chapter 1 The Nature of Science

section 2 Standards of Measurement

Before You Read

If someone asked you how wide your desk is, how would you measure it? Would you measure using inches, centimeters, feet, yards, or meters? Write why you selected this unit of measure.

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What You'll Learn

- the SI units and symbols for length, volume, mass, density, time, and temperature
- how to convert related SI units

Read to Learn

Units and Standards

A **standard** is an exact quantity that people agree to use to compare measurements. A standard is always exactly the same quantity when it is used anywhere in the world. Without standards, it is difficult to compare things that can be measured. Suppose you and a friend want to measure your desk but do not have a ruler. Instead, you use your hands as tools to measure the desk. If you each measure the desk using your own hands, will you both get the same measure? You can't be sure, because you don't know if your hands are the same size.

Precision and Accuracy

Imagine you are watching two people shoot arrows at a target. The first person shoots five bull's-eyes in a row. The second person never hits the bull's-eye, but all the arrows are close to one spot. What can you say about these two archers? The first person's aim was both precise and accurate. The second person's aim was only precise. Precision describes how closely measurements are to one another and how carefully measurements were made. Accuracy compares a measurement to a real or accepted standard. When you take measurements, the goal is to be both accurate and precise.

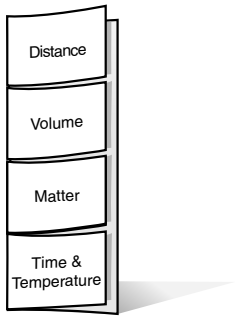
Study Coach

Make an Outline Make an outline of the information in this section. Use each of the headings as part of the outline.

FOLDABLES™

B Organize Information

As you read this section, make the following Foldable to organize information about different types of measurements and units.



International System of Units

In 1960, an improvement was made to the metric system. This improvement is known as the International System of Units. This system is often abbreviated **SI** from the French *Le Systeme Internationale d'Unites*. The SI standards are accepted and used by scientists all over the world. Each type of SI measurement has a base unit. The base unit for length is the meter. The names and symbols for the seven base units are in the table below. All other SI units come from these seven base units.

SI Base Units

Quantity Measured	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Intensity of light	candela	cd

Picture This

1. **Recognize** Circle the base units that you have seen before.

What are SI prefixes?

The SI system is easy to use because it is based on multiples of ten. A prefix is added to the name of the base unit to indicate how many multiples of ten it should include. For example, the prefix *kilo-* means 1,000. That means that one kilometer is equal to 1,000 meters. This also means that one kilogram equals 1,000 grams. The most commonly used prefixes are shown in the table below.

Common SI Prefixes

Prefix	Symbol	Multiplying Factor
kilo-	k	1,000
deci-	d	0.1
centi-	c	0.01
milli-	m	0.001
micro-	μ	0.000 001
nano-	n	0.000 000 001

Picture This

2. **Identify** Which of the following is the smallest? (Circle your choice.)

   a. decigram
   b. nanogram
   c. milligram
   d. kilogram

How do you convert between SI units?

Sometimes quantities are measured using different units. Suppose a teacher has 1.3 L of water for a class experiment. She needs 125 mL to conduct the experiment. To determine if she has enough water, she must first find out how many mL of water she has.

Conversion Factors A conversion factor is used to change measurements from one unit to another. A conversion factor is a ratio that equals one. For a ratio to equal one, the numerator and denominator must have the same value. The numerator of a conversion factor should be the new unit. The denominator should be the old unit. For example, if you are converting liters to milliliters, use the following conversion factor.

$$\frac{\text{new unit}}{\text{old unit}} = \frac{1000 \text{ mL}}{1 \text{ L}}$$

To find out how much water she has in mL, the teacher multiplies the amount of water she has by the conversion factor.

$$1.3 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}}$$

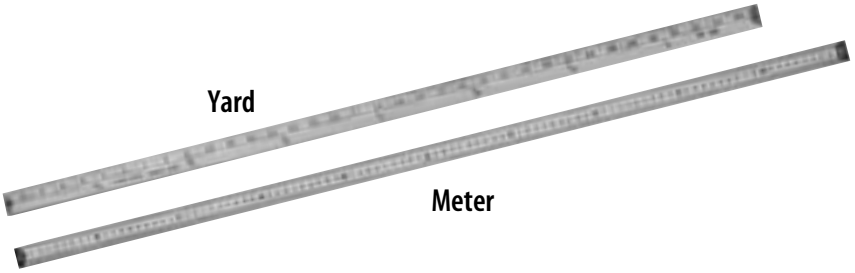
$$1.3 \cancel{\text{L}} \times \frac{1000 \text{ mL}}{1 \cancel{\text{L}}}$$

$$1.3 \times 1000 \text{ mL} = 1{,}300 \text{ mL}$$

The teacher has 1,300 mL of water. That is enough for her experiment!

Measuring Distance

In science, the word *length* is used to describe the distance between two points. The SI base unit of length is the meter, m. A baseball bat is about 1 m long. Metric rulers and metersticks are commonly used to measure length. A meter is slightly longer than 1 yard, as shown by the meter-stick and the yardstick in the figure below.



