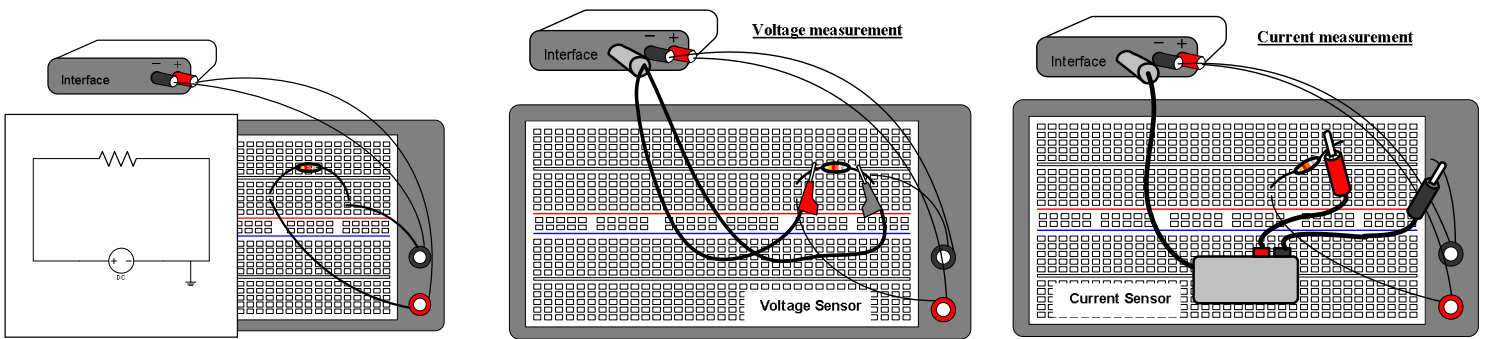
# 1. Test of Ohm's Law:

① Pick up one of the resistors and measure the resistance with a multimeter.

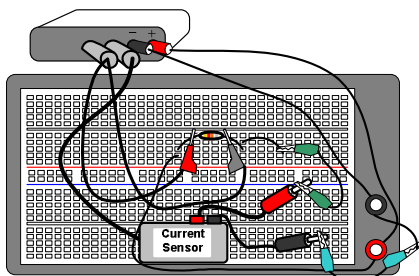
Resistance value (by multimeter):  $R_1 = \underline{\hspace{2cm}}$  ( )  $\Leftrightarrow$  Unit

② Implement the following circuit to measure the voltages and currents with voltage and current sensors. [Note that PASCO sensors and a multimeter are equivalent devices. When one of them does not work, use the other one or any one of the backups flexibly.]

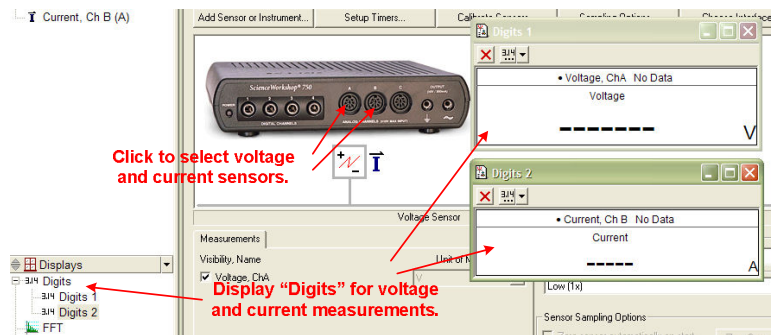
With PASCO Voltage and Current Sensors:



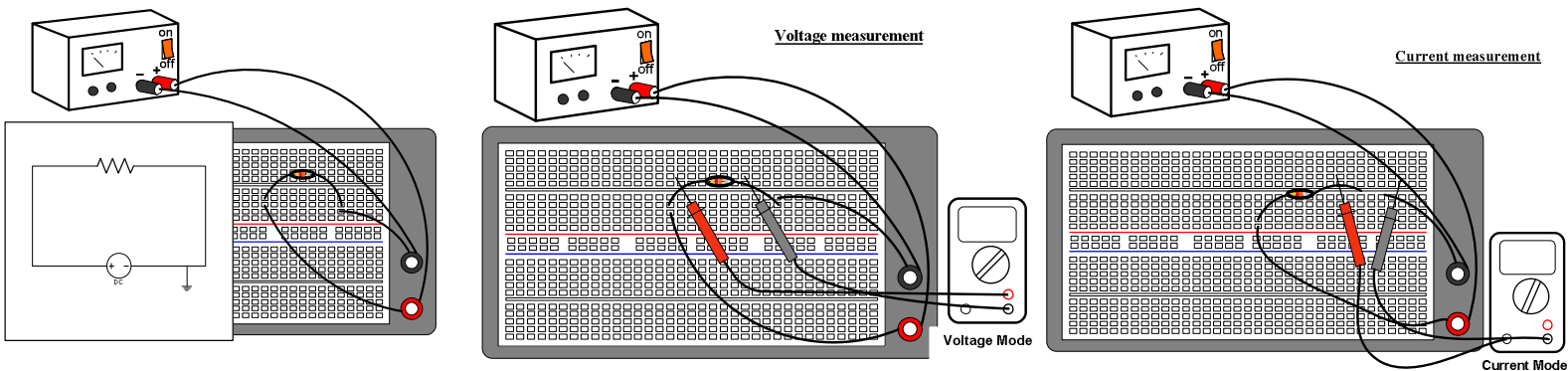
③ For PASCO sensors, start up DataStudio and click "Create Experiment." Then, follow the figure to display the measurements.



