

Batteries and Current

Inquiries **1**
Periods **2**

CONCEPTS

An equal amount of current flows through electrical components connected in series.

An increase in the current through a lightbulb increases the amount of electrical energy transformed into light and heat in the filament of the lightbulb.

The current through a lightbulb is proportional to the voltage across the lightbulb.

Components in the same line in a circuit have the same current through them.

STUDENT OBJECTIVES

Design and conduct an experiment to determine the relationship between the number of batteries in a circuit and the current through a lightbulb.

Observe the effect on a lightbulb's brightness when the current through the lightbulb is changed.

OVERVIEW

In Lesson 7, students observed how changing the voltage across a circuit affects the brightness of a lightbulb. They found that adding batteries in series increased the voltage across the circuit, resulting in an increase in the brightness of the lightbulb.

In this lesson, students expand their knowledge of electrical circuits by investigating how the current through the lightbulb affects its brightness. They begin by measuring current in a simple series circuit that has an ammeter in series with a lightbulb. Students then predict how changing the current through the lightbulb might affect its brightness. To find out whether their predictions are correct, students design an experiment to change the current through a lightbulb and then record changes in brightness. After collecting their data, students assess their predictions and summarize what they have learned by sharing their results with the class.

In Lesson 9, students will use another version of a water model to develop explanations for their observations in Lessons 7 and 8.

BACKGROUND

Ohm's Law

Ohm's law provides the basis for the activities in this lesson. It describes the relationship between the current through a device and the voltage across it. This relationship is expressed in mathematical form as

$$V = IR$$

where V is the voltage across the device, I is the current through the device, and R is the

resistance of the device. If R is constant, then the graph of current (I) versus voltage (V) will be a line through the origin. Figure 8.1 shows that as the voltage across a circuit increases, the current through the circuit increases in direct proportion. For example, doubling the voltage doubles the current.

However, not all electrical devices maintain a constant resistance over their operating range. In reality, the resistance of the lightbulb will

change with its temperature, getting higher as the temperature increases. If the resistance of a device changes during its operation, the graph of current versus voltage will not be a straight line (see Figure 8.2). The lightbulbs in the circuit systems kit do not have a constant resistance over their operating range, a fact that will be evident in the graphs of current versus voltage in this lesson.

