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Experiment 2.03: Ohm's Law

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I. EXPERIMENT 2.03: OHM'S LAW

A. Abstract

Ohm's law is used to determine the resistance of several resistors.

B. Formulas

$$\Delta V = IR \tag{1}$$

$$R_{\text{eq}} = R_1 + R_2 + \cdots, \text{ series} \tag{2}$$

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots, \text{ parallel} \tag{3}$$

Resistor color codes:

color	no.
black	0
brown	1
red	2
orange	3
yellow	4
green	5
blue	6
violet	7
gray	8
white	9

$$R = (10c_1 + c_2) \times 10^{c_3} \tag{4}$$

where $(c_1\ c_2\ c_3)$ represents the resistor's 3-color bands and R is the value of the resistance in Ohms. For example, Brown-Black-Brown corresponds to $(1, 0, 1)$, therefore $10c_1 + c_2 = 10$ and $R = 10 \times 10^1 = 100$.

C. Description and Background

In this experiment, you will become familiar to some standard equipment (ammeter and voltmeter). You will also learn how to build electric circuits with resistors and wires (Fig. 2). Then, you will learn how to measure the current through a wire, as well as the voltage between two points in a circuit. Finally, you will verify Ohm's law. See Appendix I at the end of this document for important instructions on the use of multimeters.

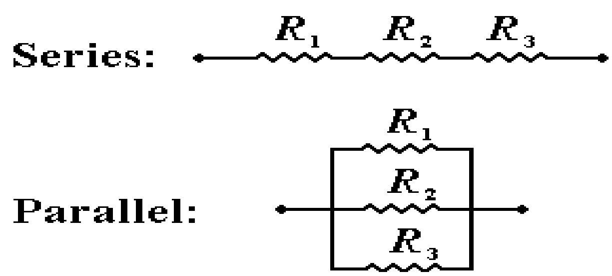

FIG. 1. (a) Flow of current from A to B through a resistor R. ΔV is the potential difference between points a and b. (b) Ohm's law.

As we learned in class, Georg Simon Ohm (1787-1854) established experimentally that the current, ΔI, flowing through a resistor (*e.g.*, a metal wire) is proportional to the potential difference ΔV applied to its two ends (points a and b in Fig. 1a). The magnitude of the electric current depends not only on the potential difference but also on the resistance of the wire (see (b) in Fig. 1). We define the electrical resistance, R, to be:

$$R = \frac{\Delta V}{\Delta I}, \text{ Ohm's law}$$

The unit for resistance is called the Ohm (Ω).

Resistors connected in series (Fig. 2b) have an equivalent resistance, R_{eq}, given by Eq. 2, while resistors in parallel (Fig. 2c) have an equivalent resistance given by Eq. 3. In both cases, the equivalent resistance draws a current I, such that $V = IR_{eq}$.

Typical resistors have a four–color code (Fig. 3). From the figure, the tolerance (colored line D) could be either silver (10%) or gold (5%); if there is no D–line it means that the tolerance is 20%. The value of the resistor is given by colored lines (see Table above) $A = c_1$, $B = c_2$, and $C = c_3$, according to Eq. 4.

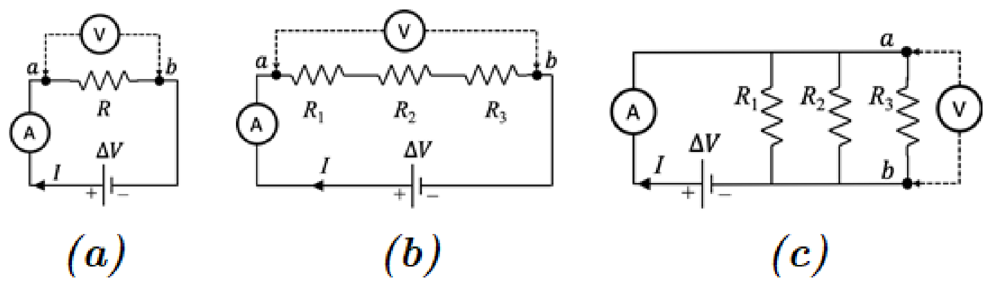

FIG. 2. (a) A single resistor. (b) Resistors in series. (c) Resistors in parallel. The (A) and (V) indicate the ammeter and voltmeter, respectively.

