11.5 Electric Current

The movement of electrons (an electric current) is required for an electrical device to operate. Electric current is responsible for the transfer of electrical energy along a conducting wire. Your computer, refrigerator, stove, and battery charger simply would not work without moving electrons in conducting wires.

Direct Current

direct current (DC) the movement of electrons in only one direction

Direct current (DC) is the flow of electrons in only one direction through a circuit. The electrons flow from the negative terminal of the source of electrical energy and travel through the conducting wires toward the positive terminal.

The outer electrons in the atoms of a metal conductor are not tightly held to their nuclei; rather, they move around randomly and are considered "free electrons." When a source of electrical energy (for example, a battery) is supplied to a circuit, free electrons will move in one direction through the conductor (**Figure 1**). This movement of the free electrons is the direct current. The more free electrons that are moving in one direction, the greater is the direct current.

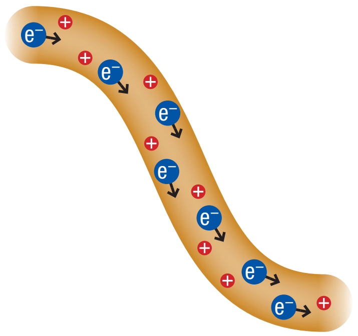

Figure 1 Direct current showing the electrons moving in one direction only. The positive charges represent the nuclei of the atoms and do not move.

The first sources of electrical energy were similar in design to batteries and all produced a direct current. In 1820, French physicist André-Marie Ampère performed experiments on direct currents in wires. He was interested in measuring the *intensity* of the current, which is why today we use the symbol *I* to represent electric current. In recognition of his contributions to the understanding of electric current, the unit of measurement for electric current is called the ampere (A). The equation that describes the amount of electric current is

$$I = \frac{Q}{\Delta t}$$

where I = current (A), Q = amount of charge (C), and Δt = time interval (s). One coulomb of charge (or electrons) passing one point every second in a circuit is equivalent to one ampere. Therefore, 1 A = 1 C/s. In illustrations of current, we often depict only a few electrons. However, a coulomb of electrons is 6.2×10^{18} electrons. So a current of 1 A means over 6 billion billion electrons moving past a point each second.

Tutorial 1 Using the Current Equation

When you are given the amount of charge and the change in time, you can use the equation $I = \frac{Q}{\Delta t}$ to find the amount of current. We will apply the current equation in the following Sample Problem.

Sample Problem 1

Calculate the amount of current through a wire that has 0.85 C of electrons passing a point in 2.5 min.

Given: $Q = 0.85$ C; $\Delta t = 2.5$ min

Required: I

Analysis: $I = \frac{Q}{\Delta t}$

Solution: Convert time to seconds to get the answer in coulombs per second, or amperes:

$$\Delta t = 2.5\ \cancel{\text{min}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}}$$

$$\Delta t = 150\ \text{s}$$

$$I = \frac{Q}{\Delta t}$$

$$= \frac{0.85\ \text{C}}{150\ \text{s}}$$

$$I = 0.0057\ \text{A}$$

Statement: The current is 0.0057 A.

Practice

1. What is the current travelling through a cellphone charger when 0.20 mC of electrons pass a point in 0.75 min? Answer in amperes and microamperes (μA). T/I [ans: 4.4×10^{-6} A; 4.4 μA]
2. How many electrons, measured in coulombs, result from a current of 15 A for 24 h? T/I [ans: 1.3×10^{6} C]

Effects of Current on Your Body

The nerve cells in your body communicate with each other by creating very small electric currents. If a larger current is transmitted through your body it can overload your nervous system. By touching a wire with a current flowing through it, you can affect the current in your body (**Table 1**). Muscles will contract and you may not be able to let go of the wire. The electric current will also cause burns, because some of the electrical energy will be transformed into thermal energy. An electric shock can burn tissue deep inside the body, not just on the surface.

Table 1 Effects of Current on Your Body

Direct current (A)	Sensation
0.0008	slight tingling
0.051	painful but can still control muscles
0.064	painful but can let go of wires
0.075	severe pain with difficulty breathing
0.50	possible heart fibrillation

Measuring Electric Current

An **ammeter** is a device that measures electric current. An electrician uses an ammeter to determine the current in a home circuit. Too much current can be dangerous because moving electrons cause wires to heat up. Ammeters must be connected in series in a circuit (**Figure 2**), so that all the electrons flowing through the wire also have to flow through the ammeter, giving an accurate reading of the current. If the ammeter were connected in parallel, there would be more than one path for the current to flow along: one path would be into the circuit while the other path would be through the ammeter. You would not be sure how much of the current went through the path. The symbol for an ammeter is —(A)— .

