Activity 12, "Ohm's Law"

from

Science & Global Issues: Global Energy & Power

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12 Ohm's Law

LABORATORY • 2–3 CLASS SESSIONS

OVERVIEW

In this activity students derive Ohm's law by graphing current vs. voltage for different resistors. The graphs allow them to determine the mathematical relationships between current, voltage, and resistance.

Next Generation Science Standards (NGSS)
DISCIPLINARY CORE IDEAS
PS.3.A: Definitions of Energy
SCIENCE AND ENGINEERING PRACTICES
Analyzing and Interpreting Data
Engaging in Argument from Evidence
Obtaining, Evaluating, and Communicating Information
Planning and Carrying Out Investigations
Using Mathematics and Computational Thinking
CROSSCUTTING CONCEPTS
Cause and Effect
Energy and Matter
Scale, Proportion, and Quantity

KEY CONTENT

1. Ohm's law states that the current, I, through a conductor between two points is directly proportional to the potential difference, V, across the two points, and inversely proportional to the resistance, R, between them, given as

   $V = IR$

2. Displaying data in a graph may reveal trends not easily noticeable in data tables.
3. Grounds, fuses, and circuit breakers prevent dangerous current loads in devices and household circuits.
4. A device that uses less current at a given voltage uses less power than a device that uses more current at the same voltage.
5. Not all conducting materials are ohmic.

MATERIALS AND ADVANCE PREPARATION

For the teacher

Scoring Guide: ANALYZING DATA (AD)
Scoring Guide: ORGANIZING DATA (OD)
Scoring Guide: UNDERSTANDING CONCEPTS (UC)
Literacy Transparency 3, "Read, Think, and Take Note" *(optional)*
Science Skills Sheet 3, "Scatterplot and Line Graphing Checklist *(optional)*

For each group of four students

3 D cell batteries in holders
2 wires with alligator clips
4 resistors
$R_1 = 150\ \Omega$
$R_2 = 180\ \Omega$
$R_3 = 82\ \Omega$
$R_4 = 120\ \Omega$
2 Cir-Kit slides
6 Cir-Kit junctions
Cir-Kit switch
Cir-Kit component holder
Cir-Kit ammeter (0–50 mA)
Cir-Kit voltmeter (0–5 V)
colored pencils *(optional)*

For each student

3–5 sticky notes
graph paper*
Scoring Guide: ANALYZING DATA (AD) *(optional)*
Scoring Guide: ORGANIZING DATA (OD) *(optional)*
Scoring Guide: UNDERSTANDING CONCEPTS (UC) *(optional)*

**Not supplied in kit*

Masters for Scoring Guides are in Teacher Resources IV: Assessment. Masters for Literacy transparencies are in Teacher Resources III: Literacy.

Label the resistors individually, R_1, R_2, R_3, and R_4, or sort the resistors into separate labeled cups. Make sure the voltmeter and ammeters are properly zeroed.

TEACHING SUMMARY

Getting Started

- Review current, voltage, and resistance.
- Challenge students to determine a relationship between the three variables.

Doing the Activity

- (OD ASSESSMENT) Students attempt to derive Ohm's law by experimenting with known resistors.
- Students apply Ohm's law to determine the resistance of a fourth resistor.
- (LITERACY) Students read the Technology Connection about electrical safety devices.

Follow-up

- (AD ASSESSMENT) Review Ohm's law and how it could be determined from the graph of voltage against current.
- (UC ASSESSMENT) Apply Ohm's law in various calculations.

BACKGROUND INFORMATION

Ohm's Law

A circuit element or material obeys Ohm's law if the resistance of the circuit element is independent of the voltage applied across it. A circuit element that obeys Ohm's law is said to be ohmic. Note that the equation

$$V = IR$$

is commonly referred to as Ohm's law, and this equation is always true regardless of whether a circuit element is ohmic or not. Nonohmic materials have a resistance that varies as the voltage across it changes. For ohmic materials, the resistance will be constant (regardless of the voltage) at a given temperature. This results in a linear plot graph of V vs. I for an ohmic circuit element, where the slope of the line is equal to the resistance of the material.