Applying Math

3. Convert Units A length of rope measures 3,000 millimeters. How long is it in meters?

$$3{,}000 \cancel{\text{mm}} \times \frac{1 \text{ m}}{1{,}000 \cancel{\text{mm}}}$$

$$\frac{3{,}000}{1} \times \frac{1 \text{ m}}{1{,}000}$$

$$\frac{3{,}000 \text{ m}}{1{,}000} = \square$$

Picture This

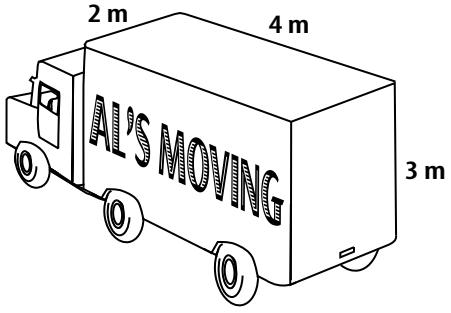
4. Circle Circle the length by which the meterstick is longer than the yardstick.

How do you choose a unit of length?

When measuring distance, it is important to choose the proper unit. The unit you choose will depend on the object being measured. For example, you would measure the length of a pencil in centimeters (cm). The length of your classroom would be measured in meters. The distance from school to your house would be measured in kilometers (km). By choosing the best unit, you can avoid very large or very small numbers. It is easier to say something is 21 km rather than saying it is 21,000 m.

Measuring Volume

Volume is the amount of space an object fills. The volume of a rectangular solid, such as a brick, is found by multiplying its length, width, and height ($V = l \times w \times h$). If the sides of the brick were measured in centimeters, cm, the volume would be expressed in cubic centimeters, cm^3. When you multiply all three measurements, you multiply "cm" three times, once with each measurement. The result is cm^3. If you were trying to find out how much space there is in a moving van, you would measure the van using meters. Its volume would be expressed in cubic meters, m^3. Let's find the volume of this van.



First find the length, width, and height of the van.

Length = 4 m
Width = 2 m
Height = 3 m

Substitute these values into the formula for finding volume.

$$\begin{aligned} V &= l \times w \times h \\ &= 4\text{ m} \times 2\text{ m} \times 3\text{ m} \\ &= (4 \times 2 \times 3)(\text{m} \times \text{m} \times \text{m}) \\ &= 24\text{ m}^3 \end{aligned}$$

The volume of the moving van is 24 m^3.

Applying Math

5. Define In the calculations for finding the volume of the van, (m × m × m) is rewritten as m^3. The 3 in m^3 is called an exponent. What does an exponent represent?

Applying Math

6. Calculate What is the volume of a brick that has a length of 20 cm, a width of 6 cm, and a height of 5 cm? Show your work.

How do you measure the volume of a liquid?

Measuring the volume of a liquid in a container is different from measuring a solid object because the liquid does not have sides. To measure the volume of a liquid, you must use a container with a known capacity. Its measuring units should be marked. The most common units for expressing the volume of liquids are liters (L) and milliliters (mL). A milliliter is equal in volume to 1 cm^3. So, the volume of 1 L equals 1,000 cm^3. Look at food cans and bottles to see how these measurements are used.

Reading Check

7. Measure What are the most common units for expressing the volume of liquids?

Measuring Matter

Mass is the measure of how much matter is in an object. **Matter** is anything that has mass and takes up space. A golf ball and a table-tennis ball are about the same size. The golf ball has more matter and mass, than the table-tennis ball.

What is density?

Another property of matter is density. The **density** of an object is the amount of mass in one cubic unit of volume of the object. You can find density by dividing an object's mass by its volume. Suppose an object weighs 10 g and has a volume of 2 cm^3. The density of the object is 5 g/cm^3.

If two objects are the same size and one object has a greater mass, it also has a greater density. This is because the more dense object has more mass in one cubic unit of volume than the other object has in one cubic unit of volume. The golf ball and the table-tennis ball have about the same volume. However, the golf ball has a greater mass. This means that the golf ball also has a greater density.

Applying Math

8. Calculate Suppose an object weighs 15 g and has a volume of 5 cm^3. What is the density of the object?

What are derived units?

The measurement for density, g/cm^3, is a combination of SI units. A unit made by combining different SI units is called a derived unit. An SI unit multiplied by itself is also called a derived unit. For example, the liter, which is based on the cubic decimeter, and a meter cubed, m^3, are both derived.

Measuring Time and Temperature

Sometimes scientists need to keep track of how long it takes something to happen or whether something heats up or cools down. These are measurements of time and temperature.

Time is the interval between two events. The unit of time in the SI system is the second (s). Seconds are usually measured with a clock or stopwatch.

What's hot and what's not?

Sometimes scientists need to measure how much something heats up or cools down. Temperature is a measure of how much energy something has. Later, you will learn the scientific meaning of temperature.

What is Celsius?

Scientists use the Celsius (C) scale to measure temperature. This scale was designed to show that 0°C is the freezing point of water, and 100°C is the boiling point of water. The scale is divided into 100 equal divisions, or degrees, between the freezing point and the boiling point of water.