ammeter electrical device that measures electric current; must be connected to the circuit in series

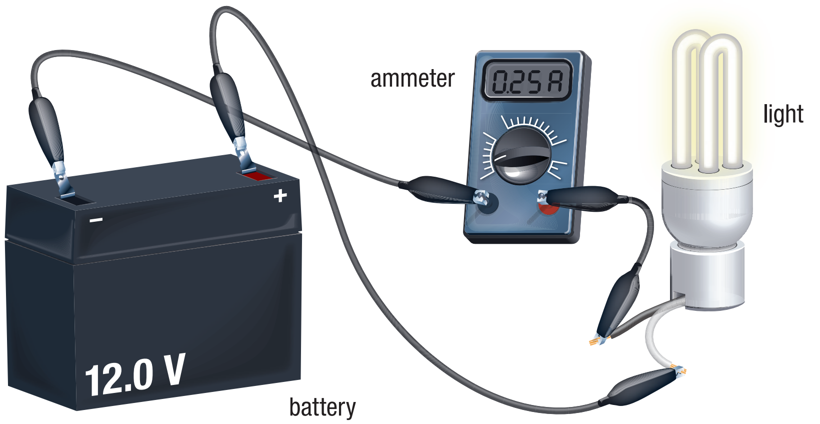

Figure 2 An ammeter is connected in series to measure electric current.

Mini Investigation

How Much Current Can a Lemon Produce?

Skills: Performing, Observing, Analyzing

SKILLS HANDBOOK A3.2

A lemon cell is a source of electrical energy. Other fruits, vegetables, and juices will also work. The foods just need to contain an acid, which acts as an electrolyte or conducting solution. You also need two electrodes (conductors) made from two different materials. When you connect the lemon cell to an ammeter, you will be able to measure the current that is produced. Alternatively, you could use a galvanometer, which is essentially a more sensitive ammeter.

Equipment and Materials: zinc strip; copper strip; ammeter with a milliamp scale; 6 or more alligator clip leads; LED; lemons

1. Construct a lemon cell by inserting a zinc electrode strip and a copper electrode strip into the lemon. Connect the negative terminal of an ammeter (set to the milliamp scale) to the zinc strip using an alligator clip lead. Then connect the positive terminal to the copper strip (**Figure 3**).
2. Read the scale on the ammeter and record your measurement. Now connect a load to the lemon cell. The load can be an LED, for example.

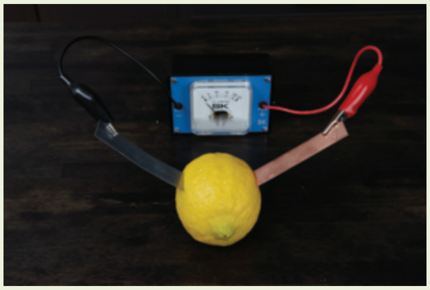

Figure 3

3. Read the scale from the ammeter with the load connected, and record your measurement.
4. Try connecting more lemon cells in series and record the effect on the load and the reading on your ammeter.

A. What is the difference in current measurements between Steps 2 and 3? T/I

B. What is the effect of connecting more lemon cells in series on the current and the brightness of the LED? T/I

11.5 Summary

- Direct current is the flow of electrons in one direction only.
- The symbol for current is I and current is measured in units of amperes (A).
- The equation that describes current is $I = \frac{Q}{\Delta t}$.
- An ammeter is used to measure current in a circuit and must be connected in series. An ammeter has the circuit symbol —(A)— .

11.5 Questions

1. What is direct current? In which direction does current go according to the electron flow convention? K/U
2. What is the current if 2.5 C of charge (electrons) passes a point in a circuit in 4.6 s? T/I C
3. Calculate the amount of charge travelling through a car battery when a current of 800.0 A is produced for 1.2 min. T/I
4. For how long can a battery produce a current of 250 mA if 1.7×10^2 C of charge passes through it? Answer in seconds and minutes. T/I
5. LED lights require less power than incandescent lights. Calculate the time required for 150 µC of charge (electrons) to pass through an LED light if the current is 0.21 mA. T/I
6. Batteries have a rating system that includes the current and the time. A rechargeable AA battery might have a rating of 2650 mAh. That is, the battery can produce a current of 2650 mA for 1 h before it is depleted. For how long could it produce a current of 883 mA? T/I
7. A student connects an ammeter in parallel and notices that the reading is a very large number. Provide a possible explanation for the high reading. K/U C
8. Is it possible to produce an electric current in a material that does not have any free electrons? Explain your answer. K/U
9. Refer to Table 1 on page 517. Electricians routinely work on household circuits that have current ratings of 15 A or more. Why do you suppose they turn off the power before working on the circuit? K/U