**Section 1**
# Tools and Measurement

**Key Concept** Scientists must select the appropriate tools to make measurements and collect data, to perform tests, and to analyze data.

### What You Will Learn

- Scientists use tools to make observations, take measurements, and analyze data.
- Scientists have determined standard ways to measure length, area, mass, volume, and temperature.

### Why It Matters

In science, measurements must be precise and data must be correct so that scientists can share information.

---

Would you use a hammer to tighten a bolt on a bicycle? You probably wouldn't. To carry out tasks, you need to choose the correct tools. Scientists use many tools. A *tool* is anything that helps you do a task.

## Tools for Science

If you observe a jar of pond water, you may see a few insects swimming around. But a microscope can help you see many organisms that you couldn't see before. And a graduated cylinder can help you measure the volume of water in the jar. Different tools help scientists gather different kinds of data.

### Tools for Seeing

Microscopes and magnifying lenses are tools that help you see things that are too small to see with only your eyes. Telescopes and binoculars help you make careful observations of things that are too far away to see with only your eyes. The reflecting telescope in **Figure 1** is made up of three major parts–a curved mirror, a flat mirror, and an eyepiece. Light enters the telescope and is reflected from a curved mirror to a flat mirror. The flat mirror focuses the image and reflects the light to the eyepiece.

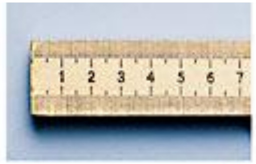
**Figure 1** By using telescopes, scientists can make detailed studies of distant objects in space, such as the moon.

## Tools for Measuring

One way to collect data during an experiment is to take meas urements. To have the best measurements possible, you need to use the proper tools. Stopwatches, metersticks, and balances are some of the tools that you can use to make measurements. Thermometers, spring scales, and graduated cylinders are also helpful tools. **Figure 2** explains what properties these tools can be used to measure.

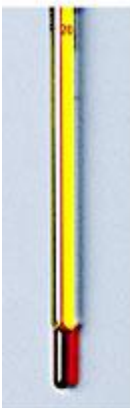
**Figure 2 Measurement Tools**

You can use a **balance** to measure mass.



You can use a **meterstick** to measure length.

You can use a **stopwatch** to measure time.



You can use a **thermometer** to measure temperature.

You can use a **spring scale** to measure force.

You can use a **graduated cylinder** to measure volume.

### Tools for Analyzing

After you take measurements, you need to analyze the data. Perhaps you need to find the average of your data. Calculators are tools that help you do calculations quickly. Or you could show your data in a graph or a figure. A computer that has the correct software can help you make neat figures. In fact, computers have become invaluable tools for collecting, storing, and analyzing data. Of course, even a pencil and graph paper are tools that you can use to graph your data.

## Measurement

Hundreds of years ago, different countries used different systems of measurement. At one time in England, the standard for an inch was three grains of barley placed end to end. Other modern standardized units were originally based on parts of the body, such as the foot. Such systems were not very reliable. Their units were based on objects that varied in size.

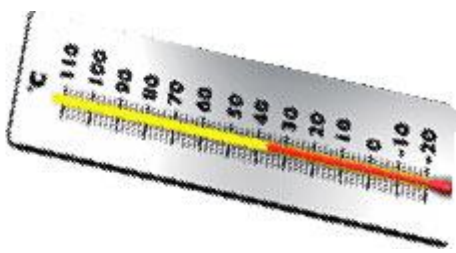
In time, people realized that they needed a simple and reliable measurement system. In the late 1700s, the French Academy of Sciences set out to make that system. Over the next 200 years, the metric system was developed. This system is now called the *International System of Units,* or the *SI.*

## The International System of Units

Today, most scientists and almost all countries use the International System of Units. One advantage of using SI measurements is that they allow all scientists to share and compare their observations and results. Another advantage is that all units are based on the number 10. This feature makes changing from one unit to another easy.

**Table 1** shows SI units for length, area, mass, volume, and temperature. Become familiar with these units. You will use SI units in the science lab when you collect and analyze data.

| **Table 1 Common SI units and Conversion** | | | |
|---|---|---|---|
| **Length** |  | **meter (m)** kilometer (km) centimeter (cm) | 1 km = 1,000 m 1 cm = 0.01 m |
| **Area** | | **square meter ($m^2$)** square centimeter ($cm^2$) | $1 cm^2$= 0.0001 $m^2$ |
| **Mass** |  | **kilogram (kg)** gram (g) milligram (mg) | 1 g = 0.001 kg 1 mg = 0.000001 kg |
| **Volume** | | **cubic meter ($m^3$)** cubic centimeter ($cm^3$) | 1 $cm^3$ = 0.000001 $m^3$ 1 L = 1 $dm^3$ = 0.001 $m^3$ |

| | | | |
|---|---|---|---|
| |   | liter (L) milliliter (mL) | 1 mL = 0.001 L =1 $cm^3$ |
| **Temperature*** |   | **kelvin (K) celcius (-°C)** | 0°C = 273 K 100°C = 373 K |

*The Celcius (°C) scale is a commonly used non-SI temperature scale.