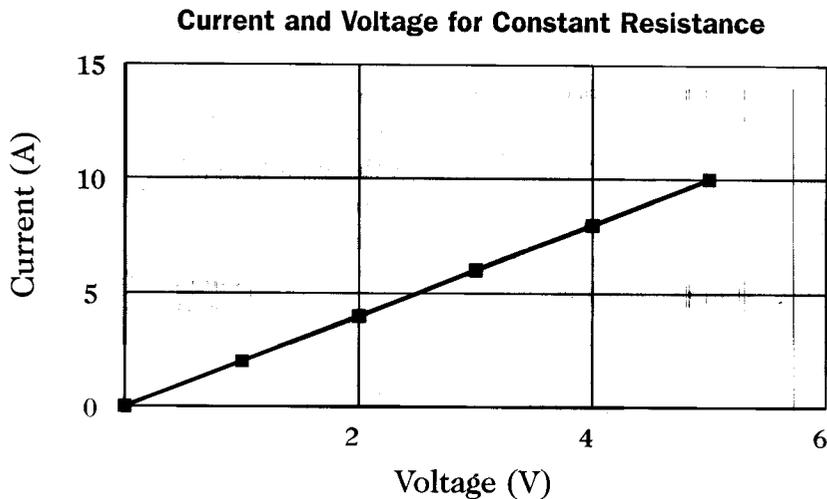


Figure 8.1 Current versus voltage with constant resistance

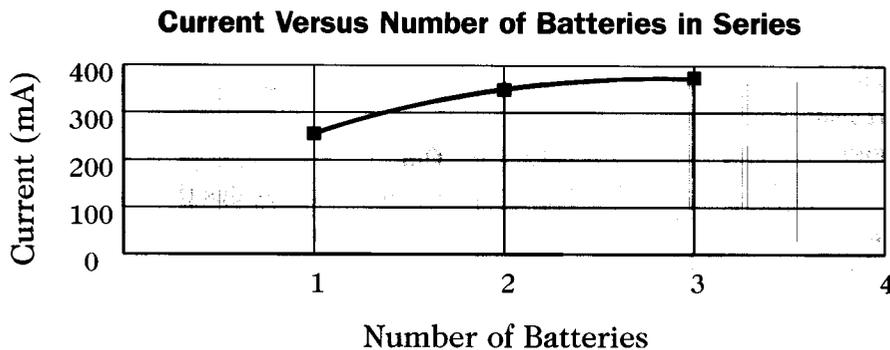


Figure 8.2 Current versus voltage with changing resistance

Batteries and Current in a Series Circuit

To understand this relationship between current and the number of batteries in a circuit, think about Lesson 3, in which students investigated electrical forces between charged objects. They found that there are two kinds of electric charge: positive and negative. Objects with opposite charge attract one another, while objects with the same charge repel one another. These forces of attraction and repulsion can be put to work in an electrical circuit.

The electrical circuit that students use in this lesson contains a single D-cell battery, a switch, an ammeter, and a lightbulb, all in series with each other. The D-cell that provides the energy for the circuit has a positive and a negative terminal. The positive and negative terminals result from the chemical reactions within the battery (see Figure 8.3). The chemical reactions in the battery produce a positive charge on one terminal and a negative charge on the other. When the terminals of the battery are connected to the wires in the circuit and the switch is closed, the electrical forces can push negative charges in the wire away from the negative terminal and the positive terminal can attract negative charges. This arrangement sets up a net drift of charge, which is the current in the circuit (see Figure 8.4). If the battery is replaced with a combination of D-cells that produces a higher voltage, the force on the electrons will be greater and more energy will be involved. This greater electrical force, which is associated with the voltage of the battery, increases the current in the circuit.

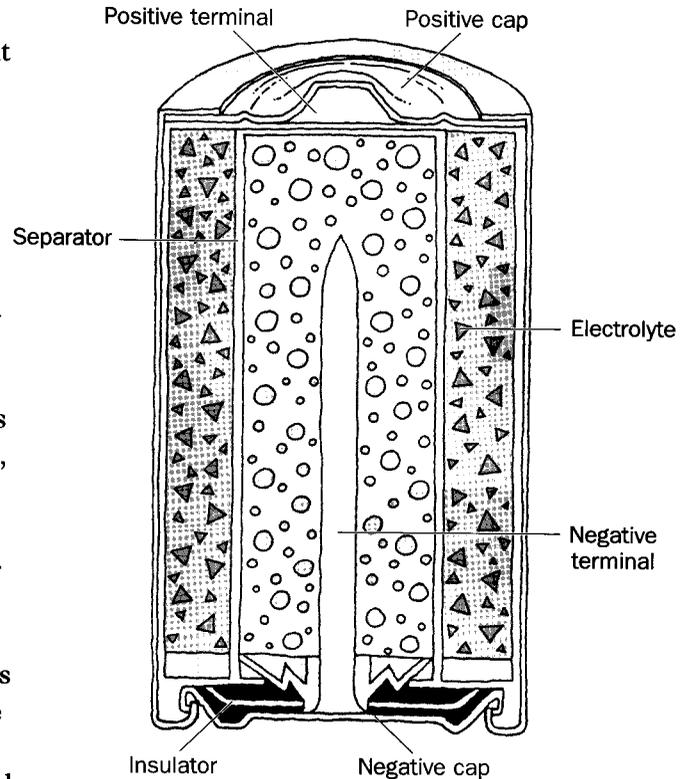


Figure 8.3 The interior of a D-cell, one kind of single-cell battery

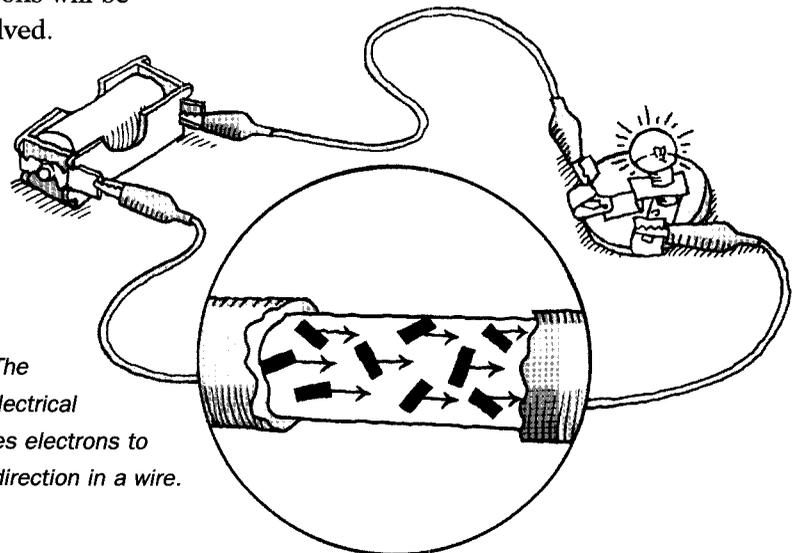


Figure 8.4 The push from electrical forces causes electrons to drift in one direction in a wire.

