

Ohm's Law

Purpose

- a. To verify Ohm's law.
- b. To compare the potential *vs.* current behavior of a resistor to that of a light bulb.
- c. To determine the equivalent resistance of combinations of resistors by current-voltage method.

Theory

The fundamental relationship among the three important electrical quantities *current*, *voltage*, and *resistance* was discovered by Georg Simon Ohm. The relationship and the unit of electrical resistance were both named for him to commemorate this contribution to physics. One statement of Ohm's law is that the current (I) through a resistor is proportional to the potential difference (V) across the resistor. Ohms law is normally written as

$$V = IR \quad (1)$$

where R is the resistance of the resistor in Ohm (Ω) when potential difference (V) is in Volt and current (I) in Ampere (A). Resistance is a measure of how difficult to flow current through the device.

In this experiment you will verify Ohm's law in several different circuits using a Current Probe and a Voltage Probe. Any device that obeys Ohm's law showing linear relationship of V and I is called Ohmic device, otherwise non-ohmic device.

You will also apply Ohm's law to determine the equivalent resistance of resistors connected in different combinations. Fig. 1a shows the resistors connected in series and Fig. 1b shows the resistors connected in parallel.

Equivalent resistance (R_{eq}) in series combination of resistors is given by

$$R_{eq} = R_1 + R_2 + R_3 + \dots \quad (2)$$

and equivalent resistance (R_{eq}) in parallel combination of resistors is given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \quad (3)$$



Fig. 1a. Series combination of resistors

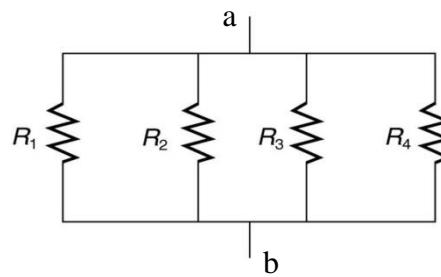


Fig. 1b. Parallel combination of resistors

Apparatus

Vernier Circuit board, LabQuest interface device, current probe, voltage probe, computer with Logger Pro, Power supply, light bulb (6.3 V), digital multimeter.

Description of Apparatus

We are going to use a Vernier Circuit Board-2 as shown in Fig. 2 for this experiment. The circuit board contains resistors, capacitors, an LED, switches, battery clips, connections for external power, a resettable fuse, connections for the addition of other components, and turreted test points for easy connection of alligator-clip test leads. The Vernier circuit board is designed for use in the study of simple electric circuits.

We will be using resistors and light bulb holders in the circuit board for this laboratory. A DC power supply with variable output, Vernier voltage probe and current probes will be used for measurements. These probes must be connected to a Vernier Lab Quest which may be connected to a computer. Vernier Logger Pro software will be used for collecting and analyzing the data.

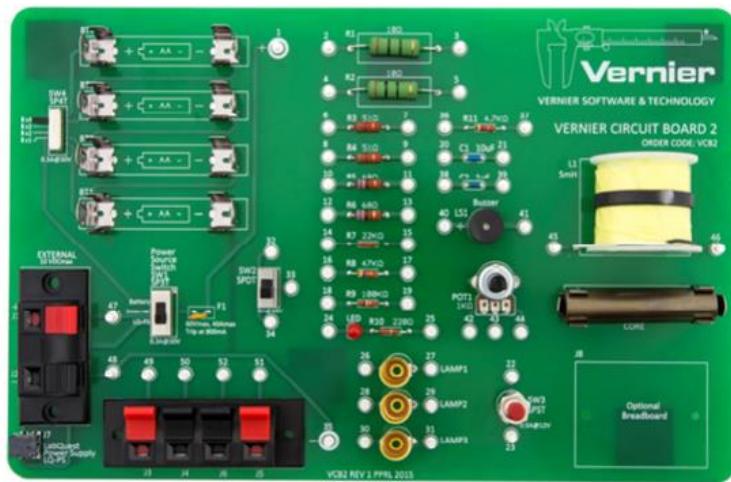


Fig. 2. Vernier Circuit board

Basic circuit diagram for this lab is shown in Fig. 3a. A resistor (a and b are terminals of the resistor) is connected to a variable power supply to change the current through the resistor. In order to measure the current an ammeter is connected in series and to measure potential difference a voltmeter is connected in parallel.

