Topic 4.4
How can people control and use the movement of charges?

Specific Expectations

- **E2.1** use appropriate terminology related to static and current electricity, including, but not limited to: ammeter, ampere, battery, conductivity, current, energy consumption, fuse, kilowatt hours, load, ohm, potential difference, resistance, switch, voltmeter, and volts
- **E2.6** use an inquiry process to investigate the effects that changing resistance and changing potential difference have on current in a simple series circuit
- **E3.3** identify the components of a simple direct current (DC) electrical circuit, and describe their functions
- **E3.4** identify electrical quantities and their symbols, and explain how they are measured using an ammeter, a voltmeter, and a multimeter
- **E3.6** describe, qualitatively, the interrelationships between resistance, potential difference, and electric current, in a series circuit
- **E3.7** explain the practical use of resistance in a common household product

Skills

- conduct inquiries
- draw and justify conclusions based on inquiry results
- communicate ideas, using a variety of formats

Materials

- Please see the teaching notes for each activity for a list of the materials required. Please see page TR-48 for a summary of the materials required in this topic.

Overview

In this topic, students will be introduced to the characteristics of a simple electric circuit. A model will be used to help explain the movement of charges through the circuit. Students will draw circuit diagrams using standard symbols to represent the various components in the electric circuit. They will learn about current, electrical resistance, and potential difference, and their corresponding SI units. Students will measure the current and potential difference in a circuit using an ammeter and a voltmeter, respectively, and investigate the effects of potential difference and resistance on current.

Common Misconceptions

- **Some students believe that current flows from the battery to the load (for example, a light bulb), but not from the load to the battery.** Have students connect a battery to a light bulb with one wire. Students will discover that the bulb will not go on since there is no path for the charges to travel from the bulb back to the battery. They will conclude that a closed path is necessary for the load to work.
- **Some students, especially English language learners, may interpret the terms *open circuits/switch* and *closed circuits/switch* differently because an *open* door lets people through while a *closed* door does not.** Use the analogy of a bridge that can lift on one end. When the bridge "opens," the cars cannot pass. When it comes back down ("closes"), the cars can continue on their way. The bridge represents the switch in a circuit.

Background Knowledge

A simple circuit consists of a source, a load, and connecting wires, connected to form a closed loop to allow charges to flow through it. Every charge that flows through the circuit carries a certain amount of energy. Potential difference is the change in energy of a charge after it passes through the source or a load. Current is the number of charges that flow past a point in a given amount of time (1 second). Resistance describes the hindering or opposition to the movement of charges as they pass through a load.

There are meters designed to measure the current and potential difference in a circuit. These meters may show the electrical quantities by the motion of a pointer on a scale, or by a digital display of numerical digits. An ammeter is used to measure the current flowing through a specific point in the circuit, while a voltmeter is used to measure the amount of potential difference across two points in the circuit.

Some meters can be used to measure current, potential difference, and electrical resistance. These meters are called **multimeters**. A multimeter works the same way as the individual meters. When the meter selection is set to read current as an ammeter, it must be connected in series. When it is set to read potential difference as a voltmeter, it must be connected in parallel across the load.

Instructions for the proper use of ammeters, voltmeters, and multimeters is provided in Science Toolkit 9 Using Electric Circuit Symbols and Meters, and on **BLM G-20 Using Ammeters and Voltmeters** and **BLM G-21 Reading an Analogue Meter**.

The SI units for potential difference, current, and resistance are volts (V), amperes (A), and ohms (Ω) respectively.

Literacy Strategies

Before Reading

- Discuss the importance of using models in science. Ask students which models they are already familiar with, such as the particle theory of matter or the model of the atom. Some students, especially English language learners, may not have been exposed to or may not recall these scientific models. As an alternative, you could suggest that they share some similes or metaphors that they have heard of. Many cultures have their own sayings of wisdom that compare one thing or event to another. Tell students to watch for the model in this Topic that will help them learn about electricity.
  Be sure to use and emphasize the terms "like" and "similar to ... but the not the same" when introducing similes and models.
- Once students have completletd the starting points activity, use one of the circuits they created to introduce as many of the Key Terms as possible.