Find that this is a combined measurements for both voltage and current.



With a Multimeter:

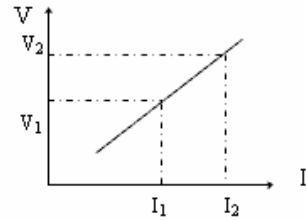
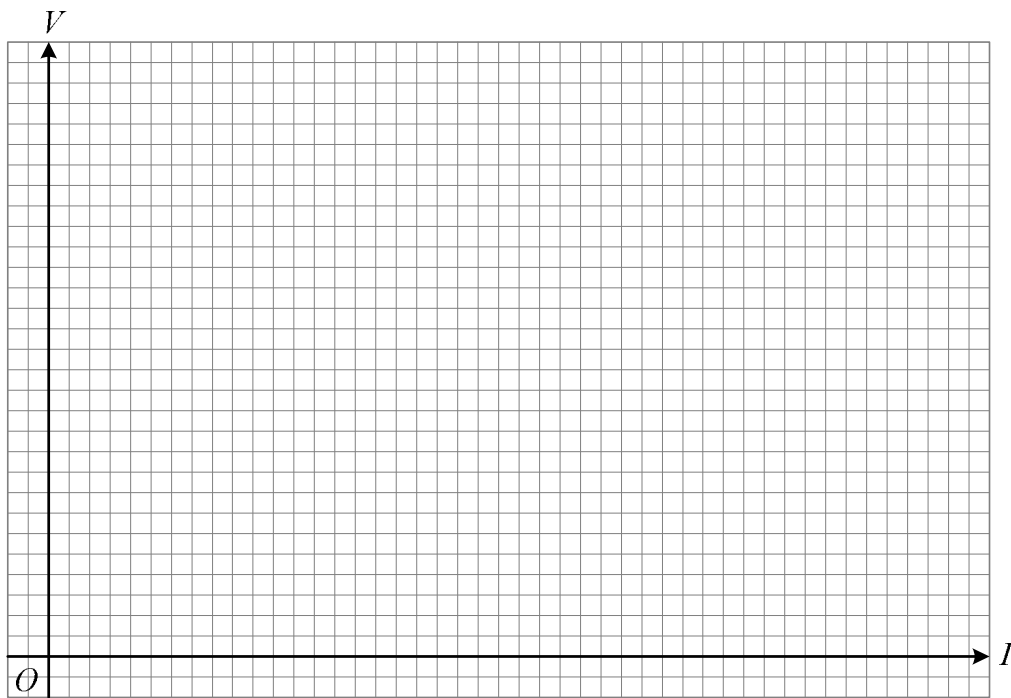


[Measuring a current with a multimeter, you read zero amperes even though the circuit is correctly arranged. This means that the fuse in the multimeter is likely blown up. Replace it and measure the same way.]

④ Change the voltage for each trial (from 1V to 5V).

	Voltage (V)	Current (A)
1		
2		
3		
4		
5		

\* Plot the data as voltage vs. current. According to Ohm's Law,  $V=RI$ , the slope of the line should be the resistance.



$$\text{slope} = \frac{V_2 - V_1}{I_2 - I_1}$$

**Question:**

Is the slope you obtain from the graph agreed with the one you measured with a multimeter?