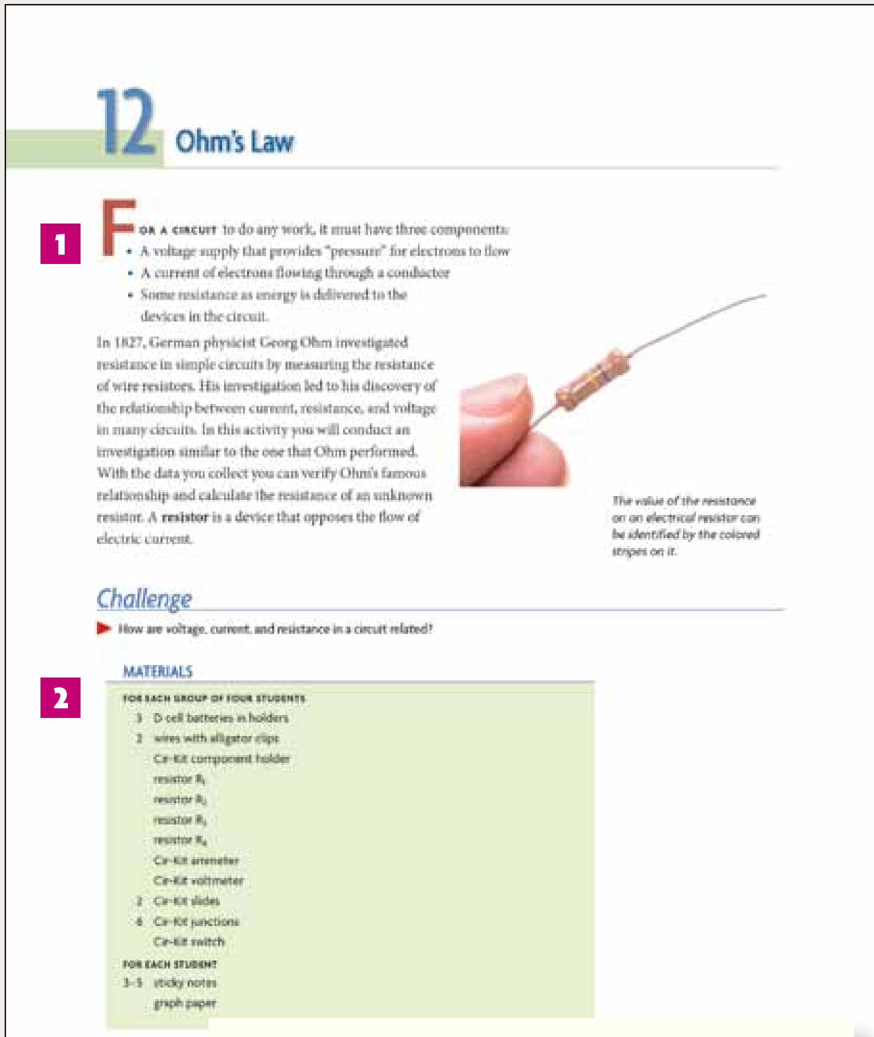
REFERENCES

Stutz, Michael. (2012). *All about circuits: Electrical safety.* Retrieved August 1, 2013 from http://www.allaboutcircuits.com/vol_1/chpt_3/index.html

GETTING STARTED

1 Review the definition of electric current, voltage, and resistance. Ask the class to suggest ways in which they think these quantities may be related. Although some students will be able to deduce that current is directly proportional to voltage and inversely proportional to resistance, others will not be able to conceptualize the relationships. At this point, accept all answers.

2 All of the resistors supplied for this activity should be about 80–180 Ω. This is to ensure optimal reading of the ammeter. The actual values of resistance chosen for the four resistors are not critical, but best results are expected if the values are equally incremented, such as the 82 Ω, 120 Ω, 150 Ω, and 180 Ω provided in the kit. Provide three of the four resistor values, leaving one unknown for them to determine.



12 Ohm's Law

1 For a circuit to do any work, it must have three components:

- A voltage supply that provides "pressure" for electrons to flow
- A current of electrons flowing through a conductor
- Some resistance as energy is delivered to the devices in the circuit.

In 1827, German physicist Georg Ohm investigated resistance in simple circuits by measuring the resistance of wire resistors. His investigation led to his discovery of the relationship between current, resistance, and voltage in many circuits. In this activity you will conduct an investigation similar to the one that Ohm performed. With the data you collect you can verify Ohm's famous relationship and calculate the resistance of an unknown resistor. A **resistor** is a device that opposes the flow of electric current.

The value of the resistance on an electrical resistor can be identified by the colored stripes on it.

Challenge

► How are voltage, current, and resistance in a circuit related?

2 MATERIALS

FOR EACH GROUP OF FOUR STUDENTS
3 D-cell batteries in holders
2 wires with alligator clips
Cir-Kit component holder
resistor R_1
resistor R_2
resistor R_3
resistor R_4
Cir-Kit ammeter
Cir-Kit voltmeter
2 Cir-Kit slides
4 Cir-Kit junctions
Cir-Kit switch

FOR EACH STUDENT
3–5 sticky notes
graph paper

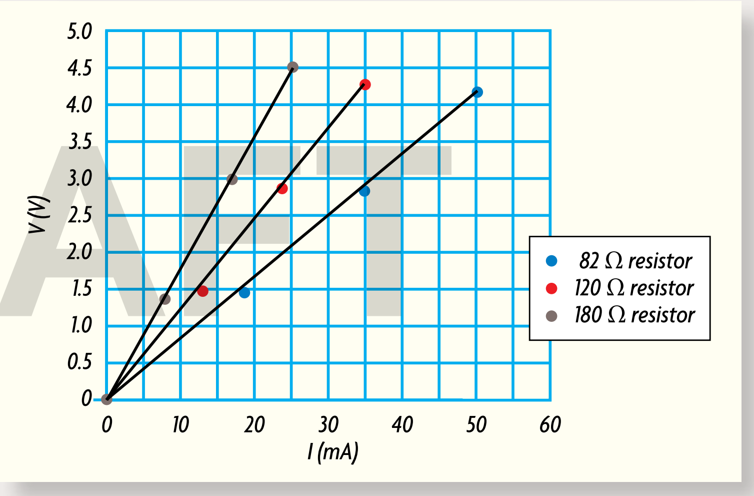
DOING THE ACTIVITY

3 Before beginning the activity, you may want to review with students how and why currents are measured in series with a conducting path, and voltage is measured in parallel with the conducting path. You may wish to refer to Appendix B, "Measuring Current" and "Measuring Voltage" to review with students how to properly connect the meters.

Sample Student response: Procedure Step 7

82 Ω resistor		120 Ω resistor		180 Ω resistor	
V (V)	I (mA)	V (V)	I (mA)	V (V)	I (mA)
1.4	18	1.4	13	1.4	8
2.8	35	2.8	24	3.0	17
4.2	50	4.3	36	4.5	25