During Reading

- Students can set up two tables to summarize the information in this Topic:
  1. In the first table, students can list the terms (potential difference, current, and resistance) in the first column, and then write the corresponding symbols, definitions, and SI units in adjacent columns.
  2. In the second table, students can list the circuit components (source, load, switch, connecting wire) in the first column, draw their circuit symbols in the second column, and describe their functions in the third column. Alternatively, students can use **BLM 4-18 Electrical Circuits** to take notes as they read.
- ELL English language learners can make flash cards, with each term written on one side of the card and its definition on the other side. They can practise identifying the meaning of these words by playing word games with other students.

After Reading

- Have students work in small groups of three or four to summarize their understanding of electric circuits using an analogy (e.g., water in a pipe system, or cars on the road). The analogy must explain the concepts of charges, current, potential difference, and resistance. Encourage students to be creative while still modelling the concepts of electricity. Emphasize that an analogy is only *similar to* another idea or concept. Students could use **BLM A-6 Developing Models Checklist** to guide them. Have a volunteer from each group share their analogy with the rest of the class. Some groups may choose to involve all members in their presentation by acting out the analogy.
- ELL Consider presenting English language learners with an analogy that uses concrete or familiar experiences, and asking them to explain how it models the different characteristics of an electric circuit, for example, cars travelling around a city block. (The road = the circuit; each car = 1 charge; a line of moving cars = electron flow or current; a house near the road = the given point being passed; construction on the road = the resistor, and so on.) Students can explain in writing, orally, or using labelled diagrams.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 279	Students explain how energy is carried from a source to an electrical device, using terms such as source, current, resistance, and load.	• Provide graphic organizers such as those on BLM G-32 – BLM G-39 for students to use in Learning Check question 2. • Display a diagram of a simple circuit, with Key Terms labeled, throughout this topic. Refer to it often as you discuss concepts with students. • Encourage students to use diagrams if it helps them explain in Learning Check question 3.
Starting Point Activity, page 274 Learning Check questions, page 281	Students build and draw a simple circuit including a source, a load, a switch, and connecting wires.	• Reproduce symbols for source, switch, and load on cards. Have students draw a rectangle on a piece of paper to represent the wiring of a circuit. Have students work in pairs. One partner can build a simple circuit and the other can represent it with the cards. Both students can draw the circuit diagram in their notebook.
Learning Check questions, page 283 Investigations 4E and 4F, pages 288-290 Topic 4.4 question 5, page 291	Students describe the relationship among potential difference, resistance, and current.	• Provide students with sentence starters such as "When the potential difference in a ciruit stays the same and the resistance changes, the current ____________." • Communicating Scientific Results with Graphs, on page 370 of the student textbook, **BLM G-25 Constructing a Line Graph**, and **BLM G-26 Interpreting Line Graphs**.

Topic 4.4 (Student textbook pages 274–291)

Using the Topic Opener (Student textbook pages 274–275)

- Have students look at the photo in the opener spread. What does it show? (Answer: It shows a satellite photo of the lights in North America. Guide the discussion to include comments on the density of the lights, an indication of the number of people who rely on electricity across the country at any given time.
- Assign the Starting Point Activity. What preconceived ideas do the students have about circuits? Ask for volunteers to draw the different connections on the chalkboard. As a class, make a list of the features of a successful connection. Use the drawings as an opportunity to introduce Key Terms by labelling the source, load, and connecting wire.

Starting Point Activity

Pedagogical Purpose

Students will design and construct a simple circuit with one light bulb.

Planning	
Materials	1.5 V battery a flashlight bulb two insulated wires with alligator clips on the ends
Time	10–15 min in class 5–10 min preparation Large batteries with metal terminals last longer than smaller batteries.
Safety	Caution students to demonstrate care in connecting the wires to the battery and light bulb; if the wires begin to get hot, disconnect them right away.

Skills Focus

- use an inquiry approach to investigate phenomena
- draw a circuit diagram of a simple electric circuit
- draw conclusions based on inquiry results

Background Knowledge

An electrical circuit involves a closed loop, giving a return path for the current. The current, which is made up of moving electrons, must be able to move from a source of electric potential (the battery) through a load (the bulb) and back to the battery. Students tend to think that something is used up at the load. In a way, this is correct. Energy, carried by the electrons, is released in the form of light, at the load. Electrons return to the battery carrying no energy. Current electricity results from the movement of charge from high to low energy.

A short circuit in an electrical circuit is one that allows a current to travel along a different path from the one originally intended. In this case, a student would connect wires directly from one terminal of the battery to the other, with no load in between.

A short circuit is an abnormal low-resistance connection between two nodes of an electrical circuit that are meant to be at different voltages. The result is an excessive electric current limited only by the equivalent resistance of the rest of the circuit. Short circuits potentially cause circuit damage and overheating.

