

Chapter 6

Introduction to DC Electricity

In this laboratory session we shall examine the relationships among the motion of electrons (current), the effect which causes them to move (potential difference), and the effects which hinder their motion (resistance). We are sensitive to electrical effects (e.g., getting hit by lightning!) but to safely quantify them we need one or more detectors. Electric current (I) is measured in Amperes (A), electric potential difference (ΔV) is measured in Volts (V), and resistance is measured in Ohms (Ω). The values of I , ΔV , and R that you will deal with and that are commonly found in electronic equipment are mA (milliAmps), V, and Ω to M Ω (megaOhms), respectively.

Apparatus PASCO Essential DC Circuits equipment, Digital multimeter, batteries, resistors

6.1 Electricity and Circuits

6.1.1 Prelab Exercises

Look up circuits/DC electricity in your physics textbook to help you answer the following questions:

1. Define current. What type of device is commonly used to measure electric current?
2. Identify the kinds of circuits shown in Fig. 6.1. Recall that elements in series have the same current flowing through them while elements in parallel have the same potential difference across them. Further, a short circuit is one where the battery is connected across a wire path only while an open circuit is one where current cannot flow.
3. Draw the electrical symbols for the following circuit elements:
A. resistor B. battery C. switch D. wire E. lamp

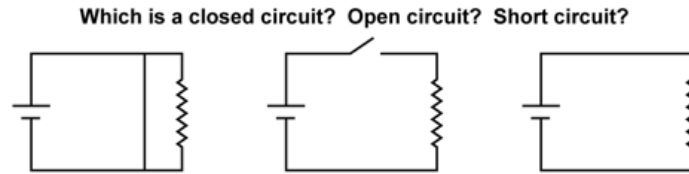


Figure 6.1: Identify the circuits.

6.1.2 Simple Circuits

This investigation explores how to build simple circuits using the kit and to relate the circuit to a comparable equivalent circuit diagram.

1. Connect a battery, lamp, switch (start in the open position), a straight wire and four wire corner modules together using 8 jumpers to create the circuit shown in Fig. 6.2.
2. Is the lamp on with the switch open? Is this an open or closed circuit? Why would you expect what you observe?
3. Now close the switch. Is this an open or a closed circuit? Is the lamp on? Again, is this consistent with what you expect?

Questions:

- With the switch open, remove the battery module from the circuit, turn it around so it is reversed, and reconnect it. Close the switch. Does the bulb light up? What do you think reversing the battery changes in the circuit?
- With the switch open, connect the two jumpers on the bulb module using an alligator-to-alligator wire to create a short circuit. Close the switch. What happens to the bulb when you create a short circuit? Try connecting jumpers on the wire and battery modules. Does connecting any two jumpers create a short circuit?
- Describe another way you can create an open circuit *without* opening the switch.

6.2 Electric Potential Difference and Batteries

6.2.1 Prelab Exercises

1. Define Electric Potential Difference.
2. Complete this sentence. A battery converts _____ energy into _____ energy.
3. Which of the following statements is correct.
 - (a) A 6 V battery maintains a potential difference of 6 V between the two ends of the battery.
 - (b) A 6 V battery generates a fixed current.