Increasing the current in the circuit means that more charge flows through the filament of the lightbulb. Since more charge flows through the lightbulb, more electrical energy is available to be transformed by the filament into heat and light. As a result, the brightness of the lightbulb increases.

Series and Parallel Battery Connections

One way to think about how series and parallel battery connections affect current is to imagine charges experiencing a push within the batteries. When connected in series, the positive terminal of one battery is connected to the negative terminal of another. Since there is only one path for charge flow in a series connection, the charges feel a force from each battery, resulting in a greater total push across the multiple batteries, which produces a greater charge flow.

When connected in parallel, batteries are connected so that the positive terminal of one is connected to the positive terminal of another, and the negative terminal of one to the negative terminal of another. This configuration produces multiple paths for charges so that individual charges pass through one battery only; thus, they get only one push. Since the push on all the charges is equivalent to the push of a single battery, the push is the same as that resulting from a single battery. The total current supplied by the parallel batteries is the same as if the circuit contained a single battery.

IMPLEMENTING LESSON 8

This lesson requires two periods. During the first period, have students complete “Getting Started” and the part of Inquiry 8.1 that involves experimental design. Have them complete their experiments during the second period.

Getting Started

The “Getting Started” activities give students an opportunity to review the use of ammeters in circuits, as well as their prior observations about current. It is important that they review not only what the ammeter measures, but also how it is connected in a circuit. Make sure to review the following concepts with students:

- An ammeter is always connected in series in line with other wires and devices.
- The positive terminal of the ammeter is connected to the line leading to the positive terminal on the battery.

By this lesson, students should be able to set up the series circuit in SG Figure 8.1. Hold students accountable for setting up the circuits and using the ammeter. Often in lab groups, one student will take on the task of setting up the equipment while others watch or serve as data recorders. Emphasize that each student should be able to demonstrate how to set up a circuit and connect the ammeters for making measurements. See the Assessment section for some recommendations on how to use this lesson to assess students’ skills in building circuits.

Review with students what they learned about current in Lesson 6. You also may want them to review their data from Lesson 5, which shows that components in the same line in a circuit have an equal amount of current through them. Here students can begin to appreciate a constructivist approach; that is, they can begin to recognize the value of reviewing their previous work to build on their understanding of circuits.

Inquiry 8.1

In Inquiry 8.1, students design an experiment to investigate the relationship between the number of batteries in a circuit and the current through a lightbulb in the circuit. Student Sheet 8.1 provides a guideline for students to follow as they perform the inquiry. Students should complete the front of the student sheet, which guides them as they design their experiment; then they should complete the back of the student sheet as they perform their experiment and record their data. Make sure they write a conclusion based on evidence from their data. If your students are experienced with experimental design, you may choose to have them record the design of their experiments in their science notebooks rather than on the student sheet. This alternative approach would provide an excellent assessment of students' understanding of experimental design.

When building their circuits, some students will investigate adding batteries in series; others may choose to place batteries in parallel. Encourage both approaches and have students in adjacent groups compare their results. You may suggest that students investigate turning the batteries around (reversing the positive and negative connections) to see the effect on the current. There are many possibilities. The more combinations students try, the richer your class discussion can be. Students should measure the current for each battery combination they use. Students also can measure the voltage across the battery combinations when the switch is closed to see how the voltage across the circuit relates to the current. Observe students to ensure that they pay attention to the brightness of the lightbulb as the current changes. You may want them to include a "brightness of the lightbulb" column in their data tables.

If necessary, review graphing procedures with your students. Students should have two sets

of data: one for the number of batteries and current, and another for current and brightness. One is appropriate for graphing, and the other is not. Students can construct a graph of the number of batteries versus the current since they have quantified their measurements of these variables with their ammeters. Because the qualitative data for brightness are based on a subjective scale (unless you chose to use a device that measures the brightness of the lightbulb), such data are best displayed in a table that shows current measurements and brightness indicator. From this table, students can draw their conclusions based on their evidence.