The electrical opposite of a short circuit is an open circuit, which is an infinite resistance between two nodes. This is what occurs when students leave the wires unconnected or connected to only one battery terminal.

Activity Notes and Troubleshooting

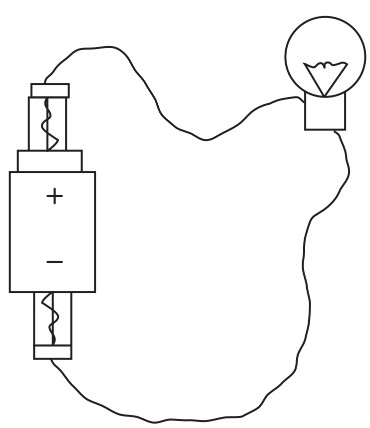
- Pay close attention to students' use of the current-carrying conductors (wires); some will attempt to build a short circuit, which is a potential hazard.
- Ensure that students share diagrams and encourage them to look for similarities.

Additional Support

- ELL Pre-teach key vocabulary, for example, conductor, wire, battery. Use concrete examples, where possible, and work with students on a concept map for the term conductor, listing examples and links to similar meanings.
- ELL Without giving away a correct solution, demonstrate for students that the are to find a way to connect them to make the light bulb light up. Once the expectation is made clear, English language learners should be able to participate fully in the activity and the visual recording of it.
- DI Spatial and bodily-kinesthetic learners will both be valuable group members. Ensure that students with strengths in these areas are included in as many groups as possible.
- Focus students' attention on the movable electric charges, which are electrons, and their requirement for an uninterrupted path to move along.

Answers

1.



Instructional Strategies for Topic 4.4

An electric current carries energy from the source to an electrical device (a load) that converts it to a useful form. (Student textbook pages 276–279)

- Have students work in pairs to read pages 276-279 and make notes about the Key Terms: potential difference, current, and resistance.
  - **ELL** Instead of summary notes, English language learners could complete a chart to compare the three terms. Have them draw a table with three columns labeled potential difference, current, and resistance. Below these headings, they should write the definition of the term and one other fact about it. For more intensive support, allow them to choose from a list of pre-written point form notes to organize under the corresponding terms.
- Introduce the idea of a simple circuit, described on page 280, with a quick demonstration: Ask for 10 volunteers to form a circle and hold hands. Select one student to represent the source of energy or battery in the circuit. Tell this student to squeeze the hand of the person standing to the right. Once this person on the right feels the squeeze, he/she will squeeze the hand of the next person on the right. This process continues around the circle until the squeeze is passed back to the source. Discuss with students what the hand-squeezing analogy represents. (Answer: The squeezing of hands is like the movement of negative charges along a circuit. The movement is continuous and orderly along a closed path. The strength of the squeeze may represent the energy of each charge.) Now, designate one of the students to represent a load, such as a light bulb. Ask students: How does the presence of the load affect the squeezing action that is passed around the circuit? (Answer: After the load, the strength of the squeeze should be smaller to reflect the drop in energy as the load converts some of it into useful energy.)

A source, a load, and connecting wires form a simple circuit.
(Student textbook pages 280–281)

- Have students examine the circuit symbols on page 281. Ask them to explain how they will associate each symbol with the circuit component that it represents. For example, a switch looks like a door that is opened or closed.
- Create cards for English language learners, to be used to review Key Terms. For example, on one set of cards, write the name of each circuit component. On another set of cards, draw their symbols. On a third set of cards, write their definition/function. You might play a five-minute trivia game at the beginning of class, where you read a definition and ask students to say the corresponding word or symbol.
- Read how meters are used to measure potential difference and current on page 282. Demonstrate how each meter is used. Have students conduct Activity 4.11 and Investigation 4D.
- Assign Investigation 4E and Investigation 4F for students to investigate the effects of potential difference and resistance on the current.

Activity 4.10 Battery Size (Student textbook page 277)

Pedagogical Purpose
Students will use an inquiry process to investigate battery size and potential difference.

Planning	
Materials	Examples of different size batteries: 1 each of AAA, AA, A, D, 9-volt, lantern batteries (optional)
Time	10 min in class

Skills Focus

- use an inquiry approach to investigate simple electrical circuits
- draw conclusions based on inquiry results

Background Knowledge

Alkaline batteries are dependent upon the reaction between zinc and manganese (IV) oxide (ZnO/MnO_2). Compared with zinc-carbon batteries or zinc chloride types, while all produce about 1.5 volts per cell, alkaline batteries have a higher energy density and longer shelf-life.