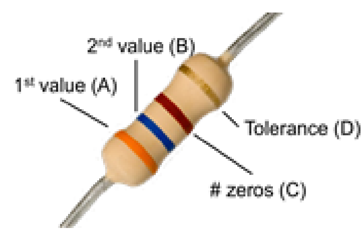

FIG. 3. Typical resistor with a 4-color code.

For the resistor in the figure, $c_1 = 3$ for orange, $c_2 = 6$ for blue, $c_3 = 2$ for red, and D is gold. Using Eq. 4:

$$R = (3 \cdot 10 + 6) \times 10^2 = 3600\ \Omega$$

With a tolerance of:

$$3600 \times 0.05 = 180\ \Omega$$

Thus the resistance is

$$R = (3600 \pm 180)\ \ \Omega$$

D. Procedure

1. Using the color codes in the Table, find the value of each of three resistors in the figure below and record them.

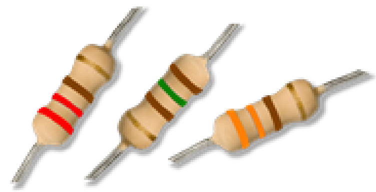

FIG. 4. From left to right R_1, R_2, and R_3.

2. For each of three resistors (resistance range: $150 - 560\ \Omega$), set up a simple circuit that includes the resistor and a variable emf source ($\mathcal{E} \leq 5\ V$).

3. Use a voltmeter to measure the voltage across the resistor and an ammeter to measure the current in the circuit. The ammeter should be set to measure *milli-Amps*. See Appendix I at the end of this document for important instructions on the use of multimeters.

4. Do as many trials as possible by varying the emf.

5. Connect the three resistors in series and repeat steps 2 through 4.

6. Connect the three resistors in parallel and repeat steps 2 through 4.

1. *Figures*

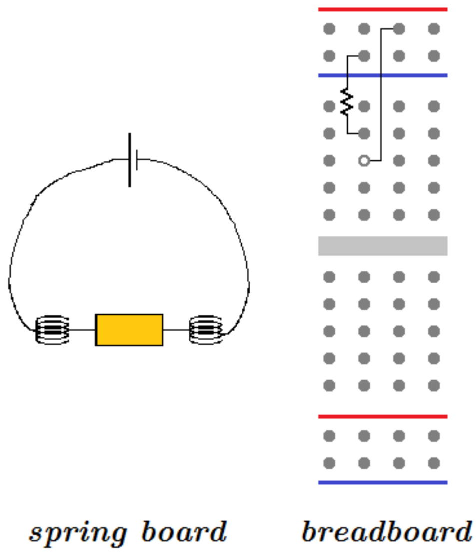

FIG. 5. Single resistor.

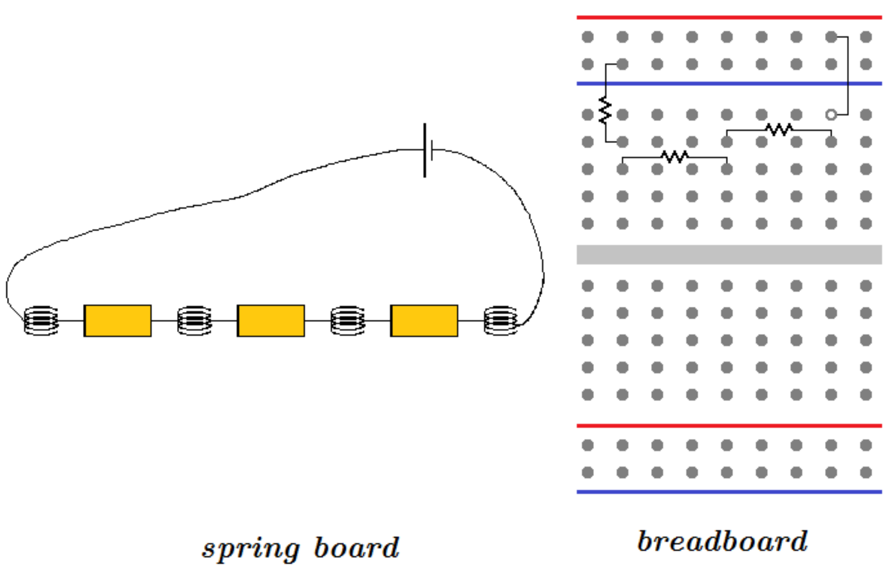

FIG. 6. Resistors in series.

