Engineering Physics – E & M Lab 4

OHM'S LAW

INTRODUCTION

During the nineteenth century so many advances were made in understanding the electrical nature of matter that it has been called the "age of electricity." One such advance was made by an investigator named Georg Simon Ohm. Ohm was interested in examining the relative conductivity of metals and in investigating the relationship between the electromotive force (potential difference) and the current in a conductor.

By taking wires made from different materials but having the same thickness, passing a current through these wires and measuring the electromotive force (i.e., the potential difference between the ends of the conducting wire), he was able to experimentally determine the relative conductivity of certain metals such as silver, copper, and gold.

In another experiment using a piece of apparatus that he built himself, Ohm investigated the effect of current in a conductor on the voltage drop across the conductor. He found that for a given conductor the voltage drop was directly proportional to the current in the wire. When voltage is plotted against the current in a given conductor, the data can be fitted to a straight line, the slope of which is the ***resistance*** of the conductor. This result was published in 1826. In recognition of Ohm's work, this empirical relationship bears his name.

DISCUSSION OF PRINCIPLES

Ohm's Law can be written algebraically as $V = RI$, where V represents the potential drop across the conductor (measured in volts), I the current in the conductor (measured in amperes), and R the resistance of the conductor measured in units called "ohms" (symbolized by Ω, upper-case Greek omega).

Resistance and Resistors

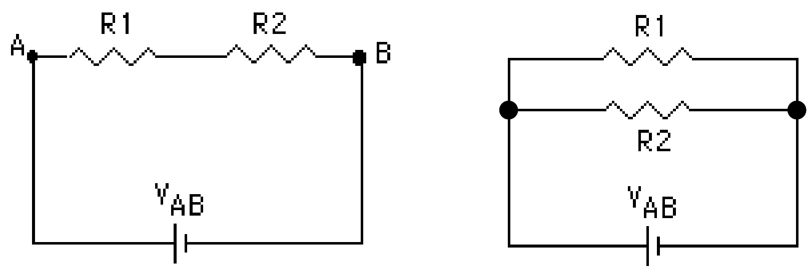
Resist<u>ance</u> is a property of materials. *Resist<u>ors</u>* are conducting devices made from materials, which satisfy Ohm's Law.

If the potential difference across a resistor is set at 1 volt, and if a current of 1 amp is measured in the conductor, then its resistance is determined to be 1 ohm, or 1 Ω. Instead of using thin wires as Ohm did in his original experiment, you will replicate his results using small cylindrical ceramic resistors. You will notice colored bands on the resistors. These bands form a code that indicates the resistance of the resistor. Later in this experiment you will learn how to read this color code.

Combinations of Resistors

Resistors can be combined in simple circuit arrangements that increase or decrease the overall resistance in the circuit. These arrangements are called ***series*** and ***parallel*** circuits. Figure

1(a) illustrates two resistors connected in series and Figure 1(b) shows the resistors in a parallel arrangement.



(a) (b)

Figure 1 Resistors in Series and Parallel Arrangements

In order for charges to move in a conductor, there must be a potential difference across the conductor. In order for charges to move through a circuit, there must be a complete path leading away from and back to the source of emf (V_{AB} in Figure 1).

As you can see, in the series arrangement shown in Figure 1(a) the current I in the circuit goes through each resistor. If we compute the potential drop V_1 across R_1 using Ohm's Law, it is merely $V_1 = IR_1$. Likewise, the drop across R_2 is $V_2 = IR_2$. The potential drop across both resistors is $V_{AB} = V_1 + V_2$. One can think of the applied voltage V_{AB} being divided between the two series resistors R_1 and R_2.

In the parallel arrangement shown in Figure 1(b), however, the current divides at the junction A and recombines at junction B. Therefore, the current through R_1 and R_2 may be different. Notice that in this case $V_{AB} = V_1 = V_2$. That is, the potential drop across each resistor is the same.

Using some simple algebra and your understanding of the potential drops in a simple series or parallel circuit, the relationships for determining **equivalent resistance** for resistors in series and/or parallel can be derived. These relationships are:

Series

$$R_{\text{equivalent}} = R_1 + R_2 + \cdots \quad (1)$$

(The equivalent resistance is simply the sum of the individual resistances.)

Parallel

$$\frac{1}{R_{\text{equivalent}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \quad (2)$$

(The *reciprocal* of the equivalent resistance is the sum of the reciprocals of the individual resistances.)