The capacity of an alkaline battery is strongly dependent on the load. An AA-sized alkaline battery might have an effective capacity of 3000 mAh at low power, but at a load of 1000 mA, which is common for digital cameras, the capacity could be as little as 700 mAh. The voltage of the battery declines steadily during use, so the total usable capacity depends on the cut-off voltage of the application.

The nominal voltage of an alkaline battery cell is 1.5 V. Multiple voltages may be achieved with series of cells. The effective zero-load voltage of a non discharged alkaline battery varies from 1.50 to 1.65 V. The average voltage under load depends on discharge and varies from 1.1 to 1.3 V. The fully discharged cell has a remaining voltage in the range of 0.8 to 1.0 V.

Activity Notes and Troubleshooting

- Encourage students to compare results with each other.
- This activity could be entirely "dry", i.e., textbook only, or you could expand upon the activity with examples and the use multimeters.

Additional Support

- ELL Pre-teach vocabulary by showing students a variety of sizes of batteries, for example, AAA, AA, A, C, D, lantern. Present them with simple oral challenges to encourage use of this vocabulary in context of familiar concepts. For example, have them complete the sentence: "At home, we use a _____ battery to run _______".)
- ELL Pair English language learners with students who have strong English communication skills, to support them as they take part in group discussion.

Answers

1. AAA, AA, A, C, and D batteries all have a nominal voltage of 1.5 V. Battery D (page 277) is a 9 V battery. Lantern batteries (battery A, page 277) have a nominal voltage of 6 V.
2. **a)** No, the size of the battery has nothing to do with the potential difference. The potential difference is dependent on the chemistry changes inside the cell. Since the size does not change the chemistry, the potential difference is unchanged by the size.

   b) The size, however will affect the battery life, because there are more chemicals inside the cell, so more reactions can occur.

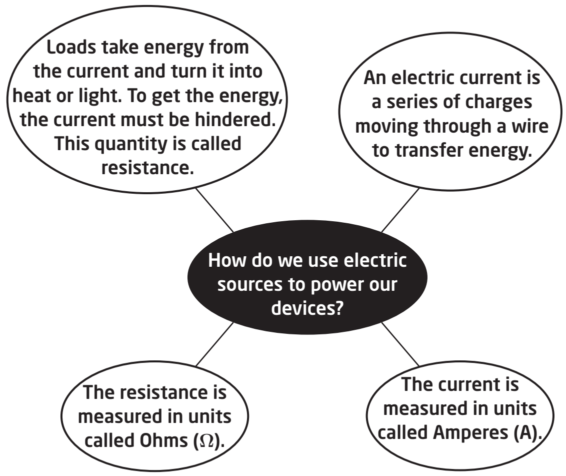
Learning Check Answers (Student textbook page 277)

1. An electrical source is a device that supplies electrical energy to operate any electrical equipment. Two examples could be a battery or an electrical outlet.
2. Potential difference (*V*) is the change in energy of a unit of charge after passing through a source or a load. A volt (V) is the SI unit that measures potential difference.
3. A battery uses chemical changes to separate charges.
4. The chemical changes are like the person in the diagram moving the electrons from one end to the other.

Learning Check Answers (Student textbook page 279)

1. You need an electrical cord or wire to connect the source to the load.

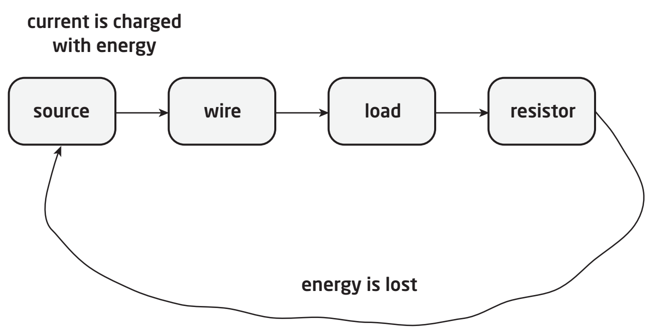
2. Answers may vary. For example:



3. The source for the electric stove is probably from an electrical outlet in the wall. By plugging in a cord, the current will be able to flow to the load, in this case, a stove. The current from the cord is probably transferred into the heating element, which is much thinner than the cord. Thus, the electrons will have more collisions in the smaller area generating a significant amount of heat.