What is Fahrenheit?

The temperature measurement you are probably most familiar with is the Fahrenheit (F) scale. On this scale, water freezes at 32°F and boils at 212°F.

Reading Check

9. Restate At what temperature does water freeze, and at what temperature does water boil on the Celsius scale?

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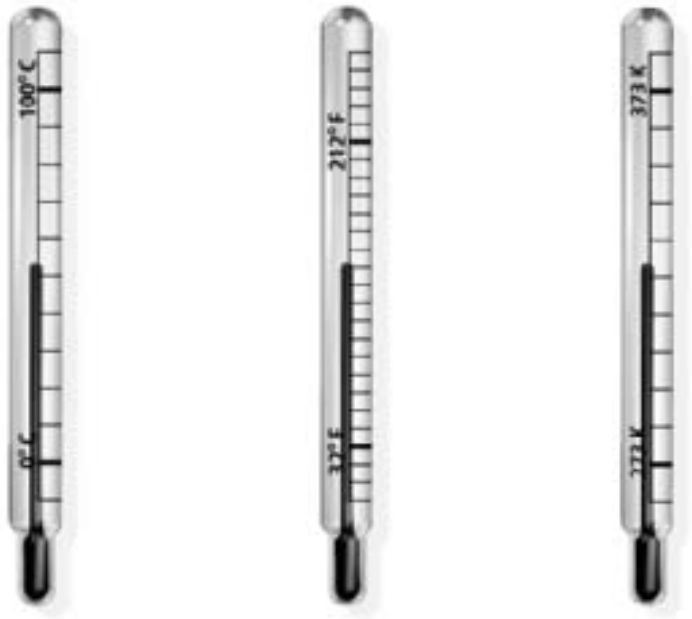
What is Kelvin?

The SI unit of temperature is kelvin (K). On the Kelvin scale, 0 K is called absolute zero. This is the coldest possible temperature. Absolute zero is equal to –273°C, which is 273° below the freezing point of water. The divisions on the Kelvin and Celsius scales are the same size. This makes it easy to convert between the two scales. Water freezes at 0°C. To convert to Kelvin, you add 273 to the Celsius temperature. So, on the Kelvin scale, water freezes at 273 K. Water boils at 100°C. So, on the Kelvin scale, water boils at 373 K.

Picture This

10. Label each thermometer in the diagram with the name of its temperature scale.



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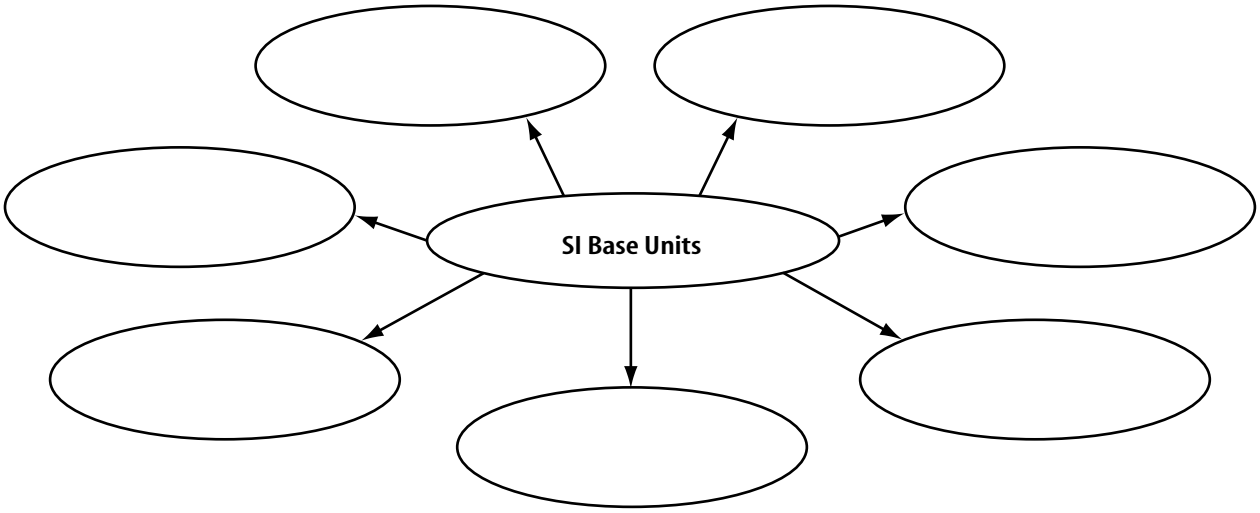
After You Read

Mini Glossary

density: the mass per unit volume of a material
mass: the measurement of the quantity of matter in an object
matter: anything that has mass and takes up space
standard: an exact quantity people agree to use to compare measurements
SI: International system of units; includes metrics
volume: the amount of space occupied by an object

1. Review the terms and their definitions in the Mini Glossary. In your own words, write a sentence that explains how mass affects an object's density.

2. Complete the chart below to organize the information from this section. For each unit include the unit's name, what it measures, and its symbol.



3. Study Coach Think about what you have learned. Write a way to help you remember the meaning of volume.

End of Section