TOPIC 3.3

How do charges flow through the components of a circuit?

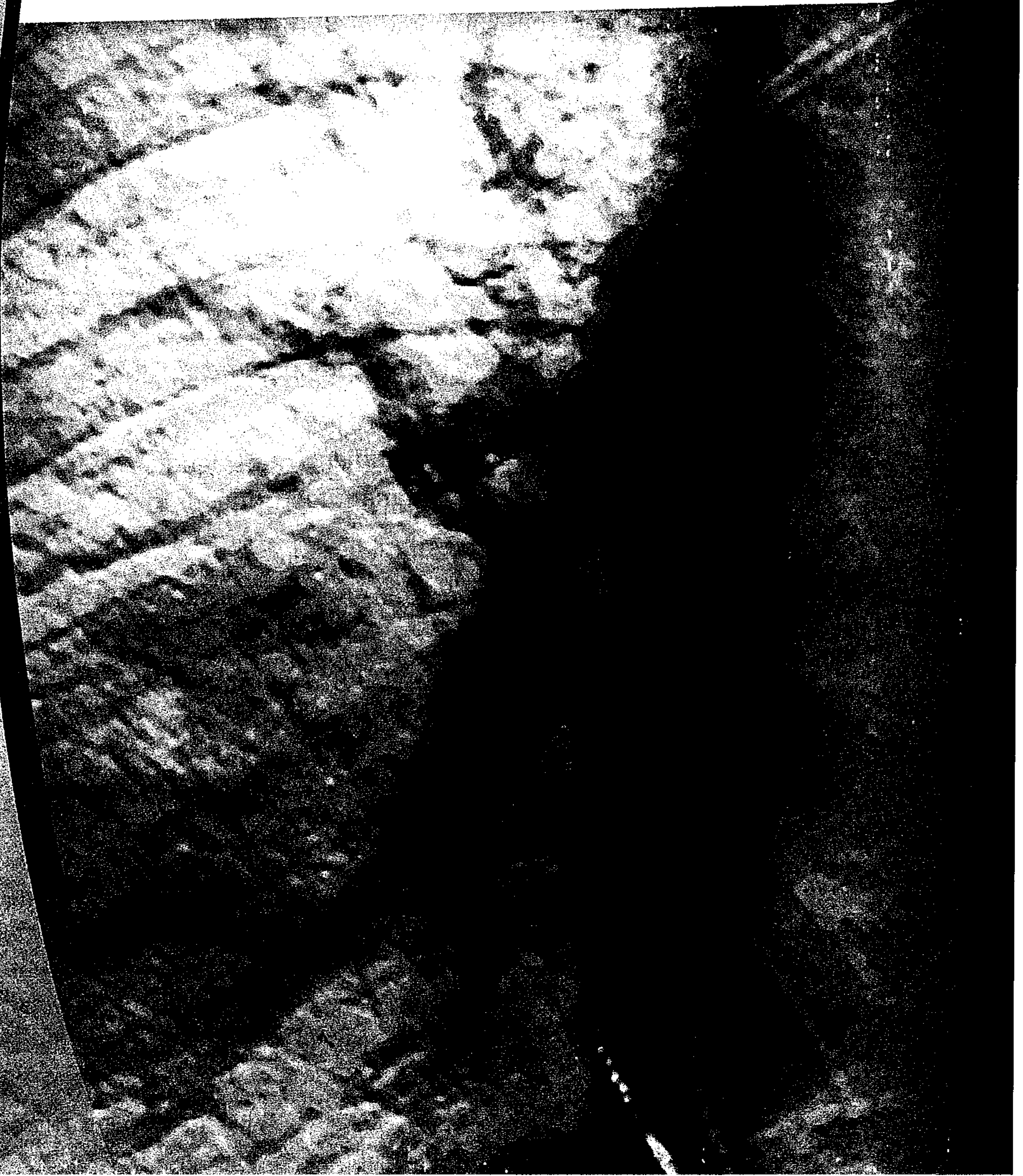
Key Concepts

- Chemical energy separates electrical charges in cells.
- Charges can flow through conductors, but not insulators.
- Moving electrical charges form an electric current.
- A load resists the flow of current.
- Conductors must form a closed loop to allow current to flow.

Curricular Competencies

- Collaboratively and personally plan, select, and use appropriate investigation methods to collect reliable data.
- Select and use appropriate equipment to systematically and accurately collect and record data.
- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.

In 1950, Canadian Drs. Wilfred Bigelow and John Callaghan first used an external electrical device, developed by Dr. John Hopps, to pace the beating of a dog's heart. The device was the first pacemaker. Modern technology has brought the pacemaker a long way since those days. Pacemakers are used to help people with irregular heartbeats. As well, they are small enough to be surgically inserted under the skin on the chest. The electrical energy to run a pacemaker comes from a battery that lasts 10 years or longer. Electrical charges flow through the tiny electrical device, completing an electrical pathway called a circuit within the human body.



