TOPIC 2 Electricity Within a Circuit

Figure 4.8 Electronic devices often contain hundreds of parts, connected in carefully designed circuits.

Have you ever looked inside a computer or television? Electronic devices, especially older ones, are a maze of mysterious parts connected by a tangle of different coloured wires. No matter how simple or complex, however, every electric **circuit** provides a continuous pathway for charges to move. In the next activity, you can experiment with a very simple circuit, and find out how the energy of moving charges can be harnessed.

Find Out ACTIVITY

Light That Bulb?

In past studies you may have experimented with wires, bulbs, switches, and cells in order to come up with an arrangement that will light the bulb. What requirements must the circuit meet? What role does each component play in a simple circuit?

Materials

2 D-cells (without holders)
4 copper wires (with alligator clips)
1 knife switch
1 3.7 V bulb (without holder)

Safety Precautions

Procedure ✷ Performing and Recording

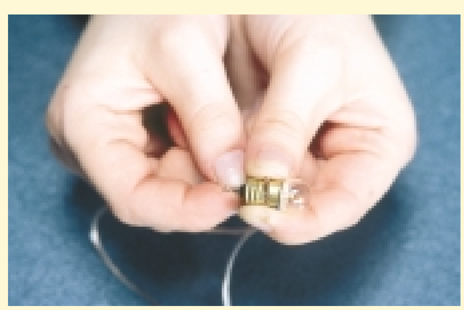
1. Arrange and connect all of the supplied components so the bulb lights. Draw a simple sketch that illustrates how you constructed your circuit.
2. Arrange all of the supplied materials in at least four additional different configurations that also allow the bulb to light. Make and sketch at least one circuit design with:
   (a) the switch at a different location.
   (b) the cells in a different location or alignment.
   (c) the bulb connected in a different manner.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Describe all of the requirements that a circuit must meet in order to light the bulb.
2. List at least three possible explanations for a situation in which the bulb did not glow.
3. Does electricity have to travel through the bulb in a particular direction in order for it to glow? Give evidence from this activity that supports your answer.
4. What role does the switch play in the circuit? How does it carry out this role?

Extension

Study the rules on the next page for drawing a proper circuit diagram. Using this information draw a diagram of a working circuit that includes two cells, two bulbs, and a switch that controls
(a) both bulbs.
(b) only one of the 2 bulbs



Circuit Elements and Diagrams

Even the most complex circuits are made up of only four basic elements, or types of components (Figure 4.9).

- *Source:* The source of electric energy.
- *Conductor:* The wire through which current flows.
- *Load:* Items along the circuit that convert electricity into other forms of energy (for example, light bulbs, motors, heaters, and speakers).
- *Control:* A switch or device that can turn the circuit or devices along it on or off.

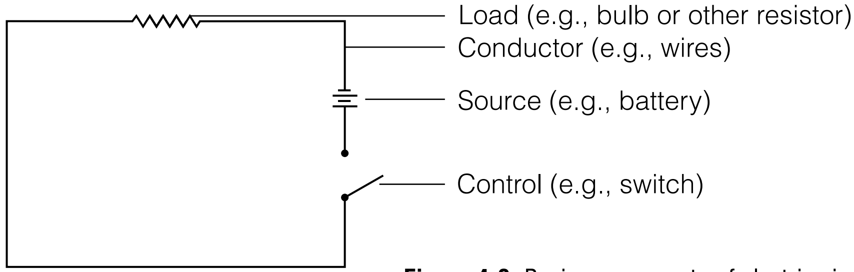


Figure 4.9 Basic components of electric circuits.

You have worked with three laboratory components of an electric circuit: a dry cell, a lamp or light bulb, and a conducting wire. Figure 4.10 shows the circuit symbols for these three components and for several other components.

The cell symbol stands for a single dry cell or a wet cell (you will study wet cells later in this unit). A **battery** is a combination of cells. You can use a **switch** to "open" or "close" a circuit to control the current through it. The **resistor** symbol is used to represent one of many different **loads**. One load is used so much in laboratory work that it has its own symbol: the lamp. Circuit diagrams are drawn in a standard way designed to make them simple and easy to prepare and read. Your circuit diagrams should meet the following criteria.