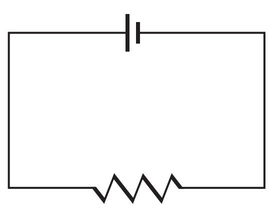
Learning Check Answers (Student textbook page 281)

1.



2. The switch controls the electric current. When the switch is closed, the circuit is completed and the current will flow. When the switch is open, the circuit is not complete, and the current cannot flow.

3.



Learning Check Answers (Student textbook page 283)

1. A voltmeter measure potential difference over a resistor or source and the ammeter measures the current at any point in the circuit. The voltmeter should be connected in parallel to the resistor or source so it does not affect the potential difference in the circuit and the ammeter should be connected in series to it does not affect the current at any point.
2. By increasing the potential difference and keeping the resistance constant, the charges will have more energy and will flow more easily. Thus, the current will increase.
3. If you increase the resistance and keep the potential difference constant, you are hindering the flow of the charges so there will be less current.

Using Making a Difference

Literacy Support

Before Reading

- Copy the two questions in the blue boxes onto the chalkboard: "Have you ever witnessed a problem that could be solved with the help of a simple electrical device?" and "What ideas about electrical applications could make a difference in your life and in the world around you?" Divide the class into small groups to discuss these questions. Have each group record their responses on a large sheet of paper. Then discuss them as a class. Invite members of each group to contribute some of their group's ideas to the class discussion.
- Ask students to skim the two sections for unfamiliar terms, and make a list of them. Tell them to look up the definitions of the words before reading the sections.

During Reading

- Ask students to use a three-column table to describe the purpose of each invention, state the electrical applications associated with the product, and make connections to what they have learned so far in the unit. For example, the cane was designed to signal the presence of an object in the person's path. It does so by lighting and sounding an alarm whenever it hits something. This suggests that a switch is closed to complete the circuit that lights or sounds the alarm.

After Reading

- Have students write a reflective piece on the advice given at the end of each section: "Good ideas never strike when you want them to" and "The key is to do something you are curious about". Do they agree or disagree with the advice? Remind them to provide evidence for their opinions.

Instructional Strategies

- This feature can help students realize how it is possible for someone their age to take a scientific concept learned in class and to apply it to make something useful to society and/or beneficial for the environment. Encourage students to write down three ideas with electrical applications that they would like to explore further.

Answers

1. Answers may vary. For example: By hooking up a treadmill or an exercise bike to a television set, it would be possible to provide the power needed to make the television work and to get some exercise at the same time.
2. Answers may vary. For example: Some auto companies are producing electric cars or looking for ways to produce more effective electric cars. If more people drove such cars, it would reduce the global dependence on gasoline.

Activity 4.11 Voltmeters and Ammeters In Circuits

(Student textbook page 285)

Pedagogical Purpose

Students will design and draw circuit diagrams to demonstrate knowledge and understanding of where to place an ammeter and voltmeter to safely and correctly measure current and voltage, respectively, in a simple series circuit.

Planning	
Time	30–40 min in class

Skills Focus

- select appropriate locations and instruments to measure current and voltage in simple circuits
- use appropriate graphic modes of representation

Background Knowledge

Ammeters measure current in electric circuits. As such, ammeters must be inserted into circuits where a reading is required. This necessitates the breaking of the circuit and insertion of the correct sign leads of the ammeter to match the polarity of the existing circuit. Voltmeters measure potential difference across a load in a circuit. As such, the voltmeter is connected to an existing circuit with each lead of the voltmeter matching the polarity of the individual component of the circuit.

Current is constant throughout a simple series circuit. No electrons are lost, so no current is lost. However, the amount of energy carried by electrons varies in a simple series circuit. Electrons at the source carry more energy than after passing through a load. At the load, electrons give off their energy in the form of light and heat. Electrons returning to the source carry no significant energy.

Activity Notes and Troubleshooting

- Students will find it easier to draw where the ammeter or voltmeter should be placed than to actually make the measurements. This is a good time to examine student misconceptions.
- Students may believe that the current will differ at different points in the circuit, because intuitively, they think that some of it is used up. This is definitely not the case; current remains constant throughout a simple series circuit.
- Encourage students to make neat drawings that can be referred to when actually constructing circuits.