Why are the ammeter connected in series and voltmeter in parallel to the resistor?

As we are using a variable power supply, voltage and current sensors and Vernier apparatus, our real circuit connection will look like in Fig 3b. CS is the current sensor and VS is the voltage sensor. The arrow in the CS indicates the direction of current when the reading is positive. Voltage sensor reads positive when the potential at the red terminal is higher than that at the black terminal.

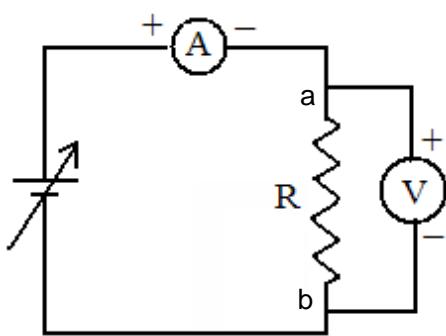


Fig. 3a. Basic Circuit diagram

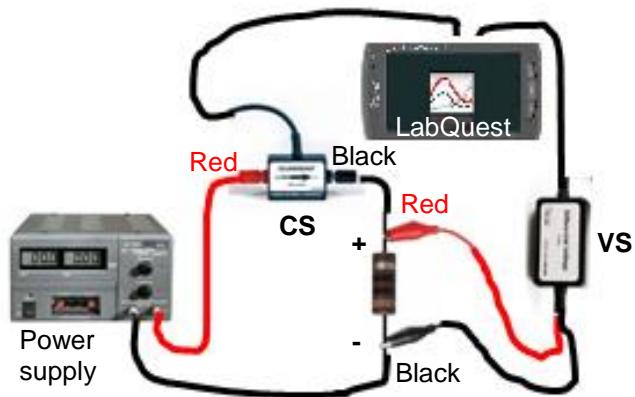


Fig. 3b. Sketch of circuit connection

Procedure

Preliminary Set Up

- Connect the Current Probe to channel 1 and the Differential Voltage Probe to channel 2 of the LabQuest. The LabQuest should be connected to a computer
- With the power supply turned off, connect the variable output of power supply to a $10\ \Omega$ resistor in the circuit board along with voltage sensor (VS) and current sensor (CS) using wires and clips as shown in Figure 3b. Take care that the positive lead from the power supply and the red terminal from the Current & Voltage Probes are connected as shown in Figure 3b. **Note:** Attach the red connectors electrically closer to the positive side of the power supply. Have your instructor check the arrangement of the wires before proceeding.
- Open Logger Pro in the computer and choose New from File menu. You should see the current and voltage readings. Otherwise you need to set up the sensors.
- Before taking the measurement, you need to zero both probes with no current flowing and with no voltage applied (i.e. power supply off). With no current flowing and with no voltage applied, wait for the readings on the screen to stabilize. Then, click Φ on menu bar or choose **Zero ► All Sensors** from the Sensors menu. The readings for both sensors should be close to zero.
- The current and voltage readings on the screen are updated about once a second. Turn the control on the DC power supply to 0 V and then turn on the power supply. Slowly increase the potential to 5 V (**DO NOT EXCEED 5 V**). Monitor the readings and describe what happens to the current through the resistor as the potential difference across the resistor changes. If the potential doubles, what happens to the current? What type of relationship do you expect between potential difference and current?

Turn down the power supply voltage to zero. You are now ready to take measurements

Part I. Potential difference (V) versus current (I) behavior in a resistor

1. Record the value of the resistor in the data sheet.
2. Change the data-collection mode to *Selected Events mode* so that the interface will record the potential and current only at times you specify. On menu bar, click *Experiment* and choose *Data Collection*, and select *Selected Events in mode*. Click *Done*. [You can also use short cut icon, , on the menu bar.]
3. Start data collection. Check to see that your power supply is set to 0 V, and then click **Keep**, next to the start button, to record the current and potential.
4. Increase the potential on the power supply to approximately 0.5 V. Click **Keep** to record another data pair.
5. Increase the potential by about another 0.5 V and click **Keep** to record another data pair.
6. Repeat this process until you reach a potential of 5.0 V. **After the last point, click stop** to stop the data collection and **Set the power supply back to 0 V**.