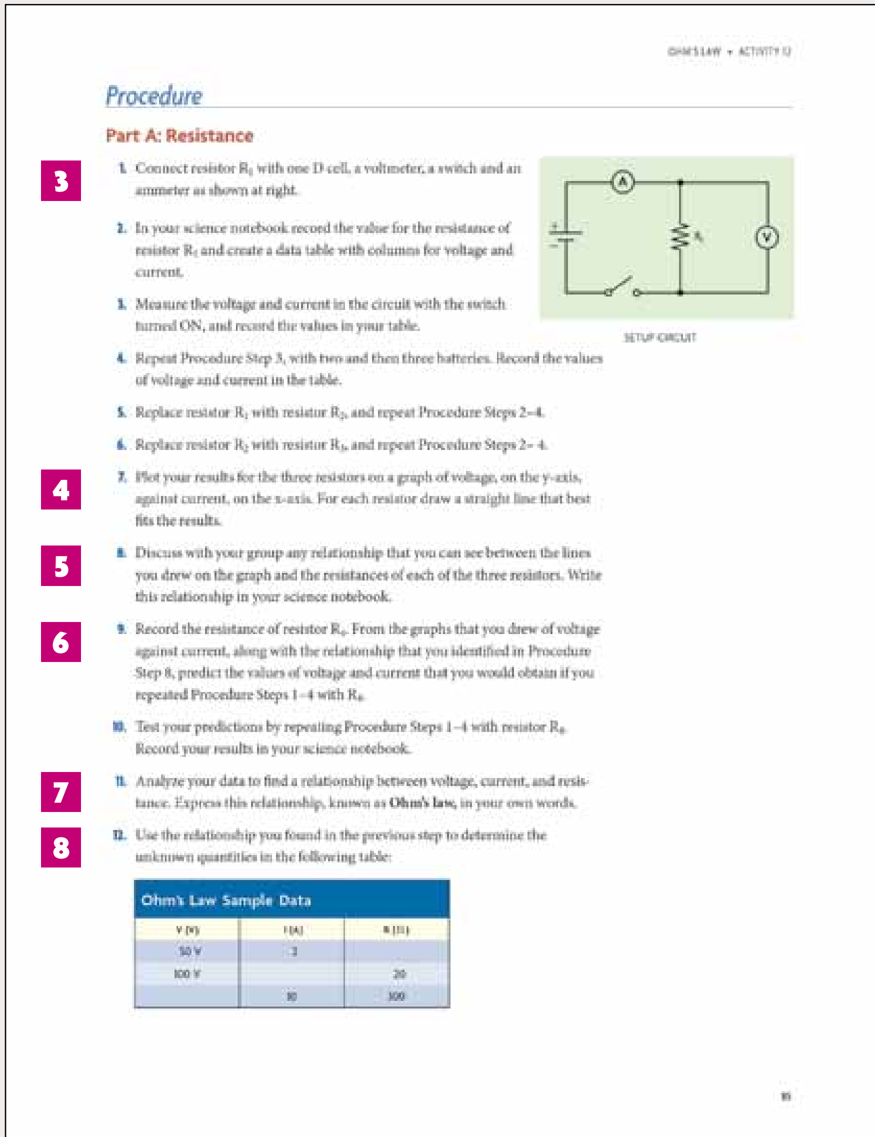
4 (OD ASSESSMENT) Students' written work from Procedure Step 7 may be scored with the ORGANIZING DATA (OD). A complete and correct response is shown at right, although students' results may vary.



The lines of best fit should look linear, supporting that voltage and current are proportional to one another. Each line should go through, or close to, the origin (0, 0). Even though the independent variable in this activity is voltage, it is common to plot voltage on the y-axis for Ohm's law data.

Doing this simplifies the calculation of resistance since with V on the y-axis and I on the x-axis the slope of the graph will equate to the resistance, after converting milliamps to amps. Therefore, higher-value resistors will produce steeper lines, which will help to reinforce the idea that slope equals resistance.

For students who need support in constructing the graph, consider reviewing the content presented on Science Skills Sheet 3, "Scatterplot and Line Graphing Checklist."



OHM'S LAW • ACTIVITY 12

Procedure

Part A: Resistance

3 1. Connect resistor R_1 with one D cell, a voltmeter, a switch and an ammeter as shown at right.

2. In your science notebook record the value for the resistance of resistor R_1 and create a data table with columns for voltage and current.

3. Measure the voltage and current in the circuit with the switch turned ON, and record the values in your table.

4. Repeat Procedure Step 3, with two and then three batteries. Record the values of voltage and current in the table.

5. Replace resistor R_1 with resistor R_2, and repeat Procedure Steps 2–4.

6. Replace resistor R_2 with resistor R_3, and repeat Procedure Steps 2–4.

4 7. Plot your results for the three resistors on a graph of voltage, on the y-axis, against current, on the x-axis. For each resistor draw a straight line that best fits the results.

5 8. Discuss with your group any relationship that you can see between the lines you drew on the graph and the resistances of each of the three resistors. Write this relationship in your science notebook.

6 9. Record the resistance of resistor R_4. From the graphs that you drew of voltage against current, along with the relationship that you identified in Procedure Step 8, predict the values of voltage and current that you would obtain if you repeated Procedure Steps 1–4 with R_4.

10. Test your predictions by repeating Procedure Steps 1–4 with resistor R_4. Record your results in your science notebook.

7 11. Analyze your data to find a relationship between voltage, current, and resistance. Express this relationship, known as **Ohm's law**, in your own words.

8 12. Use the relationship you found in the previous step to determine the unknown quantities in the following table:

Ohm's Law Sample Data

V (V)	I (A)	R (Ω)
50 V	2	
100 V		20
	10	100

SETUP CIRCUIT

5 Students should see that the higher resistances have steeper slopes, and, therefore, resistance is related to the ratio of voltage to current. If necessary, assist groups in calculating the slope of each line. The values for slope should be very close to the resistance of each of the resistors. This supports the relationship R = V/I.

6 If students have understood that the slope of the V/I graph is equivalent to the resistance, they should be able to predict where to draw a line for then unknown resistor, R_4. The line reveals the values of I for the values of V corresponding to the use of one, two, and three D cells. For the 150-ohm resistor, students may predict the following values of voltage and current:

Sample Student Response: Procedure Step 9

V (V)	*I (mA)*
1.5	*10*
3.0	*20*
4.5	*30*

7 Use students' responses to Procedure Step 11 to create a statement of Ohm's law in both sentence form, "The current through a resistor is proportional to the voltage across it and is inversely proportional to the resistance," and as the equation R = V/I.