Reflecting on What You've Done

Use the questions in "Reflecting on What You've Done" to initiate a class discussion in which students share the results of their investigations. Encourage students to evaluate how well their conclusions support their hypotheses; however, make sure they understand that results that do not support their hypothesis do not necessarily indicate a bad experiment. Rather, they provide students an opportunity to revise their thinking about scientific principles and to refine their understanding of those principles.

READING SELECTIONS

Two readers accompany this lesson. "Batteries, Voltage, and Current" introduces the components of a battery and how batteries relate to voltage and current. Assign the reader after students have completed Lesson 8 and have presented their own experimental results. "Electrical Line Mechanic: A Tough but Rewarding Job" details the joys and danger involved in the job of Jon Rogers, a line mechanic for an electric company.

ANTICIPATED OUTCOMES

Tables 8.1 and 8.2 show sample data for student-built circuits in Inquiry 8.1. Table 8.1 shows the data for the batteries in series. Figure 8.5 is a graph of the current versus the number of batteries in series. Table 8.2 shows the data for the batteries in parallel. Students will need to choose a method for portraying their data, that is, a table or a graph. Student's data may vary depending on the condition of the batteries and the lightbulbs they use. The data for Tables 8.1 and 8.2 were obtained using a #41 incandescent lightbulb.

Table 8.1 Sample Data for Series Batteries and Current Through a Lightbulb

No. of Batteries in Series	Voltage Across Lightbulb (with switch closed) (V)	Current Through Lightbulb (mA)	Brightness of Lightbulb
1	1.5	275	dim
2	3.0	400	bright
3	4.5	500	very bright

Table 8.2 Sample Data for Parallel Batteries and Current Through a Lightbulb

No. of Batteries in Parallel	Voltage Across Lightbulb (V)	Current Through Ammeter and Lightbulb (mA)
1	0.5	250
2	0.5	250
3	1.0	300

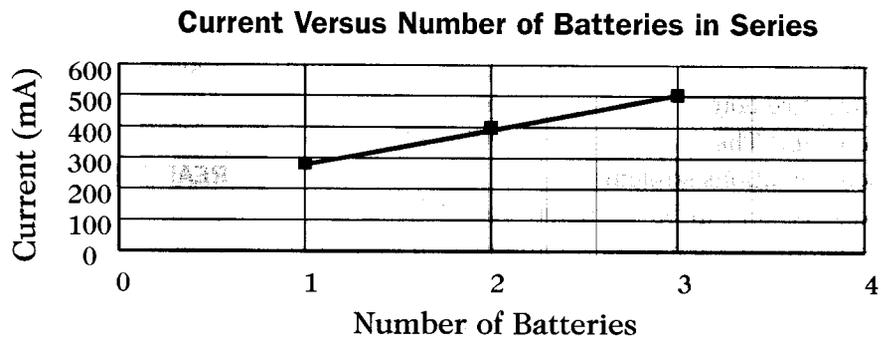


Figure 8.5 Graph of current versus voltage

MATERIALS FOR LESSON 8**For each student**

- 1 copy of Student Sheet 8.1: Batteries and Current in Circuits

For each group

- 1 circuit systems kit
 - 1 clear plastic box with lid
 - 3 D-cell batteries
 - 3 plastic D-cell battery holders
- 1 pack of connector wires with alligator clips (pack of 10)
- 2 knife switches, single-pole/single-throw
- 3 mini lightbulbs, 2.5 V
- 3 mini bulb holders
- 1 electric buzzer
- 1 ammeter
- 1 fan-motor assembly
- 1 voltmeter

Getting Started

1. Have groups review how to use ammeters in circuits.
2. Have students set up the circuit shown in TG Figure 8.6 and SG Figure 8.1.
3. Have students draw a schematic of Figure 8.6 in their science notebooks (see Figure 8.7).
4. Ask students to close the switch in their circuit and to record the current registered on the ammeter.
5. Initiate a class discussion about the following question:

Is the current through the ammeter the same as the current through the lightbulb? Explain your reasoning.