Additional Support

- ELL Match English language learners with students who have strong communication skills to help them understand the written instructions.
- The key expectation is for students to draw the ammeter as part of the circuit and the voltmeter as connected to the existing circuit; use different colours for the voltmeter and ammeter to reinforce this distinction.

Answers

1. **a)** The ammeter will read zero because the circuit is open and no current can pass through an open circuit.
   b) The ammeter readings will be the same in step 2 because current remains constant throughout the circuit.
   c), d) The voltmeter will read a lower potential difference at each load than the potential difference across the battery because the potential difference across the battery is the total potential difference for the entire circuit, so each component must be less.

Investigation 4D Using Ammeters and Voltmeters

(Student textbook pages 286–287)

Pedagogical Purpose

Students will design and construct simple circuits to demonstrate knowledge and understanding of where to place an ammeter and voltmeter to safely and correctly measure current and voltage, respectively, in a simple series circuit.

Planning	
Materials	For each pair or group of students: - ammeter - voltmeter - power supply - switch - 2 identical light bulbs with bases - 7 wire leads with alligator clips **BLM G-20 Using Ammeters and Voltmeters** (optional) **BLM G-21 Reading an Analogue Meter** (optional) **BLM 4-19 Investigation 4D** (optional)
Time	50–60 min in class 15–20 min preparation
Safety	• Before a student turns on any circuit, check to make sure it is connected properly.

Skills Focus

- selecting appropriate instruments and materials
- conducting an inquiry using instruments and materials safely, accurately, and effectively
- draw conclusions based on inquiry results
- use appropriate numeric and symbolic modes of representation

Background

Ammeters measure current in electric circuits. As such, ammeters must be inserted into circuits where a reading is required. This necessitates the breaking of the circuit and insertion of the correct sign leads of the ammeter to match the polarity of the existing circuit. Ammeters can be damaged if improperly connected.

Voltmeters measure potential difference across a load in a circuit. As such, the voltmeter is connected to an existing circuit with each lead of the voltmeter matching the polarity of the individual component of the circuit. Voltmeters can be damaged if improperly connected.

Current is constant throughout a simple series circuit. No electrons are lost, so no current is lost. However, the amount of energy carried by electrons varies in a simple series circuit. Electrons at the source carry more energy than later in the circuit, that is, after the load.

Activity Notes and Troubleshooting

- Have students work in groups of four. Assign each student a role so everyone feels accountable. Each student could perform one of the tests for current or voltage.
- Students will have difficulty locating where the ammeter or voltmeter should be placed than to actually make these measurements. This is a good time to examine student misconceptions.
- Students will believe that the current will differ at different points in the circuit, because intuitively, they think that some of it is used up. This is definitely not the case; current remains constant throughout a simple series circuit.
- Encourage students to proceed with caution when connecting instruments to the circuit.

- Insist that students use the power supply at only 3.0 V; accept no alternatives.
- The circuit diagram on page 287 of the student text is an excellent depiction of how to connect the voltmeter.

Additional Support

- DI Logical-mathematical learners, spatial learners, interpersonal learners, and bodily-kinesthetic learners will be helpful to have in each group.
- ELL Pre-teach vocabulary: ammeter, voltmeter, load, alligator clips
- ELL Match English language learners with students who have strong English communication skills to help them understand the instructions.
- ELL Model the activity for English language learners, before asking them to complete it. List and show the materials to be used, and then demonstrate the process and the safety aspects of working with electricity.
- If students require additional support using ammeters and voltmeters, work through Science Toolkit 9: Using Electric Circuit Symbols and Meters on page 365 of the student textbook, or **BLM G-20 Using Ammeters and Voltmeters** and **BLM G-21 Reading an Analogue Meter** with them.
- Perform one reading with each meter as a demonstration before students begin the activity, to demonstrate reading the meter.
- For students experiencing difficulty setting up the circuit and the ammeter and voltmeter in the correct places, have them draw the circuit diagram first, labelling the wires and connection points.

Answers

1. The ammeter in Circuit A had a lower reading than the ammeter at Circuit B.
2. The voltmeter for Circuit C is not affected by the switch, so in Circuit C, the voltmeter reading will be the same potential difference as the potential difference across the source. For voltmeters D and E, since the switch is open, there is no current flowing through, so the voltmeter readings will read zero at D and E, but the voltmeter at C will remain the same having the same potential difference as the potential difference across the source.
3. Since Circuit C is unaffected by the switch, the voltmeter readings for Circuit C are the same whether the switch is open or closed. In circuit D, the voltmeter readings for C and D are the same, and they both equal the potential difference across the power source. In Circuit E, the voltmeter reading at C remains the same, but the voltmeter readings at D and E are both less than the potential difference at the power supply. The potential difference of any individual load is less than or equal to the potential difference across the source.