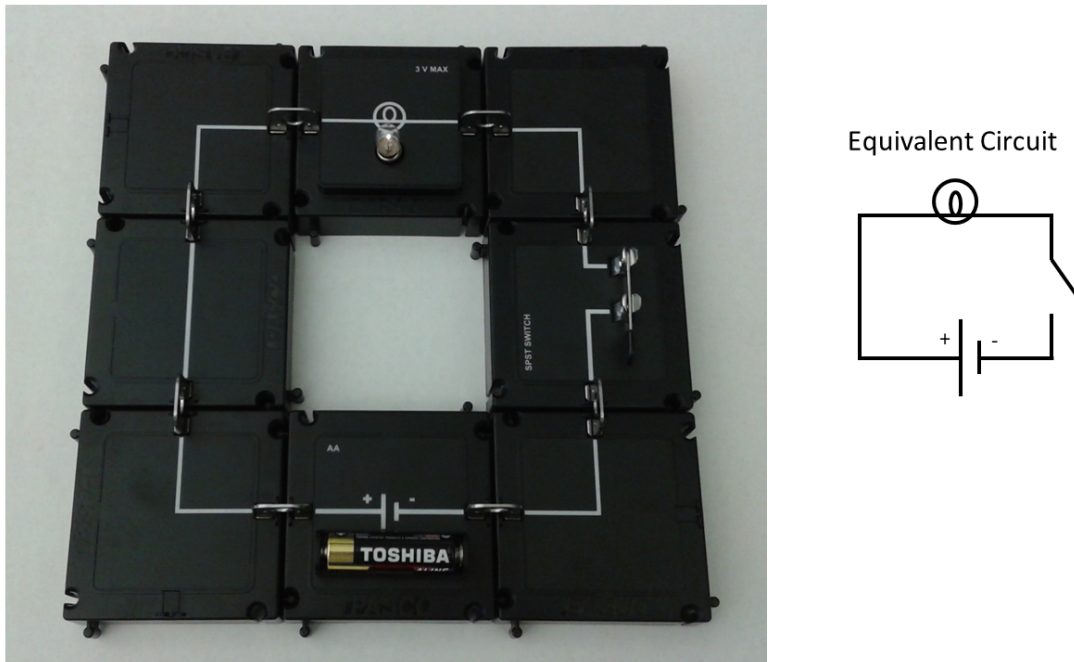


Figure 6.2: A simple circuit using modular circuit components with corresponding circuit diagram.

- (c) A car battery generates a large current.

6.2.2 The PASCO Voltage Sensor and Current Module

To measure the voltage and current in your circuits you will be using the PASCO Wireless Voltage Sensor (VS) and Wireless Current Module (CM). To get started, **ensure both the VS and CM are connected to the laptop via the USB cable**. On the laptop desktop, double click on the SPARKvue icon. Once the program is opened the home screen will display three options: *Manual Entry*, *Sensor Data*, *Remote Logging*. Select **Sensor Data**. The titles *Wireless Voltage Sensor* and *Wireless Current Module* should be displayed at the top left in white text on a blue background. If the display for the VS and CM are in grey, ensure the Enable/Disable switch is set to **Enable**.

Next, select **Digits** located underneath the Template Heading shown on the right side of the window. Now you are ready to collect data.

The VM has two alligator clips (one black, one red) that can be used to measure the potential difference between two points in a circuit. To measure ΔV , simply connect the alligator clips to the jumpers at each point where ΔV is to be measured across. To obtain a reading, click on the green Start button located on the bottom of the window to begin

the live reading. To stop the live reading click on the red Stop button.

The orientation of the alligator clips matters.

The CM will be used to measure current. Unlike the VS, the CM must be incorporated into the circuit by taking the place of a wire module. To do this, simply use the jumper clips to connect the CM into the necessary place within your circuit. Once the connection has been made and you have clicked on the Green Start button, you will be able to see the current reading displayed live on the SPARKvue program. To obtain a reading with more significant figures on the display click on the *Experiment Tools* icon (third button from the right located on the bottom of the window). Then, click on **Data Properties** and select **current** from the *Sensors* menu on the right panel. Click on **Number Format** and change the *number style* to **Significant Digits** and set the *Digits* to **3** using the drop down menus respectively. You should now see 3 significant figures displayed when measuring current.

6.2.3 Connecting Batteries in Series

How do you connect batteries to increase their total voltage? When Alessandro Volta invented the first electric battery, he connected several individual battery cells together to create a more powerful composite battery. How did he connect them? In this investigation you will connect two batteries together and determine how to make the largest combined voltage.

To connect the two batteries in series as shown in Fig. 6.3 connect the negative terminal of one battery to the positive terminal of the other battery.