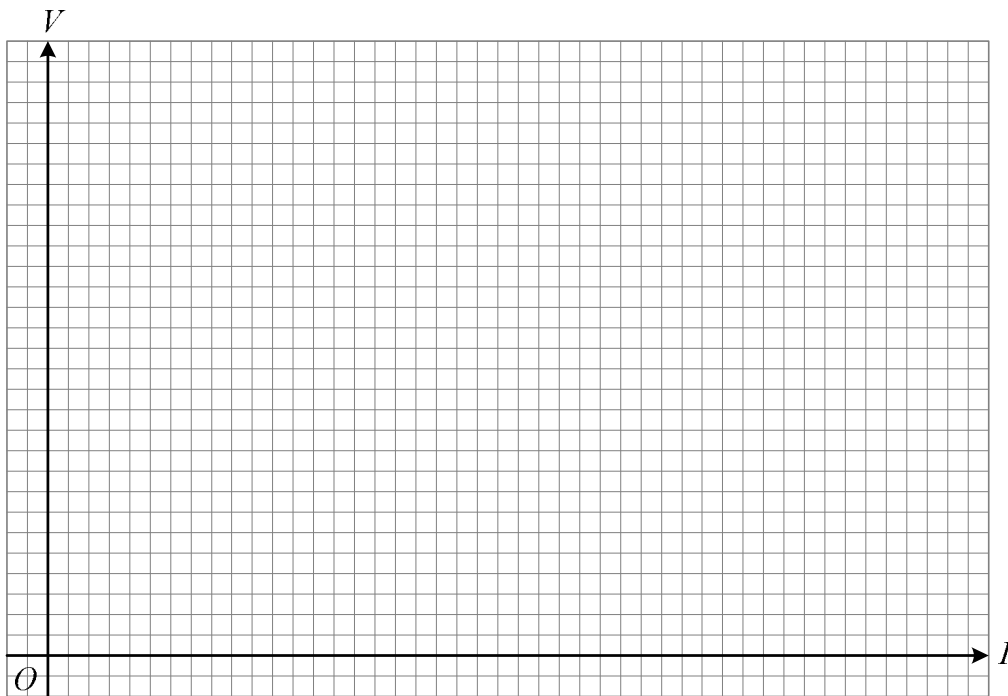
① Pick up the other resistor and measure the resistance with a multimeter.

Resistance value (by multimeter):  $R_2 =$  \_\_\_\_\_ ( )  $\Leftarrow$  Unit

② Implement the circuit to conduct the same procedure as in the first part.

	Voltage (V)	Current (A)
1		
2		
3		
4		
5		

\* Plot the data as voltage vs. current. According to Ohm's Law,  $V=RI$ , the slope of the line should be the resistance.

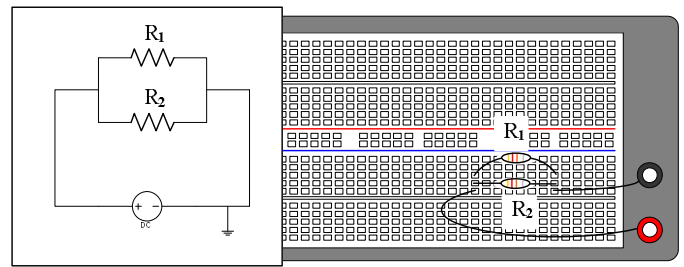
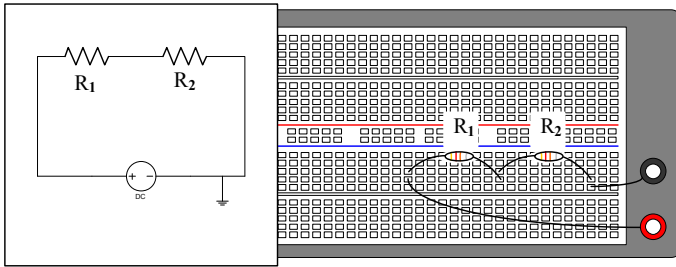


**Question:**

Is the slope you obtain from the graph agreed with the one you measured with a multimeter?

2. **Resistors Connected in Series or in Parallel:** (Use the results in the first part to calculate the theoretical values here.)

① **Implement the following circuits:**



② **Find the voltage and current. The voltage has to be measured with a parallel connection (See the first part). The current has to be measured as series connection.**

➤ **Direct Measurements**

		Voltage (V)	Current (A)	Resistance ( $\Omega$ ) (=voltage÷current)
1	both in series			
2	both in parallel			

➤ **Confirmation with the Resistance Addition Rules**

Use  $R_1$  and  $R_2$  obtained from the first part of the experiment.