Investigation 4E Observing the Effects of Resistance on Current (Student textbook pages 288–289)

Pedagogical Purpose

Students will use an inquiry process to investigate the effects that changing resistance will have on current in a simple series circuit.

Planning	
Materials	For each pair or group of students: - power supply - ammeter - switch - 3 identical light bulbs with bases - 6 wire leads with alligator clips **BLM 4-20 Investigation 4E** (optional)
Time	50–60 min in class 15–20 min preparation
Safety	Before a student turns on any circuit, check to make sure it is connected properly.

Skills Focus

- selecting appropriate instruments and materials
- conducting an inquiry using instruments and materials safely, accurately, and effectively
- draw conclusions based on inquiry results
- use appropriate numeric and symbolic modes of representation

Background Knowledge

Ammeters measure current in electric circuits. As such, ammeters must be inserted into circuits where a reading is required. This necessitates the breaking of the circuit and insertion of the correct sign leads of the ammeter to match the polarity of the existing circuit. Ammeters can be damaged if improperly connected.

Current is constant throughout a simple series circuit. Despite differences in resistance at different locations in a circuit, no electrons are lost, so no current is lost. However, the amount of energy carried by electrons varies in a simple series circuit. Electrons at the source carry more energy than after passing through a load or a series of loads. At each load, electrons give off their energy in the form of light and heat in accordance with the amount of resistance encountered. If the resistance is greater, then more electrical energy is converted into heat or light. Since each bulb is identical in this circuit, each bulb should give off the same amount of light. However, with increasing resistance, the overall current in the circuit will decrease as resistance increases.

All energy is given off before electrons return to the source. If this were not true, and electrons returned to the battery or power supply with residual energy, then a battery or power supply could begin to charge itself. This would of course violate the Law of Conservation of Energy.

Activity Notes and Troubleshooting

- Have students work in groups of four. Assign each student a role so everyone feels accountable. Each student could perform one of the tests for current.
- Students may have more difficulty locating where the ammeter should be placed than actually making these measurements. This is a good time to examine student misconceptions.

- Some students will believe that the current will differ at different points in the circuit, because intuitively, they think that some of it is used up. This is definitely not the case; current remains constant throughout a simple series circuit.
- Encourage students to proceed with caution when connecting instruments to the circuit.
- Insist that students use the power supply at only 3.0 V; accept no arguments for doing otherwise.
- The circuit diagrams on pages 288 to 289 of the student text are an excellent depiction of how to connect the ammeter. Encourage students who are having difficulty placing the meter to examine them closely and match their circuit to the diagram step by step.

Additional Support

- DI Consider grouping students according to their dominant intelligences so that each group has two circuit builders and two writers who will record the group's observations and answers to the questions.
- ELL Pre-teach vocabulary by displaying, and allowing students to handle, an ammeter and alligator clips
- ELL Pair English language learners with students who have strong communication skills, to help them understand the written instructions.
- Use multiple entry points to engage student interest with questions such as "Was each light bulb equally bright?"

Answers

1. Adding more light bulbs increased the resistance in the circuit which decreased the current.
2. Since there was less current, fewer charges passed through each bulb so they became dimmer as we added more light bulbs.
3. When potential difference remains the same, increasing the resistance will decrease the current, and decreasing the resistance will increase the current.

Investigation 4F Potential Difference and Current

(Student textbook page 290)

Pedagogical Purpose

Students will use an inquiry process to investigate the effects that changing potential difference will have on current in a simple series circuit.

Planning	
Materials	power supply ammeter switch light bulb with base 4 wire leads with alligator clips **BLM G-25 Constructing a Line Graph** (optional) **BLM G-26 Interpreting Line Graphs** (optional) **BLM 4-21 Investigation 4F** (optional)
Time	50–60 min in class 15–20 min preparation
Safety	Before a student turns on any circuit, check to make sure it is connected properly.