- Draw with a pencil and ruler on graph paper or unlined pages.
- Place components in a rectangular or square arrangement.
- Make conductors straight lines with right-angled ("square") corners.
- If possible, arrange your diagram so conductors do not cross.
- Draw neatly, making symbols a consistent size.

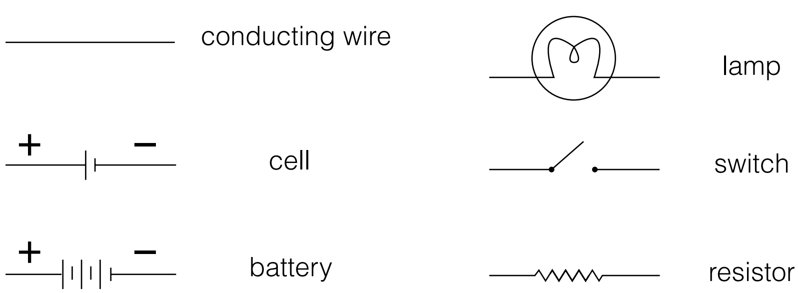


Figure 4.10 Circuit symbols are similar to words; they make communication quick and accurate.

Pause& Reflect

Make a table in your Science Log to record the symbols and names of circuit components. Record the symbols in Figure 4.9. Leave room to add to your list as you learn more symbols in your study of electric circuits.

Word CONNECT

The term "battery" describes two or more cells connected together. D, C, AA, and AAA "batteries" are more accurately called cells. Car batteries, large 6 V flashlight batteries, and small rectangular 9 V batteries are all correctly labelled as batteries since they contain more than one cell.

Pause& Reflect

Start a table in your Science Log for symbols and units, like the one shown in Table 4.2. Each time you encounter a new unit, add it to your table.

Measuring Current

Imagine a fast-flowing river. If you were to describe the current you might state the number of litres of water that flow past a certain point every minute. Similarly, scientists describe electric current as the amount of charge that passes a point in a conducting wire every second. The symbol for current is *I*. Electric current is measured in **amperes** (A) or milliamperes (mA) (see Table 4.2). Currents in common electric devices range from a few milliamperes to dozens of amperes (see Table 4.3).

Table 4.2 Symbols and Units for Current

Quantity	Symbol	Unit
Current	*I*	ampere (A) milliampere (mA)
Time	*t*	second (s)

Table 4.3 Current in Household Appliances

Appliance	Current (A)
radio	0.4
100 W lamp	0.8
colour television	1.7
toaster	8.8
microwave oven	11.7
electric kettle	12.5
electric range	40

DidYouKnow?

The galvanometer is named after Luigi Galvani (1737–1798), an Italian scientist who first recorded the presence of electric current. A galvanometer can accurately measure both the direction and strength of an electric current. The first galvanometers were based on a discovery made by Hans Oersted in 1819. He observed that a magnetic compass needle rotated slightly when electric current flowed in a nearby wire.

An instrument used to measure very weak electric current is called a **galvanometer**. Larger currents are measured with an **ammeter** or milliammeter. Figure 4.11 shows typical laboratory models of these instruments. The symbols for these instruments are a circle with "G," "A," or "mA" in the centre, respectively. You will use current and ammeters in the next investigation.

Skill FOCUS

For more information about using ammeters and voltmeters, turn to Skill Focus 14.

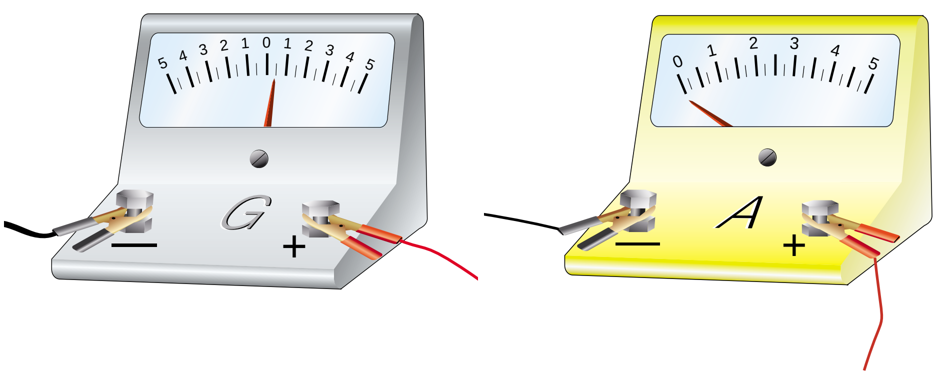


Figure 4.11 A galvanometer (left) and ammeter (right) both measure electric current.