When reviewing results, make sure that students have converted their measurements to amps, volts, or ohms so that the calculations work out correctly.

Although Ohm's law is a very useful relationship, many of today's electronic devices are actually nonohmic, meaning the slope of the V vs. I graph is not linear. A common example of a nonohmic material is a semiconductor.

8 (LITERACY) If appropriate, project Literacy Transparency 3, "Read, Think, and Take Note Guidelines," to review with students. Begin the discussion of the Technology Connection by asking students to discuss with their partners or groups the main points of the text and their comments on their sticky notes.

Part B: Technology Connection

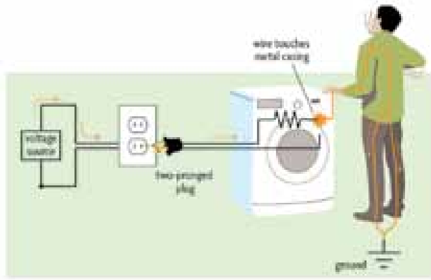
13. Individually, read the Technology Connection, "Circuit Safety." As you read, follow the literacy strategy, "Read, Think, and Take Note."

14. Share your thinking with your group. Place your sticky notes on the table in front of you. Look for connections between your notes and those of others in your group.

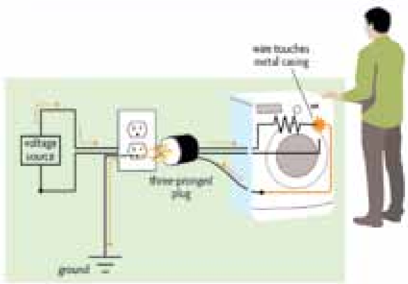
15. Place your sticky notes in your science notebook. Below them write a short summary of what your group discussed and any conclusions your group came to.

Technology Connection: Circuit Safety

Ohm's law predicts that if there is little resistance in a circuit with a given voltage source, the resulting current will be very large. When current is allowed to travel along a path with little or no resistance as described above, it is called a short circuit. Short circuits result in overheating, explosions, and possibly fire that may cause property damage and injuries or death.

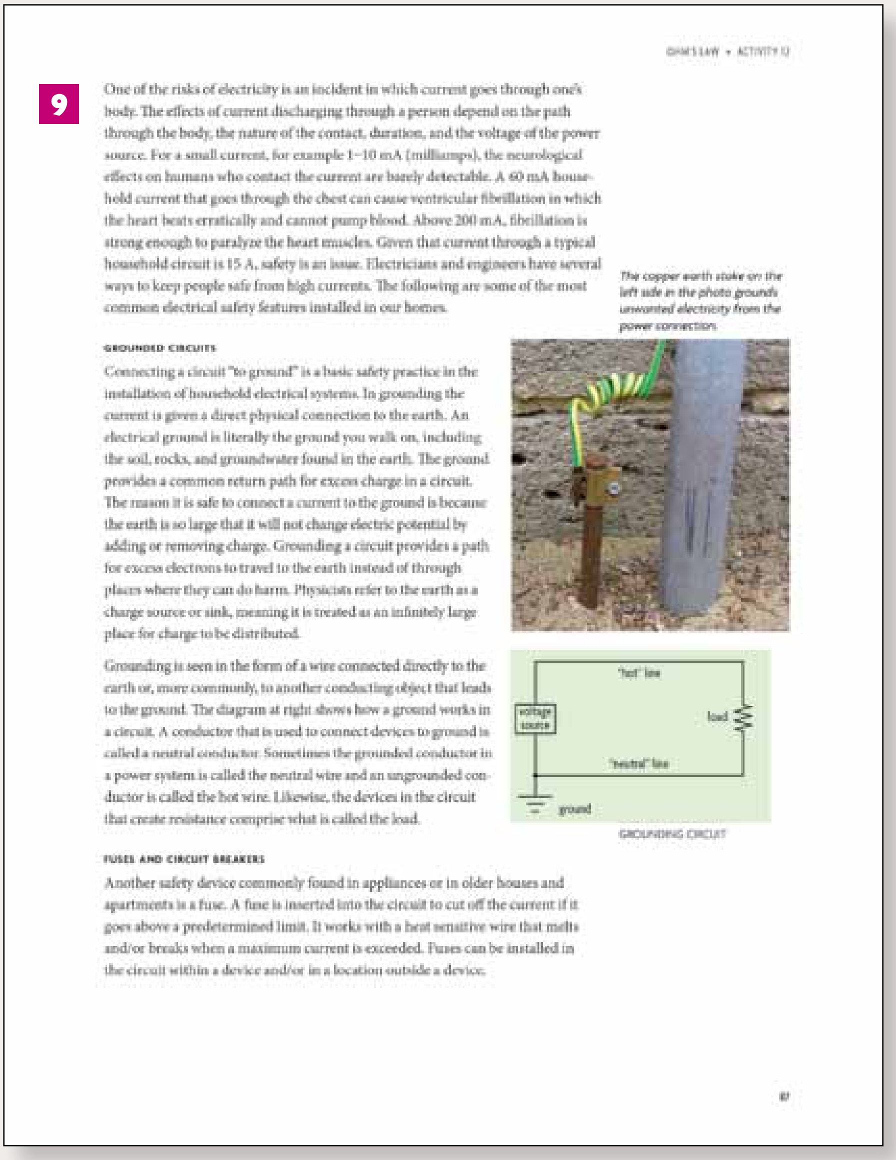


SHORT CIRCUIT



SAFE CIRCUIT

9 Although none of the currents in this unit are high enough to pose a hazard, students may be curious about more dangerous situations, such as those discussed in the "Technology Connection." Refer to the *Science and Global Issues* page of the SEPUP website at www.sepuplhs/SGI for more information on potential causes, symptoms, and first aid for electrical shock.



