Physics 108 Lab
DC Circuits
Activity A: Signing in

(1) Before starting this experiment you must sign in. All students working with this piece of apparatus MUST enter their names in the boxes on this page.

(2) IMPORTANT If you want to clear data from a graph (for example, to redo a measurement) DO NOT use the command under the "EXPERIMENT" menu ... "DELETE ALL DATA RUNS". If you do you will LOSE ALL YOUR DATA and you, and your partners will have to redo the ENTIRE experiment. Instead use the command "DELETE LAST DATA RUN" under the "EXPERIMENT" menu.
Activities in this Experiment.

Page 2... Activity A: Signing In
Page 4... Activity B: Resistance
  Measurement of Resistance
  Coll of Wire
Page 5... Activity C: Properties of Battery
  Potential from Battery
  Internal Resistance of Battery
Page 6... Activity D: Series/Parallel (qualitative)
  2 Light Bulbs in Series
  2 Light Bulbs in Parallel
  Single Light Bulb
  3 Light Bulbs in Both Series and Parallel
Page 9... Activity E: Series (quantitative)
  3 Resistors
  Potential in Circuit
Page 10... Activity F: Parallel (quantitative)
  3 Resistors

Page 11... Activity G: Ohm's Law
  Output from Interface Testing
  Ohm's Law
  Light Bulb
Page 14... Activity H: Kirchoff's Rules
  Voltage Rule
  Current Rule
Page 16... Activity I: Cleaning up
Activity B: Resistance

Measurement of Resistance

Resistance can be determined by simultaneously measuring the potential drop across a Resistor and the current flowing through it. To do this we will create the circuit depicted at right. A switch is included in circuit to minimize use of Battery.

Throughout this experiment 3 Resistors will be used. Their values are 3 Ω, 5.6 Ω, 10 Ω.

(1) Place Battery in "upper" holder on Electronics Board as shown below.
(2) Plug Voltage Sensor into Interface's Analog Channel A.
(3) Plug Current Sensor into Interface's Analog Channel B.
(4) Plug ends of Red and Black cables into Red and Black Current Sensor's connectors respectively.

(5) Make connections on Electronics Board between Battery, Switch and 3 Ω Resistor using 2 wires as shown at bottom left.
(6) Connect Voltage Sensor's Red and Black plugs at each end of Resistor.
(7) Plug in Current Sensor's Red and Black cables as shown. Do you see how these connections are related to the circuit diagram at above left?

Circuit is now complete with current flowing through Current Sensor.
(8) Depress Switch, keep it depressed. Click Start. After 1 s click Stop, release Switch.

Potential drop across Resistor and current flowing though it will appear below.

<table>
<thead>
<tr>
<th>Potential Drop (V) across Resistor</th>
<th>Current (A) flowing through Resistor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor (Ω)</td>
<td>Potential (V)</td>
</tr>
<tr>
<td>3</td>
<td>[ ]</td>
</tr>
<tr>
<td>5.6</td>
<td>[ ]</td>
</tr>
<tr>
<td>10</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

(9) Record values opposite.
(10) Repeat (5) to (9) for 5.6 Ω Resistor.
(11) Repeat (5) to (9) for 10 Ω Resistor.
(12) Use measured potential and current values and equation \( V = IR \) to determine actual resistances of Resistors.

Measured Resistances (Ω)

<table>
<thead>
<tr>
<th>Resistor (Ω)</th>
<th>Measured Resistance (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>[ ]</td>
</tr>
<tr>
<td>5.6</td>
<td>[ ]</td>
</tr>
<tr>
<td>10</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

For accuracy reasons, we will use measured resistance values rather than nominal ones in the calculations in this experiment.

Delete ALL Data runs, save work and then proceed to next page.
Coil of Wire

We are now going to measure resistance of Coil of wire situated at top right hand corner of Electronics Board.

(1) Remove all wires and plugs from Electronics Board.
(2) Make connections on Electronics Board between Battery, Switch, Coil, Voltage Sensor's and Current Sensor's plugs as shown below.

(3) Depress Switch, keep it depressed. Click Start. After 1 s click Stop, release Switch.