3.3 Grade 9

CONCEPT 1

Chemical energy separates electrical charges in cells.

Activity

Battle of the Batteries

Although most people buy batteries at the store, it is actually possible to make your own. Find out how online. Check your design with your teacher before building the battery. Then enter a class "battle of the batteries" to see who can get their battery to run a device your teacher specifies.

Connect to Investigation 3-C on page 228

An AA "battery" is an *electrochemical cell*. In a cell, chemical reactions of two different metals or metal compounds occur on the surface of *electrodes*. The electrodes are in a solution called an *electrolyte*. The reactions cause one electrode to become positively charged, and the other to become negatively charged. The electrodes are in contact with *terminals* in the cell. When terminals are connected to an electrical pathway, charges flow through it. **Figure 3.13** shows two types of cells. A *dry cell* contains a moist paste as an electrolyte. In a *wet cell*, the electrodes sit in a liquid solution. Both transform chemical energy into electrical energy to run portable devices.

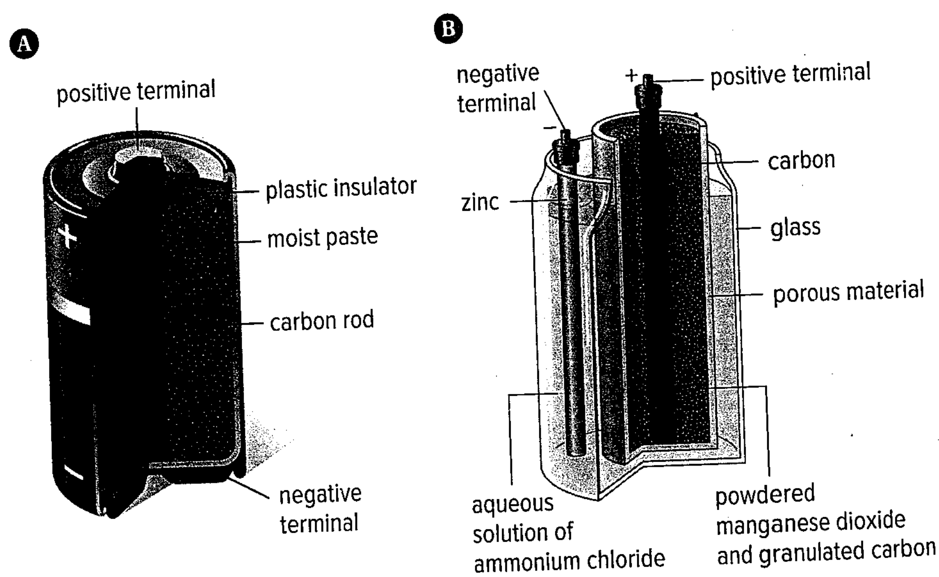


Figure 3.13 A dry cell **A** and a wet cell **B**.

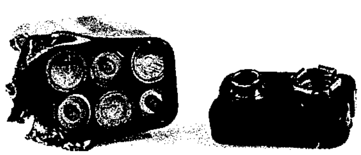


Figure 3.14 The battery shown here is made up of six individual cells.

source anything that supplies electrical energy

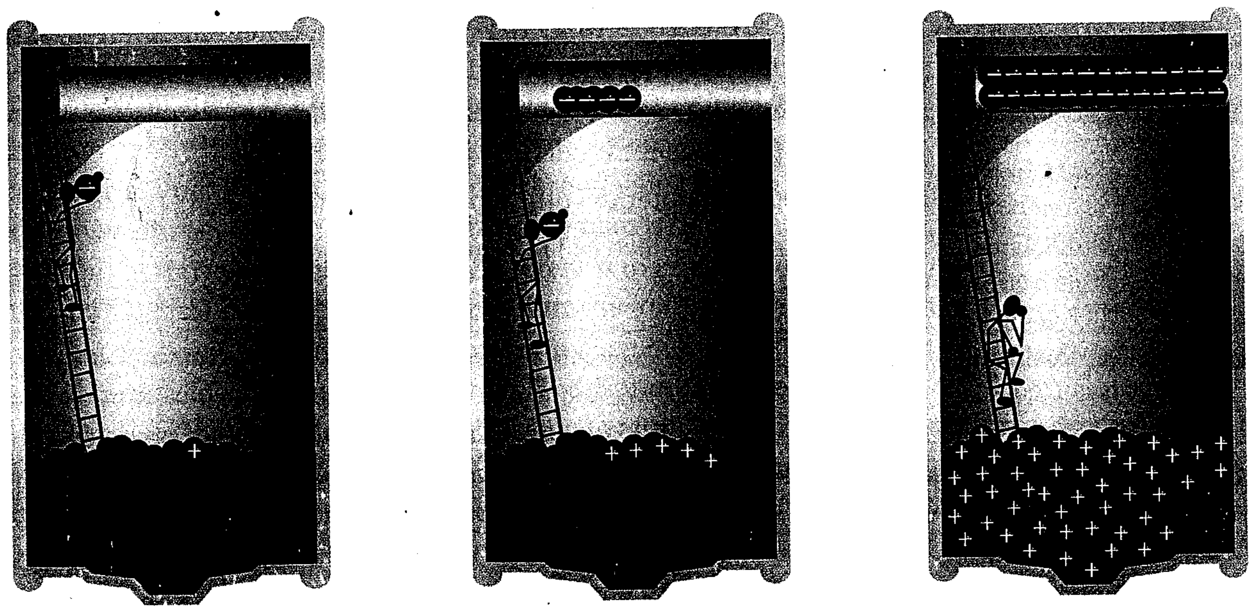
In comparison, a *battery* is a connection of two or more cells. You make a battery when you place AA cells together in an electrical device. Often, several cells are packaged together in a casing to make a battery (**Figure 3.14**). Cells and batteries are sources. A **source** is anything that supplies electrical energy. Electrical outlets are also sources.