Questions

1. Measure the ΔV across each battery individually.
 - (a) How does it compare with what you expect?
 - (b) What is the *sign* of the ΔV that you measured?
 - (c) What happens if you switch the positions of the alligator clips (i.e., put the black one where the red one is and put the red one where the black one was)?
 - (d) What does this tell you about the electric potential at the two jumpers?
2. What do you get for the ΔV across the two batteries connected in series?
3. What do you get for the ΔV across the two batteries if they are now connected with their negative terminals together? Is this what you'd expect?
4. Draw a circuit with two batteries, a switch, a resistor, and a lamp all connected in series.

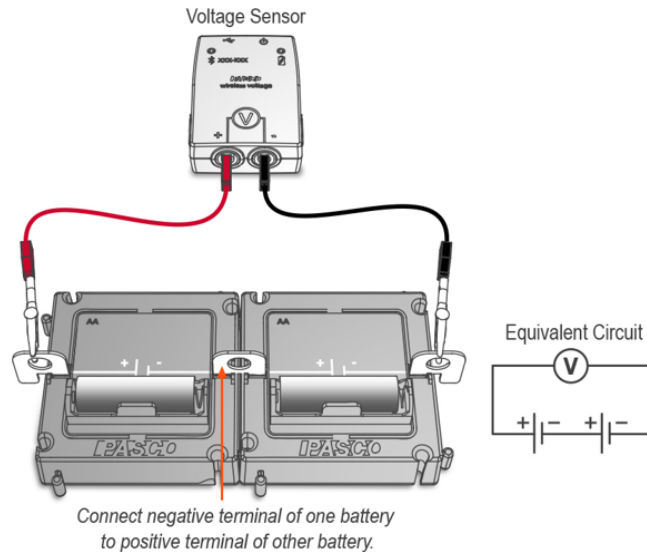


Figure 6.3: Two batteries connected in series.

6.3 Resistance and Ohm's Law

Ohm's Law $\Delta V = IR$ is the fundamental relationship between potential difference (ΔV), current (I), and resistance (R) in a circuit. Devices that measure resistance are based on Ohm's Law. These devices apply a known potential difference and/or current, and then determine the resistance. In this investigation you will use a similar experimental technique to measure the resistance of a lamp.

6.3.1 Prelab Exercises

1. Using Ohm's Law, what is the current through a 10Ω resistor when a 5.0 V potential difference is applied across it?
2. What is the potential difference across a 50Ω resistor when a current of 0.10A flows through it? Does the sign of ΔV depend on which direction the current is flowing?

6.3.2 Current through different Resistors

1. Construct the circuit of Fig. 6.4 using one battery, a switch, the current module (CM) to measure current, the spring-clip module in place of the resistor, and any necessary wire modules.
2. Secure one of the resistors provided in the plastic bag into the spring-clip module. Use the digital multimeter (DMM) to identify the values of the resistors¹.

¹The colour bands on the resistor also indicate the value and the tolerance. Even if you became proficient with understanding that system, you would still be encouraged to confirm your determination using a DMM.

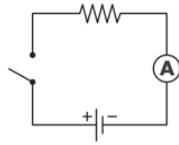


Figure 6.4: Ohm's law circuit.

- Close the switch and record the current read by the CM and the resistor value in a Table as shown in Fig. 6.5. (Set current reading scale for the current module to mA in SPARKvue.)

I (A)	R (Ω)	ΔV (V)

Figure 6.5: Table to record measured current as a function of resistor value.

As with the VS, the orientation in which you connect the CM will matter. Is the SPARKvue program reading negative or positive? What does the sign of the current tell you?

- Repeat the experiment for the other 3 resistors provided. Tabulate your results for R and I and then calculate ΔV using Ohm's law for each resistor.