Potential drop across Coil and current flowing through it will appear below.

<table>
<thead>
<tr>
<th>Potential Drop (V)</th>
<th>Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(4) Record values here.

(5) Use these values and \( V = IR \) to determine Coil's resistance.

(6) Is value recorded in (5) comparable to resistances of carbon resistors we just used ("yes/no")?

From answer to (5) we can now appreciate why resistors are made from carbon rather than coils of wire when space on a circuit board is limited.

Activity C: Properties of Battery

Potential from Battery

We will first measure potential produced by a Battery when it is not connected to a circuit.

(1) Remove wires, Voltage Sensor's and Current Sensor's plugs from Electronics Board.
(2) Connect Voltage Sensor's Red and Black plugs across Battery as shown.

<table>
<thead>
<tr>
<th>Potential (V)</th>
<th>Current (A)</th>
<th>Resistance of Coil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Delete ALL Data runs, save work and then proceed to next page.
Click Start and then click Stop.

We have just measured the "open circuit" potential, \( V_0 \), of the Battery. The value should appear in box below (ignore value of current, it is meaningless).

**Battery's open circuit potential (V)**

<table>
<thead>
<tr>
<th>Potential Drop (V)</th>
<th>Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Record potential here.

Internal Resistance of Battery

A battery also has a resistance associated with it.

We will now create a circuit that measures Battery's internal resistance. A schematic of the circuit is shown here.

Make connections on Electronic Board between Battery, switch, Voltage Sensor's and Current Sensor's plugs as shown here.

Depress Switch, keep it depressed. Click Start. After 1 s click Stop and release Switch.

Record potential and magnitude of current here.

<table>
<thead>
<tr>
<th>Potential Drop (V)</th>
<th>Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use values of potential drop, "V", and current, "I", just measured to determine Battery's internal resistance, "\( r \)". The equation that relates these various quantities is shown opposite.

Record value for "\( r \)" below.

Battery's internal resistance (\( \Omega \))

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

Internal resistance should be a small fraction of 1\( \Omega \). If it is not a mistake has been made.

Activity D: Series/Parallel (qualitative)

We are now going to study qualitatively the differences between resistances connected in series and parallel. To do this, we will use the fact that a Light Bulb's brightness is related to the current flowing through it.

2 Light Bulbs in Series

Schematic of circuit is shown opposite.
(1) Remove wires, Voltage Sensor’s and Current Sensor’s plugs from Electronics Board.
(2) Make connections α-A, B-C, D-E, F-δ, β-γ using color wires.
(3) Depress and release Switch and take note of brightness of Light Bulbs.

2 Light Bulbs in Parallel

Schematic diagram and photograph of circuit are shown below.

(1) Remove wires from Electronics Board.
(2) Make new connections α-A, B-C, C-E, D-F, D-δ, β-γ using color wires.
(3) Depress and release Switch.
(4) Are Light Bulbs brighter now?

(5) Use answer to (4) to determine whether current flowing through each Light Bulb now is less, more or the same as when they were connected in series.

Assume that potential provided by Battery is not affected by circuit it is connected to.

(6) Use answer to (5) to determine whether equivalent resistance of 2 Light Bulbs in parallel is less, more or the same as when they were connected in series.

Single Light Bulb

Schematic diagram of circuit is shown below.

(1) Disconnect one light bulb by removing connections C-E and D-F from Electronics Board.
(2) Depress and release Switch.
(3) Is Light Bulb’s brightness less, more or the same as when 2 Bulbs were connected in parallel?

(4) Use answer to (3) to determine whether current from Battery is affected by circuit it is connected to (”yes/no”)

(5) Use answer to (4) to determine whether current flowing through each Light Bulb now is less, more or the same as when they were connected in series.
3 Light Bulbs in Both Series and Parallel

Schematic and photograph of circuit are shown below.

1. Remove wires from Electronics Board.
3. Depress and release Switch and take note of brightness of Light Bulbs.
4. While holding down the switch, disconnect bulb 3 by lifting the jumper cable from post G on the Electronics Board. Describe what happens to the brightness of bulbs 1, 2 and 3. Try to explain qualitatively why this happened (Hint: Think about the pathway that the current takes in both scenarios).