[redacted]

### Length

How long is your arm? The student in **Figure 3** could describe the length of her arm by using the **meter** (m), the main SI unit of length. Remember that SI units are based on the number 10. If you divide 1 m into 100 parts, each part equals 1 cm. In other words, 1 cm is one-hundredth of a meter. To describe the length of microscopic objects, use micrometers (μm) or nanometers (nm). To describe the length of larger objects, use kilometers (km).

**Figure 3** This student's arm is 0.65 m long.

**Standards Check** What tool would you select to measure the length of an object?

## Area

How much carpet would it take to cover the floor of your classroom? To answer this question, you must find the area of the floor. **Area** is a measure of how much surface an object has. Area is based on two measurements. For example, to calculate the area of a square or rectangle, you need to measure the length and width. Then, use the following equation for the area of a square or a rectangle:

*area* = *length* × *width*

The units for area are square units, such as square meters ($m^2$), square centimeters ($cm^2$), and square kilometers ($km^2$).

## Mass

How many sacks of grain can a mule carry? The answer depends on the strength of the mule and the mass of the sacks of grain. **Mass** is the amount of matter that makes up an object. Scientists often use a balance to measure mass, as shown in **Figure 4.** The kilogram (kg) is the main unit for mass. The kilogram is used to describe the mass of things such as sacks of grain. Many everyday objects are not so large, however. The mass of smaller objects, such as an apple, can be described by using grams (g) or milligrams (mg). One thousand grams equals 1 kg. The mass of large objects, such as an elephant, is given in metric tons. A metric ton equals 1,000 kg.

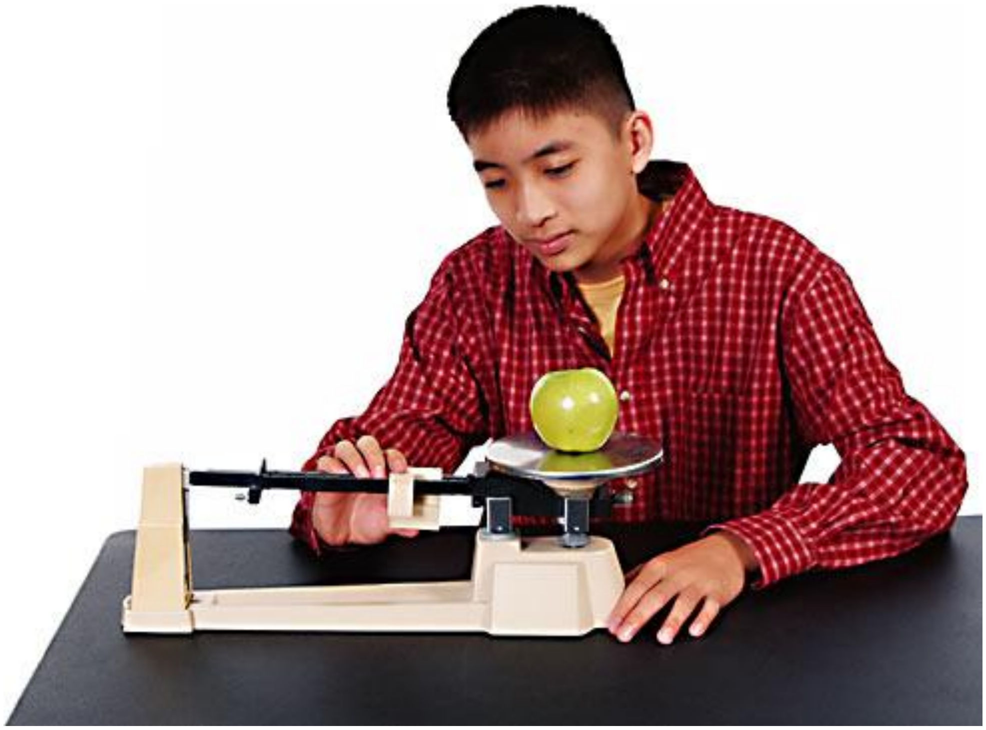


**Figure 4** This student is using a balance to measure the mass of an apple.

[redacted]

## Volume

The amount of space that something occupies or the amount of space that something contains is called **volume.** The volume of a large, solid object is given in cubic meters ($m^3$). The volumes of smaller objects can be given in cubic centimeters ($cm^3$) or cubic millimeters ($mm^3$). To find the volume of an irregularly shaped object, measure the volume of liquid that the object displaces. This process is shown in **Figure 5.** To calculate the volume of a box-shaped object, you can multiply the object's length by its width and then by its height.