Questions:

- The ΔV found using each resistor should be the same. The voltage across the resistor must equal the voltage across the battery according to Kirchhoff's Law. Calculate the average value ΔV_{avg} .
- Now compute the average deviation ($\Delta V_{\text{avg,dev.}}$) of your voltage determination as described in Appendix ???. Therefore, your best determination of the of the battery's voltage is $\Delta V_{\text{avg}} \pm \Delta V_{\text{avg,dev.}}$. Does the measured voltage of the battery fall within your determination?

6.3.3 Resistance of a light bulb.

1. Replace the spring-clip module with the bulb module and attach the voltage sensor across the bulb as shown schematically in Fig. 6.6
2. Measure the current and voltage for the illuminated bulb.
3. Calculate the resistance of the bulb using Ohm's law $R_{meas} = \Delta V/I$. Show your work, including units.

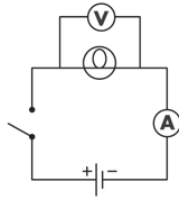


Figure 6.6: Circuit diagram for measuring the resistance of a light bulb.

Questions:

1. A simple circuit consists of a voltage source and a single resistor.
 - (a) How does the current change if the resistance is doubled?
 - (b) How does the current change if the resistance is halved?
 - (c) If you want to reduce the current in a circuit, do you increase or decrease the resistance?

6.4 Series and Parallel Resistances

Have you ever had a string of holiday lights where one bulb is burned out, preventing all the other bulbs from lighting? Was it easy to find the burned out bulb? This investigation explores series and parallel circuits by connecting bulbs and observing their brightness. By comparing the two circuit types, you will learn why the wiring of some strings of lights allows one bad bulb to disconnect all the other bulbs.

6.4.1 Connecting lamps in series

1. Create a circuit using two batteries, one lamp, a switch, and any necessary wire modules.
2. Close the switch and observe the brightness of the lamp.
3. Create a circuit with two bulbs *in series*, as shown in figure 6.7. Compare the brightness of the two lamps to the previous circuit with one lamp.
4. Remove one lamp from the series circuit. What happens to the other lamp? Why?

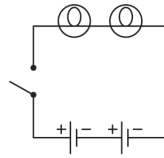


Figure 6.7: Circuit diagram with two bulbs in series.

6.4.2 Connecting lamps in parallel

1. Create a circuit with lamps bulbs *in parallel*, as shown in Fig. 6.8.

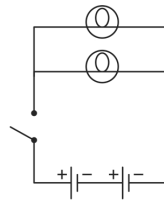


Figure 6.8: Circuit diagram with two lamps in parallel.

2. Compare the brightness of the lamps in this circuit to the prior circuit with two lamps in series.
3. Compare the brightness of the lamps in this circuit to the single lamp circuit observed in 6.4.1, step 2.
4. Unscrew one lamp from the parallel circuit. What happens to the brightness of the other lamp? Why?

Questions:

1. Is a series or parallel circuit better for connecting a string of lights? Why?
2. Design a circuit of three lamps that combines series and parallel arrangements and sketch the circuit diagram. Predict the relative bulb brightness based on the previous experiments. Build the circuit and test your predictions. Were you correct?

6.4.3 Resistors in Series

1. Create the circuit shown in Fig.6.9 using two resistor modules, two batteries, a switch, the current module (CM) and any necessary wire modules.
2. Record the current through the circuit. Relocate the CM between the two resistors and note the current. Is the current the same? What if you switch the location of the CM and switch shown in Fig. 6.9? Is the current measured still the same? Explain.
3. Measure the potential difference across points ab ($\Delta V_{ab} \equiv V_a - V_b$), bc (ΔV_{bc}) and ac (ΔV_{ac}) using the voltage sensor (VS).

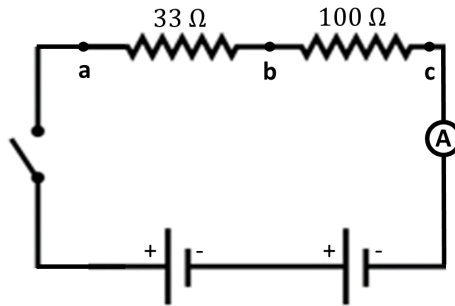


Figure 6.9: Circuit diagram with two resistors in series.