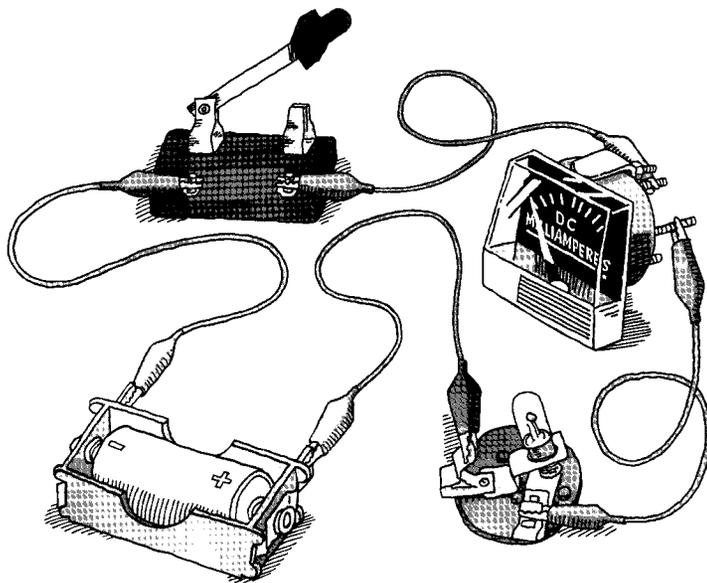


Figure 8.6 An ammeter connected in a circuit to measure the current through a lightbulb

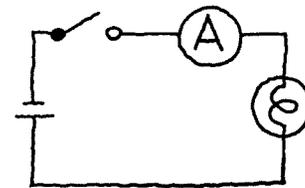


Figure 8.7 Schematic for the circuit shown in Figure 8.6

Inquiry 8.1

Investigating How Batteries Affect Current

PROCEDURE

1. Have groups discuss the following question:

What do you think would happen to the current through the ammeter if you added more batteries to the circuit?

2. Review Student Sheet 8.1 with students. Remind them that they are to complete each item on the student sheet and report their findings to the class.
3. Have students complete Procedure Step 4 in the Student Guide. They should record their findings on Student Sheet 8.1 as they design their experiment. You may want to have groups share their experimental designs before they begin their experiments.

NOTE Each group should decide if it will connect the batteries in series or in parallel. Each group should then change the number of batteries and observe the current registered on the ammeter. Remind students to open the switch before they make any changes to the circuit. Encourage them to agree on which members of their group will read the ammeter each time they change the circuit. That is, they should avoid depending on one person to record the reading each time. Have at least two students read and compare their readings of the current. This extra step often helps to catch errors that are likely when the group depends on just one student to read the meter.

4. Check to see that students are recording the number of batteries and the current measurements in their data tables.

NOTE This inquiry provides a good opportunity to assess how well students can read the ammeters. Spot check students' readings of the ammeters or ask individual students to demonstrate their ability to accurately read the ammeter's scale.

5. Discuss with students how they might graph their data. Remind them to put the independent variable (number of batteries) on the horizontal axis and the dependent variable (current) on the vertical axis.
6. Ask students to summarize their results in a conclusion that they can support with evidence from their data.

REFLECTIONS

1. Have students share with the class what they did in your experiment and what they found out about the current through a lightbulb and the brightness of the lightbulb. (Students who added batteries in series should show an increase in current as the number of batteries increases. Students who added batteries in parallel should not find a significant increase in voltage or current as batteries are added.)

NOTE You may want to have students put their data on the board or on an overhead transparency for the rest of the class to see, or you may want to make a master data table so that students can compare results among groups easily.

2. Ask students to look back at their hypothesis for the experiment. They should answer the following question in their science notebooks: Based on the results of all the groups, was your hypothesis supported or not supported by the results of the experiments? Share your answers with the class. (Student answers will vary.)
3. Review with students the results of the investigations about voltage and brightness from Lesson 7. Students should write a sentence or two in their science notebook summarizing what they have learned about batteries, current, and lightbulbs in this lesson and in Lesson 7. (Student answers will vary.)
4. Have students share their written summaries with the class.

NOTE Students can see that the brightness of the lightbulb depends on the current through it and the voltage across it. This observation sets the stage for their investigation of electrical power in Lesson 10.

HOMEWORK

1. Have students graph their data and write their conclusions from Inquiry 8.1 on the student sheet so that they will be ready to discuss their results during the next class.
2. Have students read “Batteries, Voltage, and Current” and answer the questions at the end of the reader.

EXTENSIONS

■ Language Arts

1. Have students read “Electrical Line Mechanic: A Tough but Rewarding Job,” then have them write a response to what they read. Their responses should focus on their thoughts, ideas, and questions generated by their reading. Do not have them summarize the content of the reader.