OHM'S LAW • ACTIVITY 12

9 One of the risks of electricity is an incident in which current goes through one's body. The effects of current discharging through a person depend on the path through the body, the nature of the contact, duration, and the voltage of the power source. For a small current, for example 1–10 mA (milliamps), the neurological effects on humans who contact the current are barely detectable. A 60 mA household current that goes through the chest can cause ventricular fibrillation in which the heart beats erratically and cannot pump blood. Above 200 mA, fibrillation is strong enough to paralyze the heart muscles. Given that current through a typical household circuit is 15 A, safety is an issue. Electricians and engineers have several ways to keep people safe from high currents. The following are some of the most common electrical safety features installed in our homes.

The copper earth stake on the left side in the photo grounds unwanted electricity from the power connection.

GROUNDED CIRCUITS

Connecting a circuit "to ground" is a basic safety practice in the installation of household electrical systems. In grounding the current is given a direct physical connection to the earth. An electrical ground is literally the ground you walk on, including the soil, rocks, and groundwater found in the earth. The ground provides a common return path for excess charge in a circuit. The reason it is safe to connect a current to the ground is because the earth is so large that it will not change electric potential by adding or removing charge. Grounding a circuit provides a path for excess electrons to travel to the earth instead of through places where they can do harm. Physicists refer to the earth as a charge source or sink, meaning it is treated as an infinitely large place for charge to be distributed.

Grounding is seen in the form of a wire connected directly to the earth or, more commonly, to another conducting object that leads to the ground. The diagram at right shows how a ground works in a circuit. A conductor that is used to connect devices to ground is called a neutral conductor. Sometimes the grounded conductor in a power system is called the neutral wire and an ungrounded conductor is called the hot wire. Likewise, the devices in the circuit that create resistance comprise what is called the load.

"hot" line
voltage source
load
"neutral" line
ground

GROUNDING CIRCUIT

FUSES AND CIRCUIT BREAKERS

Another safety device commonly found in appliances or in older houses and apartments is a fuse. A fuse is inserted into the circuit to cut off the current if it goes above a predetermined limit. It works with a heat sensitive wire that melts and/or breaks when a maximum current is exceeded. Fuses can be installed in the circuit within a device and/or in a location outside a device.

87

10 Surge protectors are not addressed in the reading because they protect devices rather than people, and so are not technically a safety device.

10

A woman checks a screw-in fuse in an older home (left); glass cartridge fuses are used in some electronics (top right); circuit breakers have replaced fuse boxes in modern houses (bottom right).

A circuit breaker works in a similar manner. However, instead of there being a cut in the wire where the fuse is placed, a circuit breaker throws a switch that temporarily breaks the current, or "opens" the circuit. Circuit breakers have the advantage of convenience because they need only to be flipped to reinstate the current, and do not need to be replaced like a fuse. That, however, makes it easier for the user to ignore the warning that the current is too high. Circuit breakers and fuses are made in varying sizes, from small ones that protect an individual device to large switches that protect the high-voltage circuits feeding an entire city.

GFCIs

A ground fault current interrupter (GFCI) works at the outlet, instead of at a remote box location where circuit breakers are housed. It senses the current between the hot and neutral conductors, which should be the same coming in and out of the outlet. If the difference between the two is not zero, it indicates that current is exiting the circuit somewhere, which is a hazard. The GFCI is triggered to automatically switch off the power if the current difference going in and out of an outlet is significant. Occasionally a GFCI is installed on the device itself, such as with a hair dryer, because it poses a significant fire risk.