Two graphs should be displayed on the screen one for potential (Voltage) and another for current. But we like to plot the graph of voltage versus current!

7. To view a single graph of potential *vs.* current, choose Show Graph ► Graph 1 from the Graph menu.

- Change the y-axis (the vertical axis) to Voltage.
- Change the x-axis to Current. The new plot appeared is the V-I curve.

[Short cut: click at *Event* on horizontal axis of Potential graph and select *Current*]

Are the voltage and current proportional for this resistor? If so, fit a straight line to the data using **Linear Curve Fit** under the **Analyze** menu.

Record the slope and y-intercept of the regression line in table 1, along with their units. You should include the graph in your report.

What is the physical significance of these values?

8. Now, repeat the previous Steps 1 – 7 using a different resistor in the circuit board. Analyze the V-I curve and record the data in table 1.

What will happen to the V-I curves if the current in the circuit is reversed?

Part II. Potential difference (V) versus current (I) behavior in a light bulb

In this part of the experiment, you are going to investigate the potential *vs.* current behavior of a light bulb and compare it to a resistor you just found.

- Insert a 6.3 light bulb in one of the light bulb holder on the circuit board. Replace the resistor in the circuit with the light bulb. Repeat Steps 2–7, but this time, increase the voltage in 0.1 V steps up to 1.0 V, 0.5 V steps from 1 to 4 V, and in 0.1 V steps again from 4 to 5 V.
- To examine the graph, tap any data point. As you tap each data point, the values of current and voltage will be displayed on the graph. Is the slope constant?

To compare slopes of data at different parts of the curve, estimate the slope at the start of the graph (the low-current end) using the second and third points. Record the slope in the data table. Be sure to enter the units of the slope. In the same way estimate the slope using the last two points. Record this slope in the data table.

You should include the graph in your report.

What do you expect if the current in the circuit is reversed?

Part III. Equivalent resistance in series and parallel combinations

You should have observed that resistors obey Ohm's law thus the resistors are Ohmic device. Resistance, R , is defined using $R = V/I$. The resistance could be due to a single resistor or several resistors connected in different configuration. In this part of the experiment, you are going to determine the equivalent resistance of the resistors connected in a series, a parallel and a mixed combinations.

a. Series combination

- In the circuit board, connect three resistors (two $10\ \Omega$ and one $51\ \Omega$) in series as in the circuit shown in Fig. 1a using connecting wires. Make sure you identify the terminals a and b of this combination. (Note: terminals of this combination is same as the terminals of a single resistor or a bulb).

2. Measure the resistance of the combination using the digital multimeter and record in table 2.
3. Now connect the terminals of this combination in your previous circuit to measure potential and current. Have your instructor check the circuit before proceeding.
4. Repeat Steps 2–7 of Part I. Record the value of slope in table 2.

b. Parallel combination

1. Now, remove all the wires used to prepare the previous combination of resistors and prepare a parallel combination of three resistors (two $10\ \Omega$ and one $51\ \Omega$) using connecting wires. Make sure to identify the terminals of the combination. You may connect two wires at the terminal for terminals a and b.
2. Measure the resistance of the combination using the digital multimeter and record in table 2.
3. Now connect the terminals of this combination in your previous circuit to measure potential and current. Have your instructor check the circuit before proceeding.
5. Repeat Steps 2–7 of Part I. **Take the data only up to 3 V.**
Record the value of slope in table 2.

c. Mixed combination

1. Now construct a new circuit on the circuit board with a combination of resistors as shown in the Fig. 4. Measure the resistance of the combination across the terminals a and b using the digital multimeter.
2. Connect the terminals a and b to your previous circuit to measure potential and current.
3. Repeat Steps 2–7 of Part I. **Take the data only up to 3 V.**
Record the value of slope in table 2.