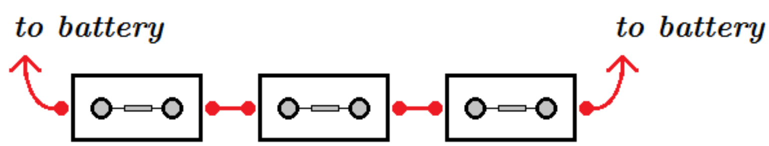

FIG. 7. Di-Binding-Post Blocks in Series

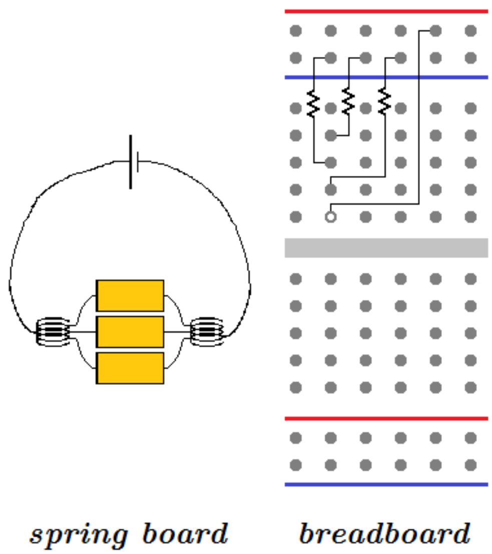

FIG. 8. Resistors in parallel.

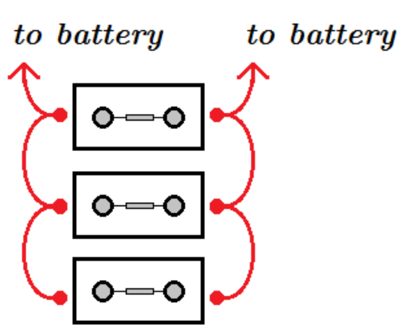

FIG. 9. Di-Binding-Post Blocks in Parallel

E. Measurements

resistor 1		
Trial	I [Amp]	ΔV [$Volt$]
1	0	0
2		
3		
4		
5		

resistor 1 colors			
by the colors R_1 [Ω]			

resistor 2		
Trial	I [Amp]	ΔV [$Volt$]
1	0	0
2		
3		
4		
5		

resistor 2 colors			
by the colors R_2 [Ω]			

resistor 3		
Trial	I [Amp]	ΔV [$Volt$]
1	0	0
2		
3		
4		
5		

resistor 3 colors			
by the colors R_3 [Ω]			

resistors in series		
Trial	I [Amp]	ΔV [$Volt$]
1	0	0
2		
3		
4		
5		

resistors in parallel		
Trial	I [Amp]	ΔV [$Volt$]
1	0	0
2		
3		
4		
5		

F. Instructions

1. Use **OhmsLawPlot.xlsx** to make plots of ΔV *vs.* I in each of the five cases, and determine the resistance from the slopes.

G. Calculations

resistor(s)	R [Ω] based on the analysis	R [Ω] based on the colors	% Difference
1			
2			
3			
series			
parallel			

II. APPENDIX I

A. Multimeters

Multimeters are versatile electronic devices that can be used to measure properties such as voltage, current, and resistance. Multimeters typically employ two leads, one of which is always plugged into a socket labelled COM for common. The second lead is plugged into the socket appropriate to the function desired and usually labelled V (Volts) for voltage, mA, μA, or 10A (Amps) for current (depending on the expected range), and Ω (Ohms) for resistance. There is also a dial that turns the multimeter on and must be turned to the appropriate setting. There is a toggle key that will switch from DC to AC mode and a toggle key that can switch the numerical range of measurements.