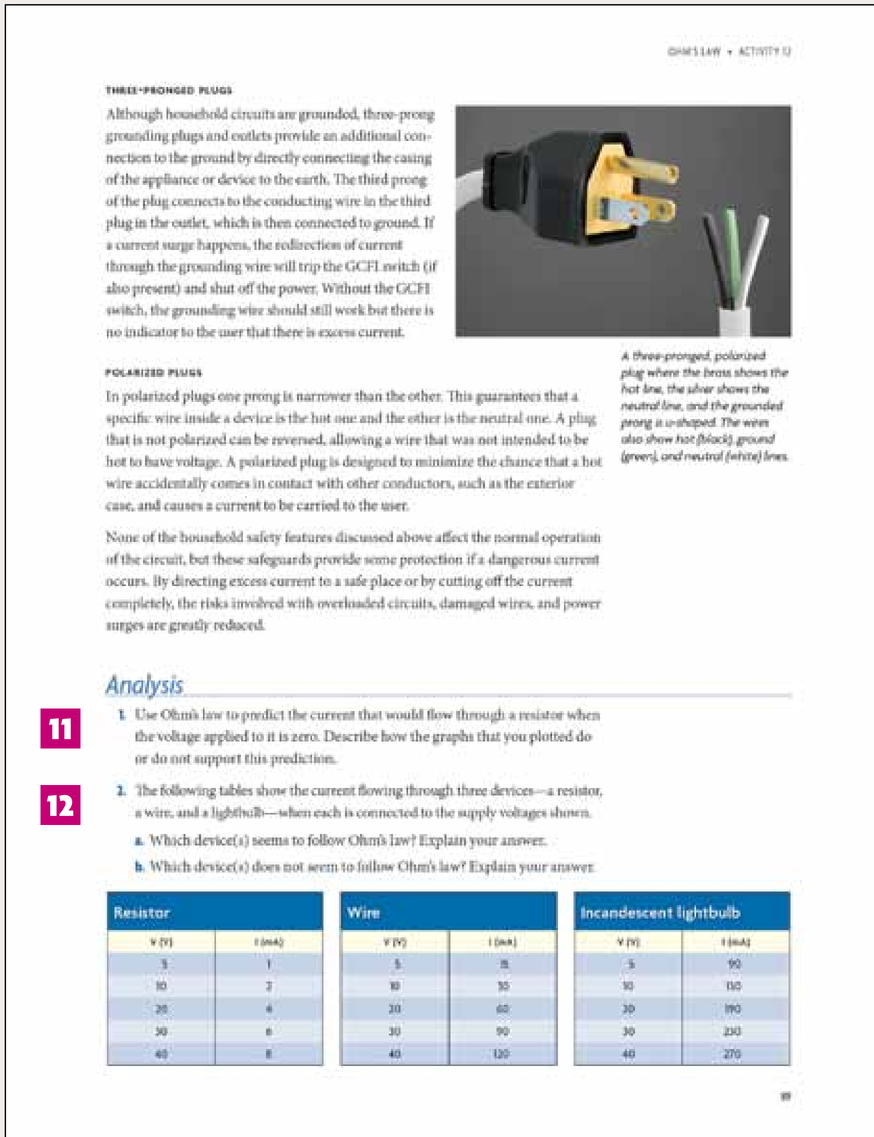
DRAFT

FOLLOW-UP

11 ✓ Analysis Question 1 serves as a Quick Check assessment to ensure students can accurately identify the key content, which is a component of the UNDERSTANDING CONCEPTS Scoring Guide.

Students should be able to predict that without a battery in the circuit no current would flow. If necessary compare the $V = 0$ V situation to removing the battery from the circuit. If students' graphs from the procedure do not go through the origin, and, therefore, do not seem to support that $I = 0$ when $V = 0$, discuss possible reasons with the class. The most likely reason is that a meter is not zeroed correctly.

12 (AD ASSESSMENT) Students' written work Analysis Question 2 may be scored with the ANALYZING DATA (AD) Scoring Guide. A complete and correct response is shown in the Sample Responses below.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THREE-PRONGED PLUGS

Although household circuits are grounded, three-prong grounding plugs and outlets provide an additional connection to the ground by directly connecting the casing of the appliance or device to the earth. The third prong of the plug connects to the conducting wire in the third plug in the outlet, which is then connected to ground. If a current surge happens, the redirection of current through the grounding wire will trip the GCFI switch (if also present) and shut off the power. Without the GCFI switch, the grounding wire should still work but there is no indicator to the user that there is excess current.

A three-pronged, polarized plug where the brass shows the hot line, the silver shows the neutral line, and the grounded prong is u-shaped. The wires also show hot (black), ground (green), and neutral (white) lines.

POLARIZED PLUGS

In polarized plugs one prong is narrower than the other. This guarantees that a specific wire inside a device is the hot one and the other is the neutral one. A plug that is not polarized can be reversed, allowing a wire that was not intended to be hot to have voltage. A polarized plug is designed to minimize the chance that a hot wire accidentally comes in contact with other conductors, such as the exterior case, and causes a current to be carried to the user.

None of the household safety features discussed above affect the normal operation of the circuit, but these safeguards provide some protection if a dangerous current occurs. By directing excess current to a safe place or by cutting off the current completely, the risks involved with overloaded circuits, damaged wires, and power surges are greatly reduced.

Analysis

11 1. Use Ohm's law to predict the current that would flow through a resistor when the voltage applied to it is zero. Describe how the graphs that you plotted do or do not support this prediction.

12 2. The following tables show the current flowing through three devices—a resistor, a wire, and a lightbulb—when each is connected to the supply voltages shown.

a. Which device(s) seems to follow Ohm's law? Explain your answer.

b. Which device(s) does not seem to follow Ohm's law? Explain your answer.

Resistor	
V (V)	I (mA)
5	1
10	2
20	4
30	6
40	8

Wire	
V (V)	I (mA)
5	15
10	30
20	60
30	90
40	120

Incandescent lightbulb	
V (V)	I (mA)
5	90
10	150
20	190
30	230
40	270

89

DRAFT

13 (UC ASSESSMENT) Students' written work Analysis Question 3 may be scored with the UNDERSTANDING CONCEPTS (UC) Scoring Guide. A complete and correct response is shown in the Sample Responses below.

Analysis Question 3 is an Ohm's law problem that allows students to apply basic problem-solving skills. You may wish to project Transparency 1.1, "Problem-solving Techniques," and review how this method may work with this and other analysis questions.

14 Connect the equation P = IV, presented in the first two activities, where students investigated the power used by devices and the power consumed by entire countries. Also connect it to the equation $P_{loss} = I^2R$, which was presented in Activity 11, "Electrical Resistance," by substituting Ohm's law into the relationship between current, resistance, and power:

$$
\begin{aligned}
P &= IV \\
&= I(IR) \\
&= I^2R
\end{aligned}
$$

Although household circuits as described in the Analysis Question and in the Technology Connection are AC, students are not introduced to AC and DC currents until later in the unit. It is not relevant in the context of this question when focusing on Ohm's law.

Likewise, students have had exposure to but have not been formally introduced to parallel circuits, where the total current is the sum of the branch currents. Clarify that the currents should be added if students are confused about the relationship of the currents in part b of this question.

You may want to follow up Analysis Question 4 by asking, *Which two devices can be used together without tripping the circuit breaker?*

Students should be able to provide combinations that add up to less than 20 A, such as the iron and toaster at 16.67 A.

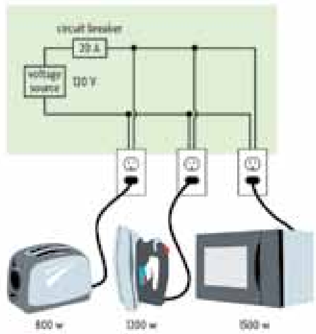
SCIENCE & GLOBAL ISSUES/PHYSICS • ELECTRICITY

13 3. Suppose your teacher gives you a fifth resistor to test. You notice that the resistor has the value 25 Ω written on it. What current would you expect to flow through the resistor when it is connected to a 5 V supply? Show your work.