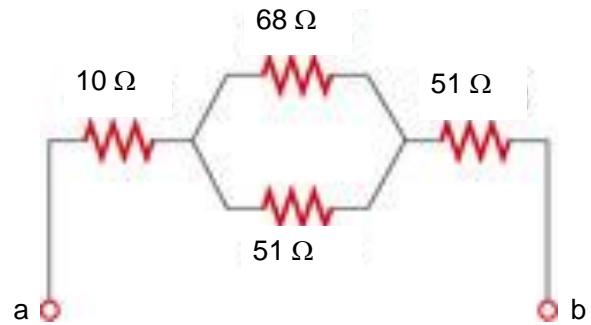


Fig. 4. Combination of resistors

COMPUTATION AND ANALYSIS

Part I

1. From your observation, is there a proportional relationship between voltage and current?
Compare your observation with the resistors and the light bulb.
2. In case of the resistors, how close is the y-intercept to zero? What is the significance of having the y-intercept close to zero?
3. Compare the value of the slope you determined in each fitting to the resistance of each resistor. Resistors are manufactured such that their actual value is within a tolerance. For most resistors the tolerance is 5% or 10%. Check with your instructor to determine the tolerance of the

resistors you are using. Calculate the range of possible values for each resistor. Is the value of slope within the appropriate range of values for each resistor?

4. Do your resistors follow Ohm's law? Base your answer on your experimental data.

Part II

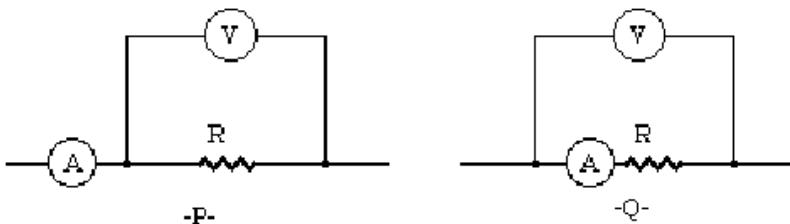
1. Describe what happened to the current through the light bulb as the potential increased. Was the change linear?
2. Since the slope of the linear regression line is a measure of resistance, describe what happened to the resistance as the voltage increased.
3. How does, you think, the resistance vary with temperature?
4. Does your light bulb follow Ohm's law? Base your answer on your experimental data.

Part III

1. For all combination, calculate the equivalent resistance and tabulate in table 2.
2. Compare the calculated resistances with measured values from digital multimeter and V-I curve. Are those values within the appropriate range?

Questions

1. If one lamp of a group of five identical lamps in series is removed, the voltage across the empty socket becomes equal to the line voltage, rather than remaining one-fifth of it. Why?
2. The circuits, P and Q, show two different ammeter-voltmeter methods of measuring resistance. Suppose the ammeter has a resistance of 0.10 ohms and the voltmeter has a resistance of 3.0 ohms; the ammeter reads 2.5 amps and the voltmeter reads 6.0 volts. What is the uncorrected value of the resistance in each case? What is the true value of the resistance in each case?



3. A piece of copper wire of resistance R is cut into 10 equal lengths. These parts are connected in parallel. How does the joint resistance of the parallel combination compare with the original resistance of the single wire?

Data Sheet

Date experiment performed:

Name of the group members:

Table 1. Potential vs. current

Part I and II

	Slope of regression line (V/A)	Y-intercept of regression line (V)
Resistor _____ Ω		
Resistor _____ Ω		
Light bulb (low current)		
Light bulb (high current)		

Table 1. Equivalent resistance

Part III

Resistors used	Combination	Resistance from multimeter (Ω)	Resistance from the slope of the V-I curve (Ω)	Calculated resistance (Ω)
10 Ω , 10 Ω , 51 Ω	Series			
10 Ω , 10 Ω , 51 Ω	Parallel			
10 Ω , 68 Ω , 51 Ω , 51 Ω	Mixed			