As suggested in Eqs. (1) and (2), the sums include a term for each resistor in the circuit.

PROCEDURE (A) – 100 Ohm Resistor:
Determining Resistance
We will use a computer and software to act as our battery and voltmeter, while we monitor the current with a hand-held multimeter. **Do not turn on the power to your circuit until your lab instructor has checked your wiring**.

1) When the computer boots up, go to the course website and follow the directions to open the Data Studio file associated with this lab. This should start the Data Studio program and a screen with windows similar to Figure 2 should appear. The windows show both a digital and analog voltmeter, both measuring the voltage from the voltage probe.

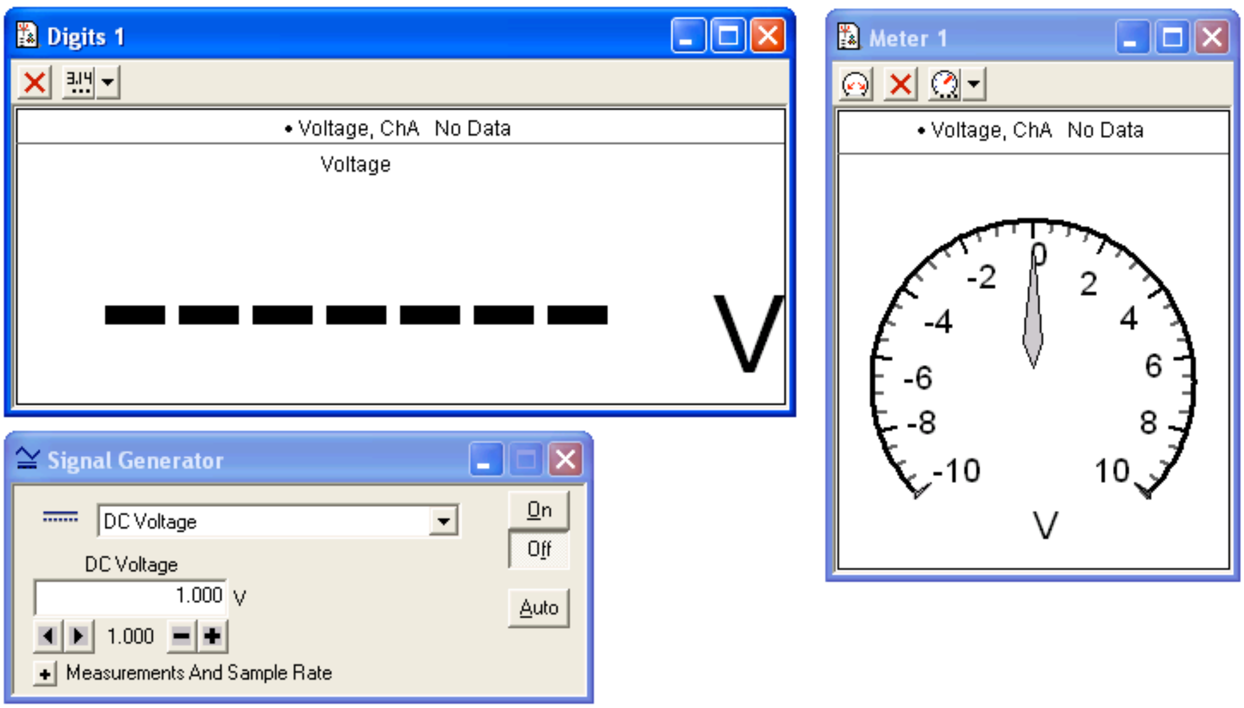


Figure 2 Start-up screen

2) Connect the circuit shown in Figure 3, using the resistor labeled as "100 Ω" on the circuit board. Our "voltmeter" is actually our computer connected to the Signal Interface. Voltmeters have a relatively **high** resistance and are placed in **parallel** with the resistor. Our "ammeter" is a multimeter. Ammeters have relatively **low** resistance and are placed in **series** with the resistor.