Measuring Voltage

Energy for pushing electrons is available if positive and negative charges are separated. A battery, for example, forces electrons to accumulate at one terminal (connection), making it negatively charged. At the same time, electrons withdraw from the other terminal, leaving it positively charged. In a battery, energy from chemical reactions does the work of separating the charges (see Figure 4.12). The energized electrons now have the ability to do work on something else, such as lighting a bulb or heating a burner on a stove.

All forms of energy are measured in joules (J). However, when describing the energy of electrons in an electric circuit, we describe the energy possessed by a standard unit of charge instead of the total energy of all of the charges. As well, we always compare one point in a circuit to another. The term **potential difference** means the difference in energy per unit of charge between one point in the circuit and another point in the circuit. Potential difference is commonly referred to as **voltage**.

The standard unit for potential difference is the **volt** (V), named after Alessandro Volta (1745-1827), who built the first battery. Most electrical devices require potential differences of 1 to 120 V, but higher voltages are not uncommon (see Table 4.5). Voltage is measured with a **voltmeter**, such as the one shown in Figure 4.13. In circuit diagrams, the symbol for a voltmeter is a circle with "V" at the centre.

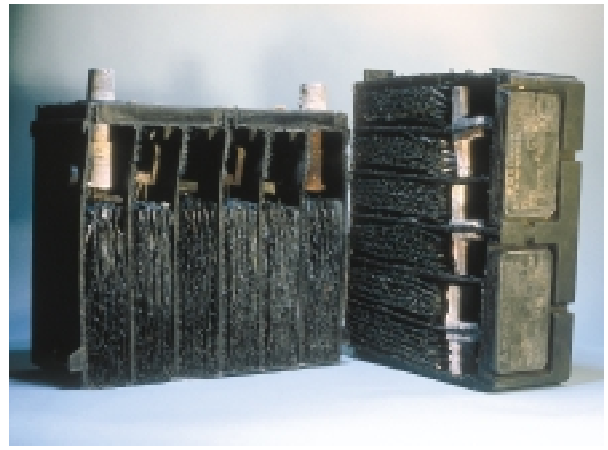


Figure 4.12 Chemical reactions inside the six cells of this car battery separate electrical charges, increasing their energy.

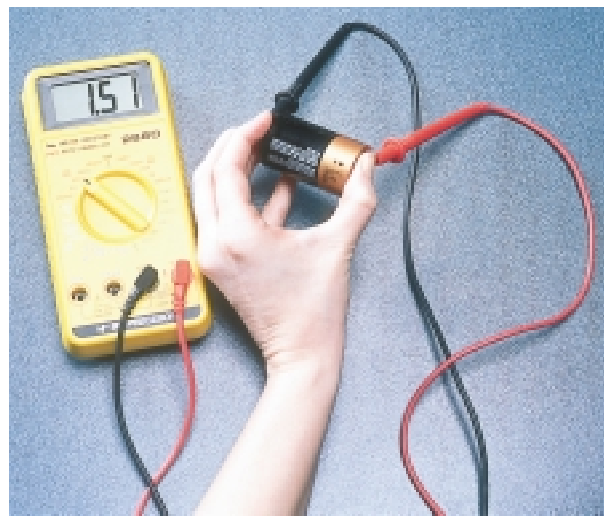


Figure 4.13 This digital multimeter can measure voltage, current, and other characteristics of electric circuits.

Table 4.4 Symbols and Units for Potential Difference

Quantity	Symbol	Unit
potential difference (voltage)	*V*	volt (V)
energy	*E*	joule (J)

Table 4.5 Voltage in Household Appliances

Energy Source	Voltage (V)
"AA"cell	1.5
household wall plug	120
electric stove wiring	240
television high-voltage supply	200 000

Pause& Reflect

Add the symbols and units for energy and potential difference (voltage) to the table in your Science Log.

