13.5 Potential Difference

potential difference (voltage) (*V*)
the difference in electric potential energy per unit charge measured at two different points; measured in volts (V)

In Section 13.3, you learned that electricians, technicians, and engineers measure current when designing and troubleshooting circuits. They also measure another quantity called potential difference. **Potential difference**, or **voltage**, is defined as the difference in electric potential energy per unit of charge measured at two points. The electric potential energy per unit charge is often abbreviated to just "electric potential." The unit for voltage is the volt (V).

LEARNING TIP

Volts and Voltage
In science, we use an italic *V* to represent potential difference, or voltage, to avoid confusing it with the symbol for volt (V).

Figure 1 A battery connected to a motor

A Model for Electric Potential Energy

Figure 1 shows a simple circuit in which a motor is connected to an electric cell. Stored electrical energy in the cell causes the shaft of the motor to spin. Let's use an analogy to help visualize what's happening inside this circuit.

For centuries people have used the energy of falling water to push waterwheels. This is possible because water above the wheel has more gravitational potential energy than it does below the wheel. As water falls, some of this energy is used to spin the waterwheel. To keep the wheel spinning you need a steady supply of falling water such as a fast-flowing stream. If this is not available, a pump can be used to push water up to its original position. As water is pumped to its original position, its gravitational potential energy also increases to its original amount (Figure 2(a)).

Similarly, there is a potential difference between the two terminals of an electric cell. Electrons leave the negative terminal with electric potential energy that can be used to operate a motor. As a result, the electrons return to the positive terminal of the cell with less electric potential energy than they started with, because some of their energy was used to run the motor (Figure 2(b)). Once inside the cell, chemical reactions "re-energize" the electrons and send them out the negative terminal again. In this way, the electric cell acts like the pump in Figure 2(a).

DID YOU KNOW?

Measuring the Voltage of Batteries
When you check if a battery is still good, you need to check the voltage drop across the two terminals. To measure the voltage, connect the positive lead of a voltmeter to the positive electrode of the battery. The positive electrode is usually marked with a + sign. Then connect the negative lead of the voltmeter to the negative electrode of the battery.

If you measure a voltage less than the rated voltage for the battery, it means that the battery is weak. If you measure 0 V, the battery is dead. Recall that a voltage of zero means that no current will flow.

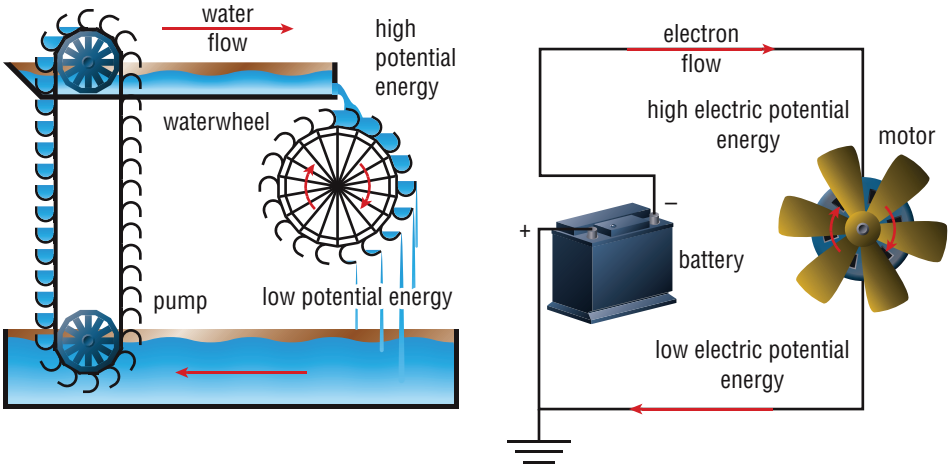

Figure 2 (a) A pump provides potential energy to the water, which can then turn a waterwheel. (b) A potential difference is necessary for current to flow in a circuit. Within the battery, the electrons flow from the negative electrode (higher electric potential energy) to the positive electrode (lower electric potential energy).