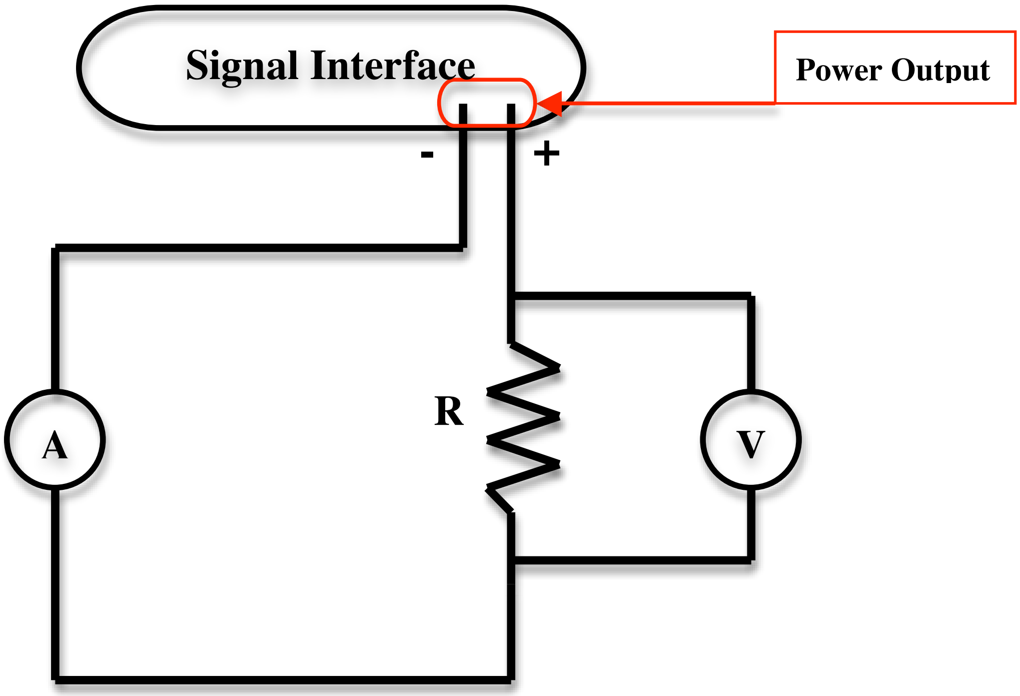


Figure 3 Circuit Diagram for Procedure A

3) Select the Signal Generator window by clicking in that window. The Signal Generator win dow is shown in Figure 4. Turn on the signal generator by clicking on the ON button. Make sure "DC Voltage" is selected. Set the DC voltage to 1 V by clicking on the small up arrow next to the voltage setting.

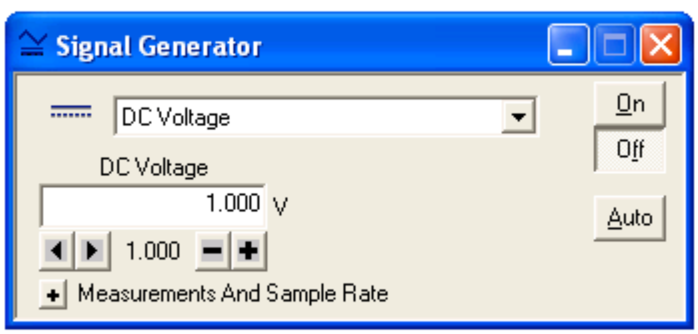


Figure 4 Signal Generator Window

4) Click on the "Start" button in the main Data Studio window to begin taking data. With R_1 in the circuit, obtain five current and voltage measurements by increasing the voltage in 1-volt steps. Note: the voltages may not be exactly what you set in the Signal Generator window.

Record the actual voltage from the voltmeter and the actual current from the ammeter in Table 1 on the worksheet below.

5) Construct a graph of voltage *vs* current using the *EXCEL* (see the EXCEL tutorial on the course website, if necessary).

6) Using the Linest function on EXCEL(see the EXCEL tutorial on the course website, if neces sary) to determine the best fitting straight line for your data and compute the slope. The slope of the line is a measure of the resistance.

Reading the resistor code

The resistance of most ceramic resistors can be determined from the colored bands printed on the resistor. Each color represents a digit from 0 to 9.

Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Gray	8
Yellow	4	White	9

The first two bands give the mantissa of a number in scientific notation; the third gives the power of ten. The fourth band gives the tolerance (uncertainty expressed as a percentage) in the value of the resistance (Gold = ± 5%, Silver = ± 10%, no 4th band = ± 20%). Therefore, in order to know which end of a resistor to “start” from when reading the color code, it is useful to remember that the 4th band, if present, is metallic in color (gold or silver). If regular colors are present instead of these metallic bands, sometimes the color bands will be spaced differently or are closer to one end of the resistor to help indicate which end to start reading from. We will not be concerned with five band resistors in this lab. If a fifth band were present, the first three bands give the mantissa, the fourth gives the power of ten and the fifth will give the tolerance (as brown, red, orange, yellow, or gold).