B. Voltmeters

Voltmeters are nonintrusive to a circuit. The leads are used to probe the voltage between two points in the circuit. When using a voltmeter to measure the voltage across a circuit element, attach the leads (alligator clips) to both ends of the element under consideration.

C. Ammeters

Ammeters, unlike voltmeters, are intrusive to a circuit in that they must be inserted into the circuit segment whose current is to be measured. The circuit segment must therefore be broken and the ammeter placed in series with the other segment elements.

When using the ammeter with the circuit spring board, lift one end of the resistor from the spring it is attached to and bridge the gap with the ammeter leads, *i.e.*, attach one lead to the spring and the other lead to the free end of the resistor.

When using the ammeter with the circuit breadboard, lift the end of the jumper wire depicted in the figures (*e.g.,* those in Experiments 2.02-2.04) by an open circle. Attach one lead to the free end of the jumper wire and the other lead to the exposed wire of the resistor on the same terminal strip (column in the figures).

The circuit should remain open until the ammeter is inserted. Once properly inserted, the ammeter is turned on. The circuit is then closed, and the current measurement taken.

Removal of the ammeter should proceed in reverse: The circuit is opened, then the ammeter is turned off and removed. *Failure to follow this procedure may result in damage to the ammeter.*

D. Ohmmeters

An ohmmeter measures the resistance of whatever is connected between its two leads. Consequently, it is important that only those elements (or arrangement), whose resistance is sought, be positioned between the leads. This may require separating the arrangement of elements from the rest of the circuit to make the proper ohmmeter measurement. Case (a) in the figure below depicts an example of a faulty ohmmeter measurement. The goal is to measure R_1, but this resistor is not the only element between the ohmmeter leads in case (a). The reading in case (a) would actually be $R_1\,(R_2 + R_3)\,/\,(R_1 + R_2 + R_3)$. In case (b) the resistor of interest is separated out and is the only element between the leads.

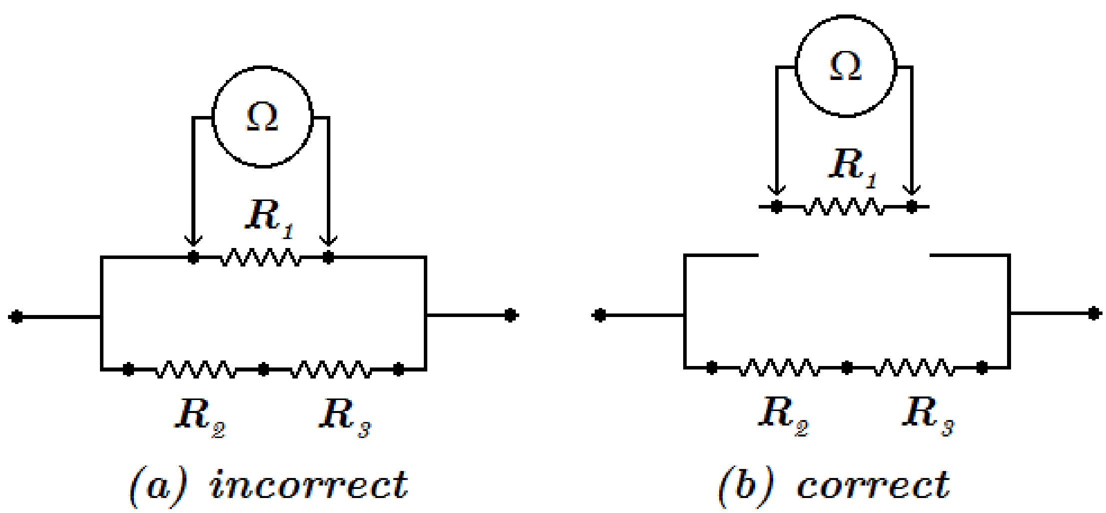

FIG. 10. Example of improper and proper use of ohmmeter.