Measuring Potential Difference

When an electrician, technician, or engineer troubleshoots a circuit, the voltage as well as the current at different parts of the circuit must be measured. A **voltmeter** is the device designed to measure potential difference (Figure 3(a)). The circuit diagram symbol for a voltmeter is shown in Figure 3(b).

voltmeter a device used to measure potential difference (voltage)

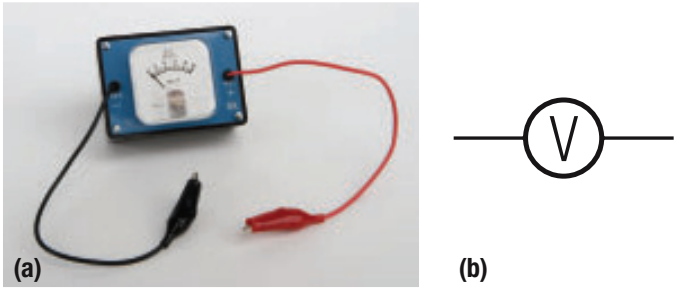

Figure 3 (a) A voltmeter (b) The circuit diagram symbol for a voltmeter

Unlike an ammeter, a voltmeter must be connected in parallel with a load or an energy source. The reason for this is that voltage is relative to two points. There is always a drop in voltage across a load or energy source.

For example, to measure the voltage across the lamp in Figure 4, connect the voltmeter in parallel with the lamp. Since the lamp is the only load in the circuit, the voltage displayed on the voltmeter will be the same as the voltage across the two terminals of the battery.

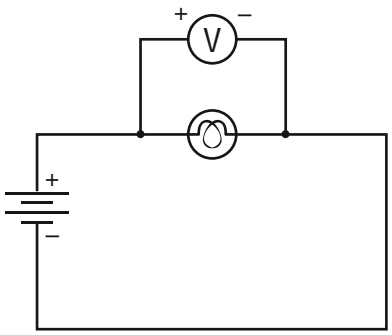

Figure 4 A voltmeter measures the potential difference across the lamp. Note that the negative side of the battery is connected to the negative side of the voltmeter.

IN SUMMARY

- Potential difference, or voltage, is the difference in electric potential energy per unit charge measured at two points.
- Electrons flow from a point of higher electric potential energy to a point of lower electric potential energy.
- Potential difference is measured in volts (V) using a device called a voltmeter.
- Voltmeters must be connected in parallel with either a load or an energy source when measuring potential difference.

CHECK YOUR LEARNING

1. Describe one idea about measuring potential difference that you think you will need to spend more time on to learn. How do you plan to study this idea? K/U C
2. In science, we use symbols to represent quantities. We assign these quantities specific measurement units. Copy and complete Table 1 in your notebook. K/U

Table 1 Potential Difference

Electrical quantity	Electrical quantity symbol	Unit of measurement	Unit of measurement symbol
potential difference			

3. Give an example of how the potential difference would be measured in a circuit. K/U
4. A student connected a voltmeter into a circuit as shown in Figure 5. Is this the correct way to connect a voltmeter? Explain your answer. K/U

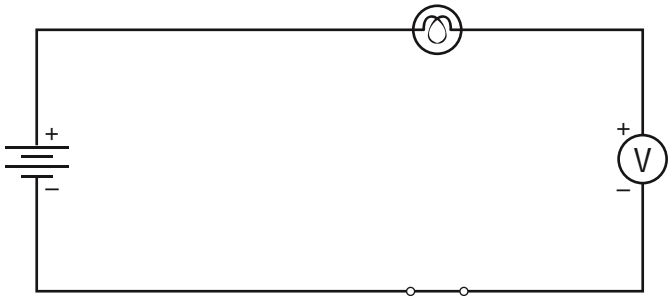

Figure 5