(Series connection)  $R_1 + R_2 =$  \_\_\_\_\_

(Parallel connection)  $\left[ \frac{1}{R_1} + \frac{1}{R_2} \right]^{-1} = \frac{R_1 R_2}{R_1 + R_2} =$  \_\_\_\_\_

**Question:**

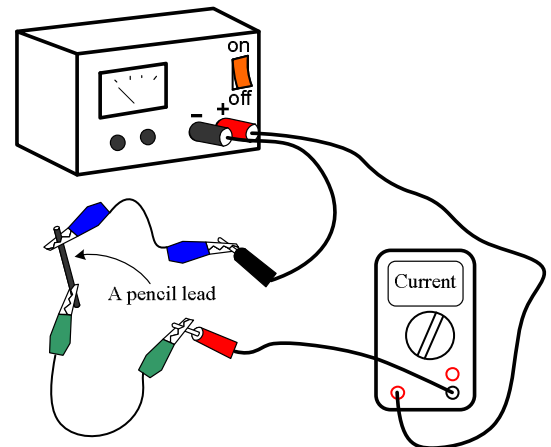
Do the theoretical results agree with the resistance values of 1 and 2 in the above table?

3. **Resistivity of carbon (graphite):**

[Ⓛ Use caution! Make sure everything with TA before you conduct this experiment.]

① Take a pencil lead and connect as shown in the figure. (Including the multimeter with current mode, the circuit must be series connection as shown in the first figure.)

② Make sure the knob of the power supply indicates zero. [You cannot use more than 2 volts. The pencil lead will be heated.]

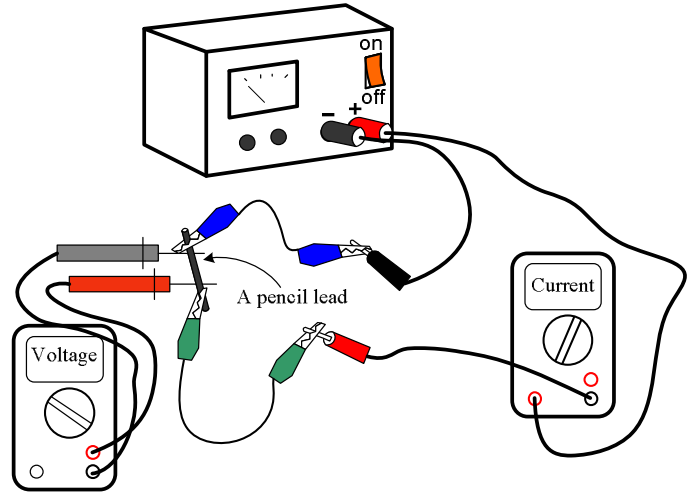


③ Simultaneously, the voltage must be measured. Use a multimeter and put both probes on the lead with a parallel connection as shown in the second figure.

④ Turn on the power and dial the knob slowly.

⑤ The current observed may be fluctuating. Thus, estimate an approximate average from the graph or multimeter display.

⑥ **Turn off the power or take the pencil lead out of the circuit immediately after the measurement.**



Now, find the resistivity of the pencil lead (carbon and clay mixture).

Recall  $R = \rho \frac{\ell}{A}$  where  $\rho$  is resistivity. From Ohm's law,  $R = \frac{V}{I}$ , the resistance can be calculated. The length of the pencil lead,  $\ell$ , is measured with a ruler and the area,  $A$ , can be calculated by the information of the diameter of the lead.

Current from the graph, $I$ (Estimate the average.)	Voltage measured by a multimeter, $V$	Resistance of the pencil lead, $R$ (Calculate this from the previous two columns.)	Length of the pencil lead, $\ell$ (must be in meters)	Area to be obtained from the diameter, $d$ , of the lead (Area of circle = $\pi(d/2)^2$ )	The resistivity, $\rho$ , of the pencil lead from $R = \rho \frac{\ell}{A}$

**Question:** The reference value of the resistivity of carbon is about  $5 \sim 20 \times 10^{-6} \Omega\text{m}$ . Have you obtained a result around that order? (Note that the pencil lead also contains clay besides carbon.)

**Questions you want to explore**

(Discuss with your partners and TA. If the TA suggests, address this to your report.)

① Human body is like an electric circuit. The muscles and fat can be the circuit elements. Muscles have more water. Namely, muscles have less resistance than fat since water is more conducting. Grab both probes of the multimeter with your right and left hands, and you will find your resistance. This can be an application to find out your muscles and fat percentage if you know the body volume and mass.

**? Question ?**

The resistance in your body is not constant through a day. You will find that the resistance is lowered after taking shower. Why is it? Can you find the other applications, such as a medical device?

② Resistors are also used for emitting light as you see in the third part of this lab. Incandescent light is the application.

**? Question ?**

Find a daily life appliance containing resistors used for lighting or heating or any other interesting purposes.