INQUIRY

INVESTIGATION 4-A

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Current and Voltage

In this investigation you will construct a simple circuit and then use an ammeter and voltmeter to find out how the electric current and voltage (potential difference) vary at or across different points within the circuit.

Apparatus
ammeter
voltmeter
knife switch
2 D-cells in battery holder
2.5 V bulbs (2) in sockets
3.7 V bulb (1)
4 copper wires with alligator clips

Safety Precautions

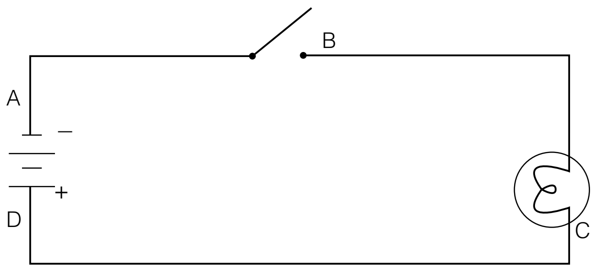
Part A: Measuring Current

Question

Does the electric current flowing through a circuit vary at different points within the circuit?

Prediction

Examine the diagram below and predict whether the electric current at points B, C, and D will be higher, lower, or equal to the current at point A.



Procedure

1. Using the 3.7 V bulb, construct the circuit illustrated.
2. Plan how to place your ammeter into the circuit. You must force all the current to flow through the ammeter to get to the rest of the circuit. The positive terminal of the ammeter must lead to the positive end of the battery.
3. Measure the current at point A with the switch open, and again with the switch closed. **Record** the ammeter readings in a copy of the current observations table.
4. Repeat step 3 at the points labeled **B**, **C**, and **D** on the circuit diagram.

Current Observations

Ammeter location	Electric current (mA)	
	Switch open	Switch closed
A		
B		
C		
D		

Analyze

1. Compare the electric current flowing out of the battery and into the battery (points A and D). Suggest an explanation for your observation.
2. Compare the current on either side of the bulb (points B and C).
3. What effect did opening and closing the switch have on the current?

Conclude and Apply

4. For an electric current to flow in a circuit, what conditions must exist?
5. Hypothesize about factors that affect the strength of an electric current in a circuit. If time permits (and with your teacher's permission), test your hypothesis.

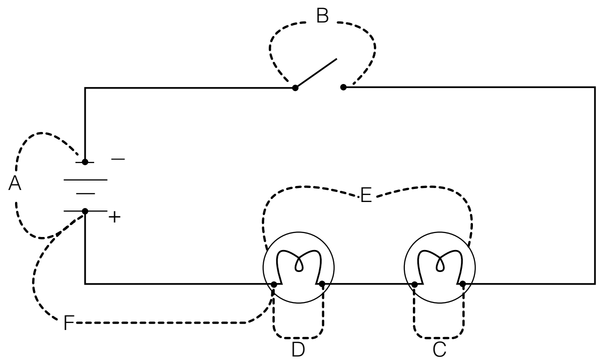
Part B: Measuring Voltage

Question

How does the voltage (potential difference) across different components within a circuit compare?

Prediction

Examine the diagram below and predict whether the potential difference (voltage) across points **B**, **C**, **D**, **E** and **F** will be higher, lower, or the same as the voltage across point **A**.



Procedure

1. Using the 2.5 V bulbs, construct the circuit illustrated.
2. Use the diagram to plan how to connect your voltmeter to the circuit. One lead from the voltmeter must be connected to each side of a circuit component. The positive terminal of the voltmeter must lead to the positive end of the battery.
3. Measure the potential difference (voltage) across point A when the switch is closed, and **record** the voltmeter reading in a copy of the voltage observations table.
4. Repeat steps 2 and 3 at the points labeled **B** , **C**, **D**, **E** and **F** on the circuit diagram.
5. Replace the 2.5 V bulb at point D with a 3.7 V bulb and measure the voltage at point D. Compare the brightness of the 3.7 V bulb with the original 2.5 V bulb.
6. Remove both bulbs and measure the voltage at point E.