14 4. In the household circuit shown below, there is a 20 A circuit breaker for the current that provides power to the kitchen. If the voltage is 120 V,

a. what current goes through each appliance?

b. will the circuit breaker be triggered "open" if all three are turned on simultaneously?



5. Suggest which safety devices would be most effective in the following situations. In each case, explain the reason(s) for your choice.

a. Supplying electricity from a power pole on the street to a home.

b. Plugging a computer into a socket in an office.

c. Charging an electric toothbrush by plugging it into a socket in the bathroom.

Enrichment

Use Appendix E, "Problem-solving Techniques: Physics," to guide your responses to the following problem.

6. In a laboratory experiment to investigate Ohm's law, a student measured the voltage across, and the current flowing through, a resistor. The results are shown in the table at right. Unfortunately, the voltmeter was not zeroed correctly, so the readings were precise but not accurate. All were off by the same amount. Plot a graph of voltage against current and from the graph determine:

a. the resistance of resistor, R.

b. the amount by which the voltmeter needs to be adjusted to read correctly.

Lab Data

VOLTAGE (V)	CURRENT (mA)
0.5	20
1.0	50
1.5	75
2.0	100
2.5	150

98

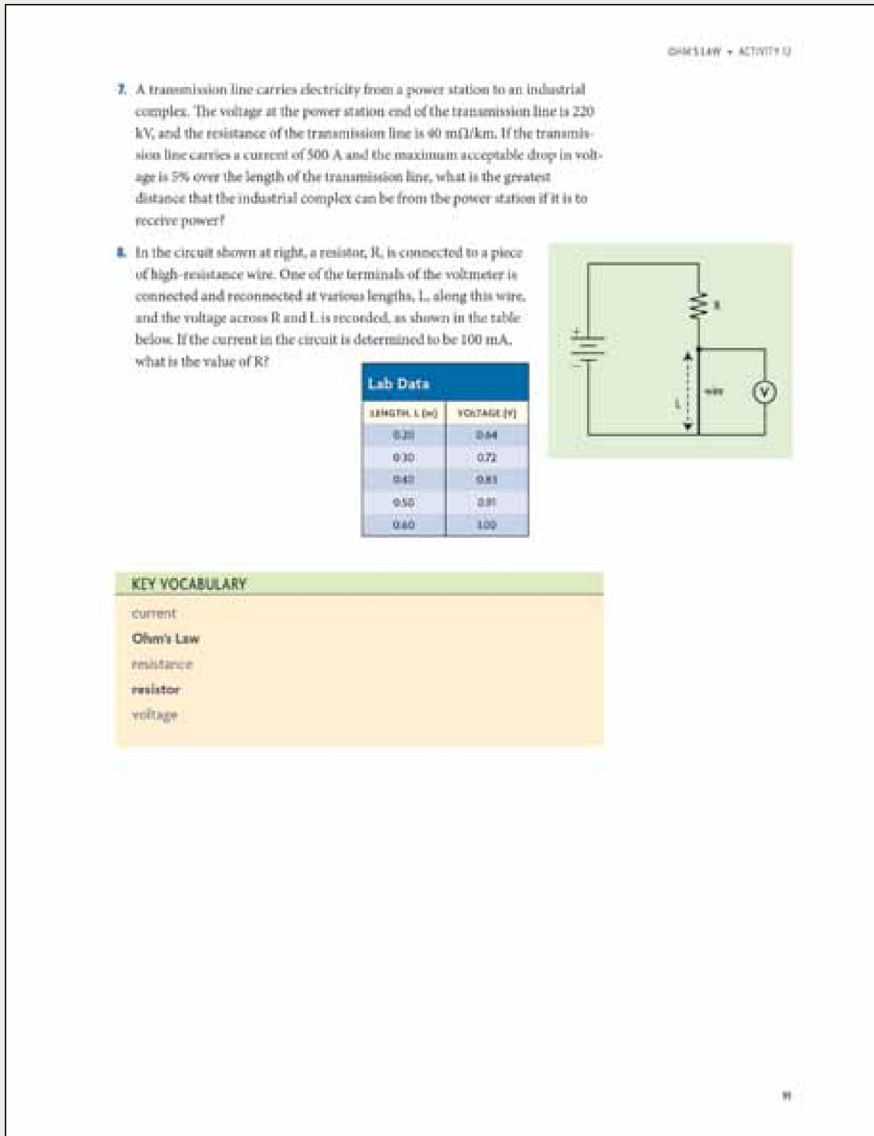
SAMPLE RESPONSES

1. ✓ Ohm's law can be stated as V = I R. If V is 0, then I should be 0. Therefore an accurate prediction is that when no voltage is applied no current will flow. The graphs plotted support this as each of the lines seems to go through the origin (0, 0).
2. (AD ASSESSMENT) Students' responses will vary. They should find that filament in the lightbulb heats up as more current flows through it. Therefore, there is not a linear relationship between V and I over the range of values shown in the table. A complete and correct response will refer to data gathered in the investigation. Students may choose to plot graphs to illustrate the relationship.

Sample Level-3 Response

2. a. The resistor and the wire follow Ohm's law since the current and voltage are directly proportional to one another. The current increases by a consistent amount each time the voltage increases by a fixed amount. For example, for those two devices the current doubles whenever voltage doubles.

   b. The incandescent bulb is not an ohmic device because its resistance does not change in a consistent way with voltage changes. My graph drawn from the incandescent light data is nonlinear, and, therefore, doesn't seem to follow Ohm's law.



OHM'S LAW • ACTIVITY 12

7. A transmission line carries electricity from a power station to an industrial complex. The voltage at the power station end of the transmission line is 220 kV, and the resistance of the transmission line is 40 mΩ/km. If the transmission line carries a current of 500 A and the maximum acceptable drop in voltage is 5% over the length of the transmission line, what is the greatest distance that the industrial complex can be from the power station if it is to receive power?