Understanding How a Cell Works

Because opposite charges attract each other, it takes energy to separate positive and negative charges. The previous Topic explained how friction can provide this energy. In a cell, chemical reactions separate the positive and negative charges. In other words, chemical energy does the work of separating the charges. (Energy is the ability to do work. Work is done on an object when a force acts on it and makes it move through some distance.) Because work went into separating the charges, the electrons now have the energy to do other work, such as running a fan or a watch. The electrical energy now stored in the cell is a form of potential energy. It has the potential to do work because of the separation or position of the charges.

Figure 3.15 shows a model that explains how charges are separated and gain electrical potential energy as a cell becomes charged. A worker represents chemical energy released in chemical reactions.

Figure 3.15 The worker in this model represents chemical energy.



The worker carries electrons up a ladder and places them at the negative terminal. The worker leaves positively charged ions on the bottom at the positive terminal. The first electron is easy to carry up the ladder because only one pair of charges is being separated. The attraction is not very strong. Only a small amount of electrical energy is stored in the cell.

After a few charges have been separated, all of the positive charges of the positively charged ions at the positive terminal are attracting the negative charge of the electron that the worker is carrying. As well, the negative charges of the electrons at the negative terminal are repelling the negative charge of the electron that the worker is carrying. So it takes more energy to carry each additional electron up the ladder. The worker (chemical energy) has done a lot of work to separate the charges. This energy is now stored in the electrical potential energy of the separated charges.

Eventually, the repulsion of the electron by the negative charges and the attraction by the positive charges gets so strong that the worker cannot carry any more electrons up the ladder. No more chemical energy will be transformed into electrical energy.

Electrical Potential Difference

A unit of charge, called a *coulomb*, gains electrical potential energy when it passes through a source, such as a battery. The quantity that provides a measure of the electrical potential energy that is gained by a unit of charge is called the **electrical potential difference**. It is called a difference because it measures the difference in electrical potential energy per unit of charge between the positive terminal and the negative terminal in a cell. Think of **Figure 3.15**. To charge a cell, a chemical reaction does work to separate electrons and positive ions. It takes more energy to carry each electron up the ladder. This is because the forces of attraction and repulsion acting on it get stronger and stronger. Separating the final charge requires the most energy of all. The electrical potential difference of the cell represents the amount of energy it took to carry the last unit of charge up the ladder.

electrical potential difference a quantity that provides a measure of the electrical potential energy a unit of charge gains when passing through a source

The electrical potential difference of a cell is determined by the nature of the chemical reaction that takes place in the cell. Cells and batteries are rated according to their electrical potential difference between one terminal and the other. Other sources, like electrical outlets, are rated in a similar manner. The symbol and units for electrical potential difference are given below.

- The electrical potential difference is measured in volts (V).
- The symbol for electrical potential difference is *V*.

Because of its symbol and units, electrical potential difference is often called the voltage. For this reason the term *voltage* is frequently used on cells and batteries (**Figure 3.16**). In the 1.5 V cell shown in the figure, it took 1.5 units of energy to carry that last unit of charge up the ladder. Note that if two cells are linked together, as in a flashlight or radio, their voltages add up. For example, if two 1.5 V cells are placed in a radio, their voltage is 3 V. Similarly, if six cells are packaged together, they form a 9 V battery.

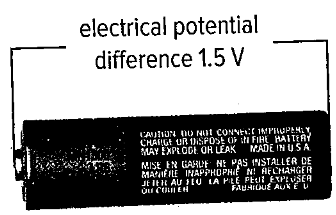


Figure 3.16 A typical AA or AAA cell provides an electrical potential difference of 1.5 V.

Before you leave this page . . .

1. Use an analogy other than a worker and a ladder to explain how chemical energy is transformed into electrical energy in a cell.
2. Why is the electrical potential difference of a source referred to as a difference?