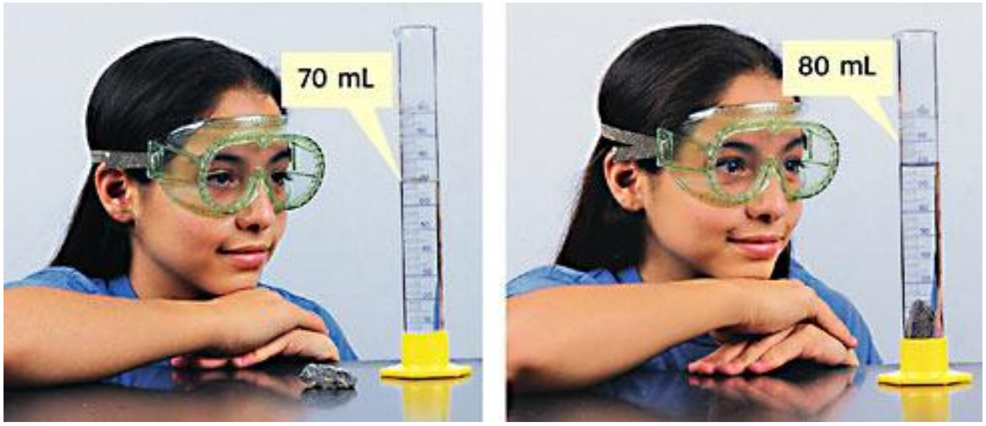



**Figure 5** Adding the rock changes the water level from 70 mL to 80 mL. So, the rock displaces 10 mL of water. Because 1 mL 1 $cm^3$, the volume of the rock is 10 $cm^3$.

The volume of a liquid is often given in liters (L). Liters are based on the meer. A cubic meter (1 $m^3$) is equal to 1,000 L. So, 1,000 L will fit into a box measuring 1 m on each side. A milliliter (mL) will fit into a box measuring 1 cm on each side. So, 1 mL = 1 $cm^3$. Graduated cylinders are used to measure liquid volume in milliliters.

**Standards Check** What tool would you select to measure the volume of a small, irregularly shaped object?

## Temperature

To find out how hot or cold something is, scientists measure temperature. **Temperature** is a measure of the average kinetic energy of the particles that make up an object. You may use degrees Fahrenheit (°F) to describe temperature. Scientists often use degrees Celsius (°C). However, the kelvin (K) is the SI base unit for temperature. The thermometer in **Figure 6** shows how two of these units are related.

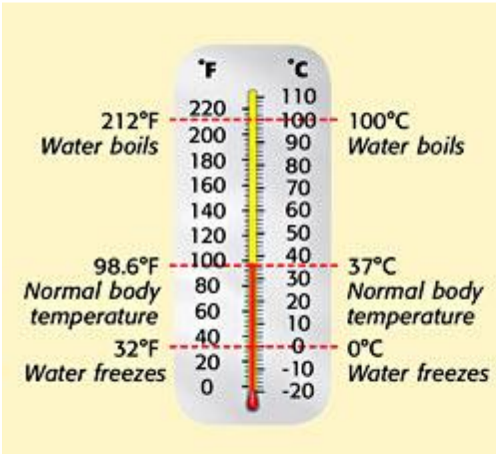



**Figure 6** This thermometer shows the relationship between degrees Fahrenheit and degrees Celsius.

[redacted]

## Writing Numbers in Scientific Notation

Scientific measurement often involves numbers that are very large or very small. For example, light moves through space at a speed of about 300,000,000 m/s. That's a lot of zeros! To make very large numbers and very small numbers more manageable, scientists use a shorthand called *scientific notation.* Scientific notation is a way to express a quantity as a number multiplied by 10 to the appropriate positive or negative power, as shown in **Table 2.** For example, the measurement 300,000,000 m/s can be written as $3.0 \times 10^8$ m/s in scientific notation.

**Table 2 Powers of 10**

| Power of 10 | Decimal equivalent |
|---|---|
| $10^3$ | 1,000 |
| $10^2$ | 100 |

| | |
|---|---|
| $10^{-1}$ | 1.0 |
| $10^{-2}$ | 0.1 |
| $10^{-3}$ | 0.01 |

## Section Summary

- Scientists use tools to make observations, take measurements, and analyze data.
- Scientists must select the appropriate tools for their observations and experiments to take appropriate measurements.
- Scientists use the International System of Units (SI) so that they can share and compare their observations and results with other scientists.
- Scientists have determined standard ways to measure length, area, mass, volume, and temperature.
- Scientific notation is a way to express numbers that are very large or very small.