Voltage Observations

Location of Voltmeter	Voltage(V)
A	
B	
C	
D	
E	
F	
D (with 3.7 V bulb)	
E (bulbs unscrewed)	

Analyze

1. Which parts of your circuit
   (a) provide electrical energy
   (b) use electrical energy?
2. Compare the potential difference (voltage) across the battery (A) to the voltage across the load (E).
3. How does the energy provided to the circuit compare to the energy used?
4. How does the potential difference across an individual bulb (C or D) compare to the voltage across the entire load (E)?

Conclude and Apply

5. How did the brightness of the 2.5 and 3.7 volt bulbs compare? Use your voltmeter readings to suggest an explanation for this difference.
6. How did the potential difference across point E change when the bulbs were removed? Suggest why.

Rivers of Electricity

Electric circuits are often compared to water systems. Electric charge flows through the parts of the circuit, just as water flows through pipes or along a river channel. The energy of the moving charge is changed to different forms as current passes through the load, just as the energy of moving water can be harnessed as it flows downhill. Study Figure 4.14 and identify the following points in each diagram:

(a) highest energy
(b) lowest energy
(c) control
(d) load

DidYouKnow?

An arrow labelled with the symbol e^- is often used to indicate the direction of electrical charge movement in a circuit. In solid conductors, the moving charges are electrons.

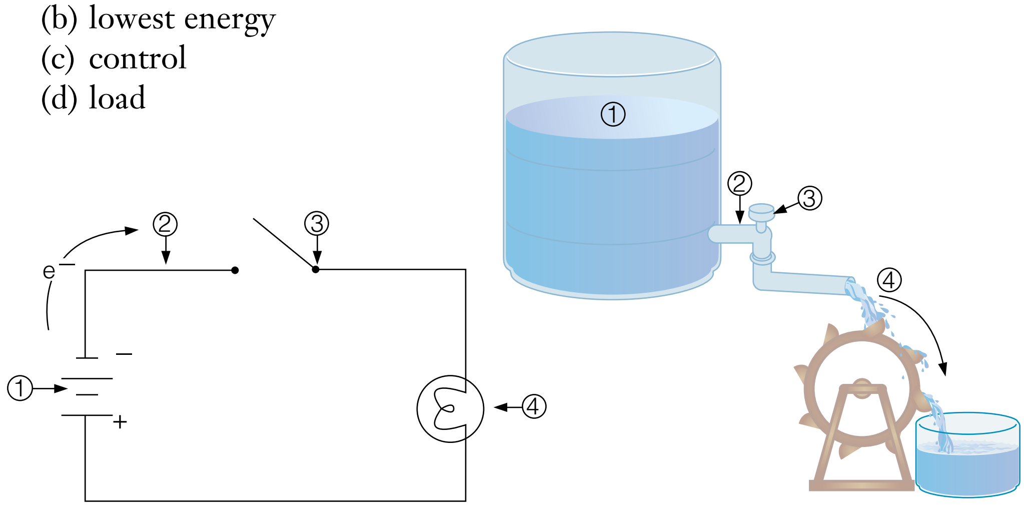


Figure 4.14 An electric circuit is similar in many ways to a water system.

TOPIC 2 Review

1. Copy the electric terms listed below into your notebook. Write the water (hydraulic) related term from the column of terms on the right that best typifies each electric term next to it. For each pair of terms, describe why you think they are similar.

(a) load	**(1)** pump
(b) switch	**(2)** pressure
(c) electric current	**(3)** pipe
(d) voltage	**(4)** water wheel
(e) battery	**(5)** valve
(f) conductor (wire)	**(6)** flow rate

2. Draw a circuit diagram using symbols. Include a battery, a switch, a lamp, an ammeter, and conducting wires. Add arrows to show the direction of the flow of electrons. Describe the function of each part of the circuit.

3. Explain how to connect a voltmeter to a circuit to measure the voltage across a light bulb. Use a sketch to clarify your explanation.

4. **Apply** Predict which current will be greater, the current passing through an electric iron or the current passing through an electric razor, when each is plugged into a 120 V outlet. Explain how you made your prediction.

5. **Thinking Critically** If a circuit contains a 12 V battery, a switch, and a light bulb, what is the voltage across the light bulb?