8. In the circuit shown at right, a resistor, R, is connected to a piece of high-resistance wire. One of the terminals of the voltmeter is connected and reconnected at various lengths, L, along this wire, and the voltage across R and L is recorded, as shown in the table below. If the current in the circuit is determined to be 100 mA, what is the value of R?

Lab Data

LENGTH, L (m)	VOLTAGE (V)
0.20	0.64
0.30	0.72
0.40	0.83
0.50	0.91
0.60	1.00

KEY VOCABULARY

current

Ohm's Law

resistance

resistor

voltage

91

3. (UC ASSESSMENT) Students' answers will vary. A complete and correct response will show competency at problem solving, including correct algebra and appropriate use of units.

Sample Level-3 Response

$V = 5\text{ V}$

$R = 25\ \Omega$

Since $V = IR$,

$$I = \frac{V}{R}$$

$$= \frac{5\text{ V}}{25\ \Omega}$$

$$= 0.2\text{ V}/\Omega = 0.2\text{ A}$$

4. a. $I = P/V$, so

$$I_{toaster} = \frac{120\text{ V}}{6.67\text{ A}}$$

$$I_{iron} = \frac{1{,}200\text{ W}}{120\text{ V}} = 10\text{ A}$$

$$I_{microwave} = \frac{1{,}500\text{ W}}{120\text{ V}} = 12.5\text{ A}$$

   b. The total current is 6.67A + 10A + 12.5 A = 29.17 A, which is more than enough to trigger the circuit breaker open.

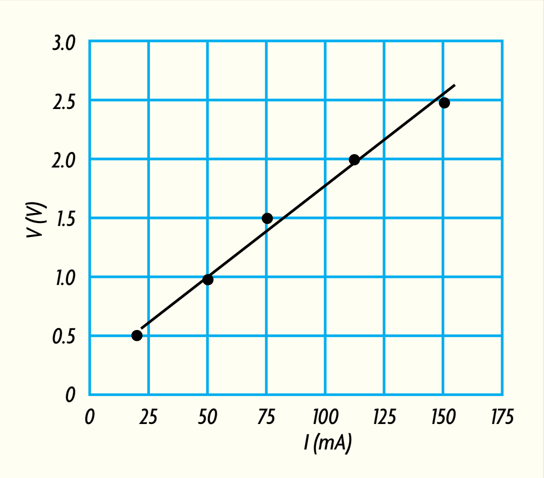
5. a. A high-amp circuit breaker would be most appropriate to protect the supply to the house. A fuse could be used but would have to be replaced in the event that it blew, whereas the circuit breaker can be reset after it has been tripped and the problem resolved.

   b. The computer can be protected with a fuse in the machine. The outlet itself can be protected with a circuit breaker or a fuse. Having a fuse in the computer will be the most valuable way of protecting the device, since the amount of current that would trip a circuit breaker might still be enough to damage the computer. Since it is not unusual to touch a computer, the device should also be grounded.

c. Because the toothbrush is in a bathroom and close to water, it should be protected by a GFI. This will quickly cut the toothbrush off from the rest of the circuit in the event of a power surge, such as when there is a malfunction or excess current due to contact with water.

ENRICHMENT

6. Students' graphs should look similar to the following:



a. The resistance of R is equal to the change in voltage divided by the change in current (i.e., $R = (\Delta V/\Delta I)$), which is equal to the slope of the graph. Calculations of slope should provide values around

1.5×10^{-2} V/mA

Converting mA to A produces a resistance of 15 ohms.

b. The line of the graph should go through the origin (0,0) because the current should be 0 when there is no potential difference across the resistor. However, extrapolating the line on the graph back to $I = 0$ mA produces a y-axis intercept of about 0.3 V. This is the value by which the voltmeter is misreading and therefore needs to be adjusted.

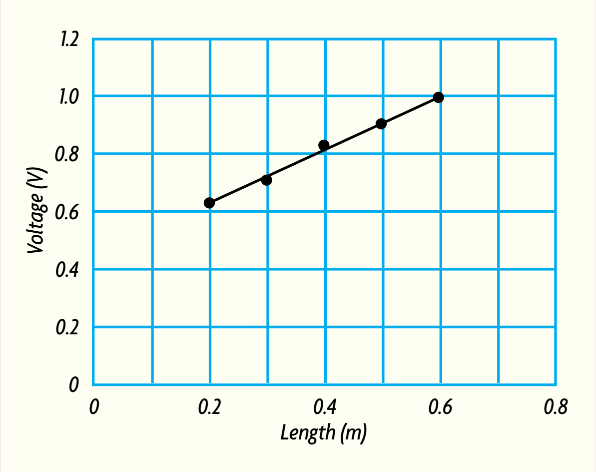
7. If V = 5% of 220,000 V, then
V = (220,000)(.05) = 11,000 V
V = IR where I = 500A, so
(11,000V) = (500 A) R
R = 22 Ω

Because each kilometer of wire has a resistance of 40 mΩ, it will take

R = (resistance)(distance)
$22\ \Omega = (40 \times 10^{-3}\ \Omega/\text{km})\ d$
d = 550 km

8. To solve this problem using Ohm's law it is necessary to isolate the impact of the wire, L, on the results. One way to do this is by plotting a graph of V against L and finding the y-axis intercept, that is, the value of V when L = 0 m. (It is also possible to use the data table directly to calculate V when L = 0 m). When L = 0 m, Ohm's law can be applied directly to R.

Extrapolating the line on the graph to the y-intercept



shows that V = 0.45 V when L = 0 m. This is the voltage across the resistor.

I = 100 mA = 0.1 A
V = IR
0.45 V = (0.1 A)R
R = 4.5 Ω

REVISIT THE CHALLENGE

Voltage, current, and resistance in a circuit are related by Ohm's law, which states that the current through a conductor between two points is directly proportional to the potential difference across the two points (the voltage), and inversely proportional to the resistance between them.