■ Science

2. Have students repeat their experiments using a buzzer or electric motor instead of a lightbulb, and challenge them to explain any differences in the results.

■ Technological Design

3. Challenge students to set up a circuit with a lightbulb in which they change the current through the lightbulb without changing the number of batteries in the circuit. Ask them to propose explanations for why their circuit works.

■ Technological Design

4. Ask students to design a circuit that has only two lightbulbs in it so that one lightbulb has twice the current through it as the other. Students should use the materials in their circuit systems kit to do this activity.

■ Technological Design

5. Have students use a computer-simulation program to design electrical circuits and to control the current in the circuit. See the list of resources in Appendix C for some suggested software that you could use for this activity.

ASSESSMENT

This lesson provides several opportunities for embedded assessment of students' skills and understanding of concepts. You may want to make a checklist to verify students' demonstrations of skills. If you choose to do this, inform students in advance that they will be expected to demonstrate these skills. Assure them that you will apprise them of their progress as they work through the activities in this lesson.

Assess students using the following criteria:

- Students set up a closed circuit.
- Students connect the ammeter in series with the lightbulb.
- Students use equipment appropriately.
- Students assemble batteries in series and parallel.

- Students read and record ammeter measurements accurately.
- Students record correct units of measure.

In assessing the completed student sheets, you may wish to use the experimental design rubric in Appendix E. Score students' performance in designing their experiments and in analyzing their data.

PREPARATION FOR LESSON 9

Make sure that students return all items to their circuit systems kits. In Lesson 9, students will work with a water-battery model. Removing the kits from students' stations will minimize distractions during Lesson 9.

Name: _____
Class: _____ Date: _____

Student Sheet 8.1 Batteries and Currents in Circuits

Directions Use this student sheet to complete the activities in Lesson 8.

A. Identify the independent and dependent variables in your investigation.

independent variable

dependent variable

B. Write a hypothesis about how changing the number of batteries will affect the current through the lightbulb.

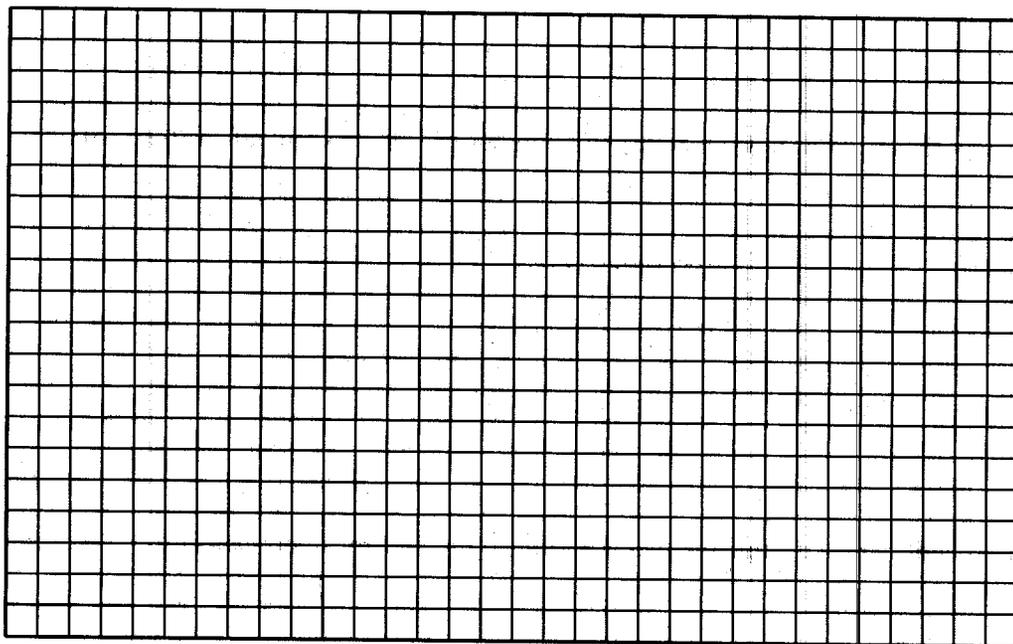
C. Write a procedure describing how you will change the batteries and measure the current.

(continued)

Student Sheet 8.1 (continued)

D. Draw a data table to record your data and observations.

E. Enter your data on the graph below:



F. Analyze your data and write a conclusion about the following:

- how changing the number of batteries affected the current

- how changing the current through the lightbulb affected its brightness