5. Are bulbs 1 and 2 in series or in parallel in the new circuit (when bulb 3 is removed)?
Activity E: Series (quantitative)

3 Resistors

We are going to create a circuit with 3 Resistors in series. Schematic diagram of circuit is shown opposite.

(1) Compute equivalent resistance

of 3 Ω, 5.6 Ω, and 10 Ω Resistors connected in series using measured values. Record value opposite.

(2) Remove wires, Voltage Sensor’s and Current Sensor’s plugs from Electronics Board.

(3) Connect 3, 5.6, and 10 Ω Resistors in series with the Switch and a single Battery by making new connections. (no pictures or symbols this time - figure it out from the diagram)

(4) Connect Voltage Sensor’s Red and Black across all 3 Resistors as shown opposite.

(5) Connect Current Sensor’s Red and Black plugs in series to complete the circuit.

(6) Depress Switch, keep it depressed. Click Start. After 1 s click Stop, release Switch.

Total potential drop across 3 Resistors and current flowing through Resistors is displayed opposite.

(7) Record potential drop

Potential Drop (V)

(8) Compute and record current flowing through circuit using values for potential drop and equivalent resistance

Computed Current (A)

(9) Record current here

Measured Current (A)

If computed current doesn’t agree within 0.005 A with measured current a mistake has been made.

Delete ALL Data runs, save work and then proceed to next page.
Potential in Circuit

We are now going to measure potential at different locations around our circuit.

1. Remove Voltage Sensor’s Red and Black plugs and connect them across only the 3 Ω Resistor.

2. Depress Switch, keep it depressed. Click Start. After 1 s click Stop, release Switch.

Potential Drop (V) ————
Current (A) ————

3. Record potential drop across Resistor.

4. Repeat (1) to (3) for 5.6 Ω Resistor.

5. Repeat (1) to (3) for 10 Ω Resistor.

6. Repeat (1) to (3) for Current Sensor.

7. Use measured potential drops to compute total/potential drop across all 3 Resistors and Current Sensor and record value here.

8. Repeat (1) to (3) for Battery.

9. Answer to (7) and (8) should be equal to within about 0.02 V. If they are not a mistake has been made.

Activity F: Parallel (quantitative)

3 Resistors

We are going to create a circuit with 3 Resistors in parallel (see schematic diagram opposite).

1. Compute equivalent resistance

of 3 Ω, 5.6 Ω and 10 Ω Resistors connected in series using measured values. Record value.

3 Ω
5.6 Ω
10 Ω
Equivalent Resistance

Delete ALL Data runs, save work and then proceed to next page.
Activity G: Ohm’s Law

Until now we have assumed that Ohm’s Law is valid but we have not proved it! In this activity we will show it is true for our Resistors but it is not true for, say, Light Bulbs. For this study we will use Interface as a source of potential rather than a Battery because it can produce a linearly increasing voltage whereas a Battery produces only a single value of voltage (about 1.5 V). We will show, using Science Workshop 750’s Output, that for every value of voltage the relationship $V = IR$ is valid for a Resistor.

Output from Interface

First we need to show that Interface’s Output produces a linearly increasing voltage.

1. Connect Voltage Sensor’s Black and Red plugs into the left-hand and right-hand sockets of Interface’s Output respectively.
2. Click Start. Data collection will automatically stop after 10 s.

If points do not lie on a straight line a mistake has been made.

From now on do not Delete ALL Data runs.

Potential Drop across Resistor (V)

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>1.2</td>
<td>1.5</td>
<td>1.8</td>
<td>2.0</td>
<td>1.5</td>
<td>1.2</td>
<td>1.0</td>
<td>0.8</td>
<td>0.6</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Save work and then proceed to next page.
We will now create a circuit (see schematic opposite) to measure potential drop across a Resistor and current flowing through it simultaneously. The green circle with a linear graph refers to the output of the PASCO 750 interface.