Skills Focus

- selecting appropriate instruments and materials
- conducting inquiry using instruments and materials safely, accurately, and effectively
- draw conclusions based on inquiry results
- use appropriate numeric and symbolic modes of representation

Background Knowledge

In this activity, students hold resistance constant while varying the potential difference of the power source. The current through a wire between two points is directly proportional to the potential difference across the two points, and inversely proportional to the resistance between them. The mathematical equation that describes this relationship is: $V = IR$, where V is the potential difference measured *across* the resistance in units of volts; I is the current through the resistance in units of amperes and R is the resistance of the conductor in units of ohms. The law was named after the German physicist Georg Ohm, who, in a paper published in 1827, described measurements of applied voltage and current through simple electrical circuits containing various lengths of wire.

Activity Notes and Troubleshooting

- Have students work in groups of four. Assign each student a role so everyone feels accountable. Each student could perform a test for current at a given potential difference.
- Encourage students to proceed with caution when connecting instruments to the circuit.
- Insist that students use the power supply at only 1.5 V, 3.0 V, 4.5 V, and 6.0 V; accept no arguments for doing otherwise.
- The circuit diagram on page 290 of the student text is an excellent depiction of how to connect the ammeter. Encourage students who are having difficulty placing their meter to examine it closely and match it step by step.

Additional Support

- DI Consider grouping students according to their dominant intelligences so that each group has two circuit builders and two writers who will record the group's observations and answers to the questions.
- ELL Pre-teach vocabulary: ammeter, load, alligator clips
- ELL Match English language learners with students who have strong communication skills to help them understand written instructions. Consider re-organizing groups to have English language learners work with a variety of peers.
- Use multiple entry points and engage student interest with questions such as was the light bulb equally bright at each level of potential difference?
- The key expectation is for students to recognize that as potential difference increases, current increases if resistance is kept constant.

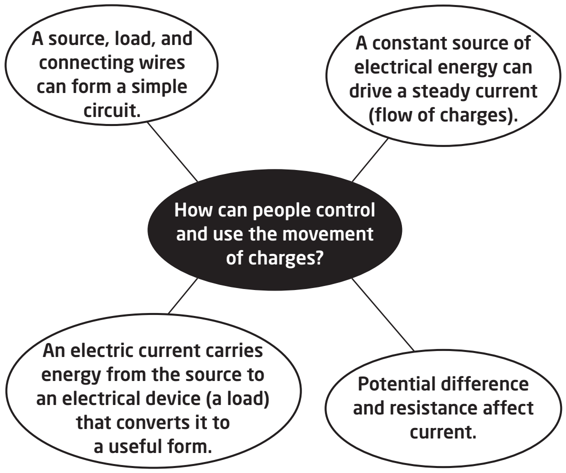
Answers

1. The current increased because increasing the potential difference gave each electric charge more energy, which helps it move through the wire easier, which makes more current.
2. It is a straight line sloping upward.
3. Increasing potential difference in a circuit with a constant load will increase the current in a constant proportion.

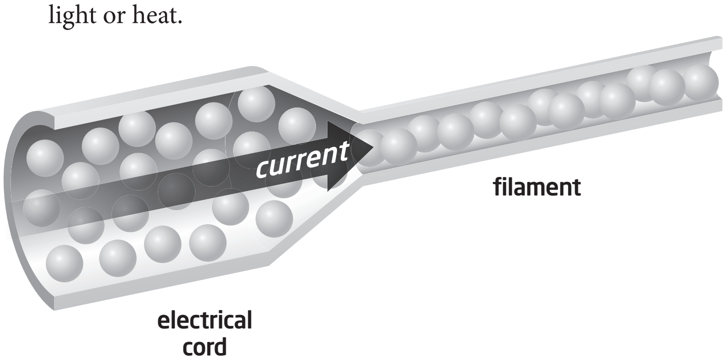
Topic 4.4 Review (Student textbook page 291)

Please also see **BLM 4-22 Topic 4.4 Review (Alternative Format)**.

Answers

1. 

2. A toaster needs to generate a lot of heat to toast bread. It gets the energy to produce the heat through a similar process of lighting a light bulb. The current passes through the wire, into the toaster, and into coils with higher resistance which generates heat. Because energy is used by the toaster, the toaster is considered a load.
3. Answers may vary. For example: The number of charges in a current that pass through a section of the wire at any given time is similar to the volume of water that passes by a section of the river at any given time.
4. Answers may vary. For example: As the current enters the load, there is an increase of resistance converting the energy from the electric charges into a usable form like light or heat.



5. When resistance is constant, increasing the potential difference will increase the current by a constant proportion. When the potential difference is constant, increasing the resistance will decrease the current, but the decrease in current diminishes as the resistance increases.