4. Use Ohm's law to calculate

$$R_1 = \frac{\Delta V_{ab}}{I}, \quad R_2 = \frac{\Delta V_{bc}}{I}, \quad R_s = \frac{\Delta V_{ac}}{I}$$

The resistance values are guaranteed to be within $\pm 5\%$ of the labelled value on the module. How do your calculated resistor values, R_1 and R_2 , compare with the resistor values labelled on the modules?

5. Taking into account the resistor uncertainties, are your values consistent with the relationship $R_s = R_1 + R_2$?

6.4.4 Resistors in Parallel

1. Use the modules to build the circuit with two resistors in parallel as shown in Fig. 6.10.

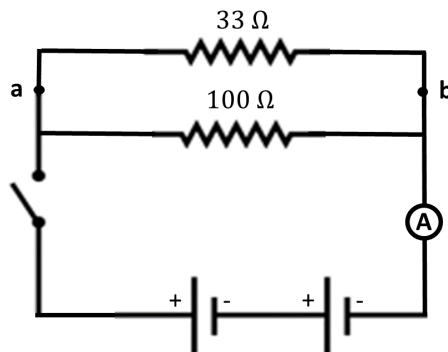


Figure 6.10: Circuit diagram with two resistors in parallel.

2. Measure the current i and the potential difference across both resistors, ΔV_{ab} .

3. Relocate the CM as shown in Fig. 6.11 and measure the current through each resistor, i_{ac} and i_{ad} . Use the VS to measure the voltage across each resistor, ΔV_{ac} and ΔV_{ad} , across the points a, c and a, d as labelled in Fig. 6.11. How are the current values at the three different locations related?

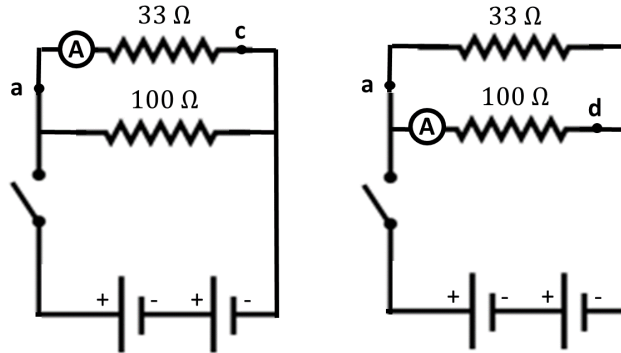


Figure 6.11: Measuring the current and voltage across individual resistors in a parallel circuit.

4. Calculate the equivalent resistance of R_1 and R_2 in parallel $R_p = \Delta V_{ab}/I$. Using the values of R_1 and R_2 calculated in section 6.4.3, calculate the expected value of R_p using:

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \implies R_p = \frac{R_1 R_2}{R_1 + R_2}$$

What is the discrepancy between your two values? (Use equation 0.2.2 described in the comparison section of the Introductory Information chapter.) Does this seem reasonable given each resistor has an associated uncertainty of $\pm 5\%$?

6.4.5 Questions

1. An ideal voltmeter should have an internal resistance approaching infinity, while an ideal ammeter should have an internal resistance equal to zero. Explain why.
2. In the circuit shown in Fig.6.9, you measured the potential difference across each resistor, ΔV_{ab} and ΔV_{bc} . Is the sum of these equal to the emf (i.e., “voltage”) of the battery?

END OF LAB

Was this lab useful, instructive, and did it work well? If not, send an email to thatlabsucked@gmail.com and tell us your issues. In the subject line, be sure to reference the your course, the experiment, and session. example subject: *PHYS1010*

Linear Motion monday 2:30. We won't promise a response, but we will promise to read and consider all feedback.