1. Remove Voltage Sensor's plugs from Interface's Output and connect them to ends of 5.6 Ω Resistor (ie, in parallel).

2. Connect the current sensor in series with the resistor, as indicated in the schematic.

3. Connect the interface output as shown in the schematic (switch can be included, but is not necessary).

Testing Ohm's Law

We will now test Ohm's Law by plotting the potential drop across the Resistor as a function of current flowing through it.

(1) Click Start. Data collection should automatically stop after 10 s.

Data points should lie along a straight line.

(2) What do you think slope of a line drawn through points corresponds to (potential drop, power, resistance or energy)?

(3) Click on "Fit" icon and choose "Linear Fit" from drop-down menu. Slope and intercept should be displayed. Do not worry about other information displayed.

(4) From fit parameters deduce value of Resistor and record it here.

(5) Can we conclude that this Resistor is Ohmic from the data shown in graph?

Save work and then proceed to next page.
Light Bulb

We are now going to see if a Light Bulb is Ohmic.

1. Remove wires from ends of 5.8 Ω Resistor and connect them to ends of Light Bulb.
2. Click Start. Data collection should automatically stop after 10s.
3. Note brightness of Light Bulb.

Potential Drop across Bulb (V)

![Graph](image)

Current flowing through Bulb (A)

4. Can we conclude that this Light Bulb is Ohmic from the data shown in graph? Explain.

5. What is happening inside Light Bulb to cause its resistance to change as the current passing through it increases?

Save work and then proceed to next page
Activity H: Kirchoff’s Rules

When there is a single Battery in a circuit it is relatively easy to determine currents flowing through its parts. However, when there are several Batteries it is necessary to use Kirchoff’s Rules.

In this activity we will verify Kirchoff’s Rules by measuring potential drops across resistors in the 2-loop circuit shown below.

Voltage Rule

1. Remove wires, Voltage Sensor’s and Current Sensor’s plugs from Electronics Board. Remove cables from Interface’s Output.

2. Make connections α-A, β-B, γ-C, δ-D, ε-E, ζ-F between Batteries, Switch and 3, 5.6, and 10 Ω Resistors as shown. Check that real circuit is consistent with schematic circuit. Connect β-γ last, as it will drain the battery.

We will use Voltage Sensor to measure potential drops across Battery and Resistors in Loop 2. Note carefully red and black arrows on diagram which depict placement of Voltage Sensor connectors. Make sure that connectors are not reversed when measurements are made.

3. Select 3 Ω Resistor.


5. Depress Switch, keep it depressed. Click Start. After 1 s click Stop, release Switch.

Potential drop will be displayed here.

6. Record potential drop in appropriate box below.

7. Repeat (4) to (6) for 10 Ω Resistor.

8. Repeat (4) to (6) for Battery, V₂.

9. Compute total potential drop around Loop 2 and record it above.

If magnitude of total potential drop > 0.02 V a mistake has been made.

Save work and then proceed to next page.
Now let's turn our attention to left-hand loop, Loop 1.

Potential Drop (V) [Diagram]

(10) Repeat (4) to (6) for 3 Ω Resistor.
(11) Repeat (4) to (6) for 5.6 Ω Resistor.
(12) Repeat (4) to (6) for Battery, V₁.

(13) Compute total potential drop around Loop 1. Record it above.

If magnitude of total potential drop > 0.02 V a mistake has been made.

Current Rule

(1) Use measured Resistor values below...

3 Ω 5.6 Ω 10 Ω

(2) ...to compute currents flowing in circuit and record them here.

I₁  I₂  I₃

(3) Compute I₁ - I₂ - I₃ and record result here.

If magnitude of I₁ - I₂ - I₃ > 0.02 A a mistake has been made.

Save work and then proceed to next page.
Activity I: Cleaning up

(1) Unplug all connectors from the Electronics Lab Circuit Board and return to plastic box.
(2) Unplug all connectors from the Interface.
(3) Return the Voltage Sensor to the wire rack.
(5) Unplug red and black cables from the Current Sensor and return them to the wire rack.
(6) Store Current Sensor in drawer.

THANK YOU!