For example

7) Apply the color code to determine the resistance of the resistor you used in the experiment and record this value on the worksheet.

8) Compute a percent error between the accepted value of the resistance and the experimental value.

<u>Checkpoint 1:</u> **Have your TA check your chart, calculations and EXCEL graph before proceeding.**

PROCEDURE (A2) – 33 Ohm Resistor:

1) Switch the wires on the circuit board so that you will measure the resistor marked 33 Ω in the circuit shown in Figure 3. Sometimes the tolerance marking is hard to see on this resistor, if this is the case you should use 5% as the tolerance.

2) Repeat steps 2-6 for Procedure (A) with the 33 Ω resistor and fill in Table 2 and the experimental value for the resistance and its uncertainty.

3) Read the accepted value for the resistance and the tolerance on the resistor. Record these value on the worksheet.

<u>Checkpoint 2:</u> **Have your TA check your chart, calculations, and EXCEL graph before proceeding.**

PROCEDURE (B)

Determining Equivalent Resistance—Series Arrangement

1) Connect the two resistors you used before in a series arrangement. Measure the equivalent resistance of the circuit by following steps 2-6 of Procedure A. Record these in table 3 and in the blanks on the worksheet.

2) Compute the theoretical equivalent resistance using Eq. (1), the formula for calculating equivalent resistance for resistors connected in series, and the values given by the color-code bands. Record this on the worksheet.

3) Compute the percent error between the measured and calculated value. Record this on the worksheet.

<u>Checkpoint 3:</u> **Have your TA check your chart, calculations, and EXCEL graph before proceeding.**

PROCEDURE (C):

Determining Equivalent Resistance—Parallel Arrangement

1) Connect your two resistors in a parallel arrangement. Measure the voltage and current as in Procedure (B), and compute the equivalent resistance of the circuit. Record these values on the worksheet.

2) Compute the theoretical equivalent resistance using Eq. (2), the formula for calculating equivalent resistance for resistors connected in a parallel, and determine the percent error.

<u>Checkpoint 4:</u> **Have your TA check your chart, calculations, and EXCEL graph before proceeding.**

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OHM'S LAW – Worksheet

Procedure A - 100 Ohm Resistor

Voltage (volts)	Current (amps)

Table 1: 100 Ohm Resistor

Resistance = _______________ ± ______________ ohm **(Experimental)**

Resistance = _______________ ± _______________ ohm **(color code)**

Percent error = __________________________ %

Does your measured resistance value agree with the expected value within the manufactured tolerance? YES or NO (circle one)

Checkpoint 1: Chart, Calculations and Excel graph

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<u>Procedure A2 – 33 Ohm Resistor</u>

Voltage (volts)	Current (amps)

Table 2: 33 Ohm Resistor

Resistance = ________________ ± _______________ ohm **(Experimental)**

Resistance = ________________ ± ________________ ohm **(Written on Resistor)**

Percent error = _______________%

Does your measured resistance value agree with the expected value within the manufactured tolerance? YES or NO (circle one)

<u>Checkpoint 2:</u> Chart, Calculations and Excel graph

<u>Procedure B – Series Arrangement</u>

Voltage (volts)	Current (amps)

Table 3: Series Arrangement

$R_{\text{equivalent}}$ **=** ________________ ± ____________ohm **(Measured/Experimental)**

$R_{\text{equivalent}}$ **=** ________________ ± ____________ohm **(Accepted/Calculated)**

Percent error = ___________________________ %

Does your measured resistance value agree with the accepted value within the calculated range? YES or NO (circle one)

<u>Checkpoint 3:</u> Chart, Calculations and Excel graph

<u>Procedure C – Parallel Arrangement</u>

Voltage (volts)	Current (amps)

Table 4: Parallel Arrangement

$R_{\text{equivalent}}$ **=** ________________ ± ____________ohm **(Measured/Experimental)**

$R_{\text{equivalent}}$ **=** ________________ ± ____________ohm **(Accepted/Calculated)**

Percent error = ___________________________ %

Does your measured resistance value agree with the accepted value within the calculated range? YES or NO (circle one)

<u>Checkpoint 4:</u> Chart, Calculations and Excel graph