Measurement

The BIG Idea

Measurement is a description using numbers.

SECTION 1
Description and Measurement
Main Idea Measurements of a single item might vary depending on the accuracy of the measuring device or the precision of the measurements.

SECTION 2
SI Units
Main Idea The SI system of units provides a worldwide standard of measurement.

SECTION 3
Drawings, Tables, and Graphs
Main Idea Data can be displayed visually using drawings, tables, and graphs.

The Checkered Flag

Race car drivers win or lose by tenths of a second. The driver has to monitor his fuel usage, speed, and oil temperature in order to win the race. In this chapter, you will learn how scientists measure things like distance, time, volume, and temperature.

Science Journal As a member of the pit crew, how can you determine the miles per gallon the car uses? Write in your Science Journal how you would calculate this.

Buck Miller/SuperStock

Start-Up Activities

Launch LAB

Measuring Accurately

You make measurements every day. If you want to communicate those measurements to others, how can you be sure that they will understand exactly what you mean? Using vague words without units won't work. Do the lab below to see how confusion can result from using measurements that aren't standard.

1. As a class, choose six objects to measure in your classroom.
2. Measure each object using the width of your hand and write your measurements in your Science Journal.
3. Compare your measurements to those of your classmates.
4. **Think Critically** Describe in your Science Journal why it is better to switch from using hands to using units of measurement that are the same all the time.
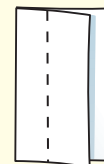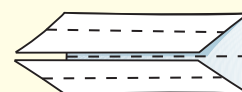
FOLDABLES™ Study Organizer

Measurement Make the following Foldable to help you organize information about measurements.

STEP 1 **Fold** a sheet of paper in half two times lengthwise. Unfold

STEP 2 **Fold** the paper widthwise in equal thirds and then in half.

STEP 3 **Unfold,** lay the paper lengthwise, and draw lines along the folds. **Label** your table as shown.

	Estimate It	Measure It	Round It
Length of			
Volume of			
Mass of			
Temperature of			
Rate of			

Estimates Before you read the chapter, select objects to measure and estimate their measurements. As you read the chapter, complete the table.

Get Ready to Read

Identify the Main Idea

① **Learn It!** Main ideas are the most important ideas in a paragraph, section, or chapter. Supporting details are facts or examples that explain the main idea. Understanding the main idea allows you to grasp the whole picture.

② **Picture It!** Read the following paragraph. Draw a graphic organizer like the one below to show the main idea and supporting details.

> What happens when you want to know the size of an object but you can't measure it? Perhaps it is too large to measure or you don't have a ruler handy. **Estimation** can help you make a rough measurement of an object. When you estimate, you can use your knowledge of the size of something familiar to estimate the size of a new object. Estimation is a skill based on previous experience and is useful when exact numbers are not required.
>
> *—from page 43*

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                    Main Idea
          ┌────────────┼────────────┐
          ↓            ↓            ↓
Supporting Details  Supporting Details  Supporting Details
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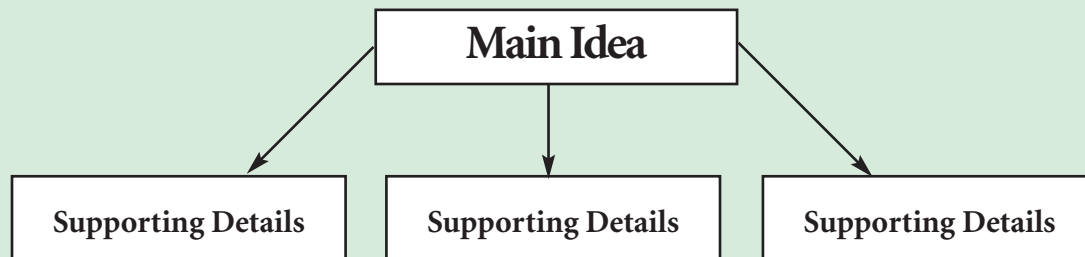
③ **Apply It!** Pick a paragraph from another section of this chapter and diagram the main ideas as you did above.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1 **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.
- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

2 **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.
- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

Science Online
Print out a worksheet of this page at ips.msscience.com

Before You Read A or D		Statement	After You Read A or D
	1	Estimation is a guess made without any additional information.	
	2	A single measurement can't be precise.	
	3	A group of measurements that is precise must also be accurate.	
	4	Units of volume are SI base units.	
	5	The volume of a rock can be measured by multiplying length $\times$ width $\times$ height.	
	6	Mass and weight are the same thing.	
	7	A table and a graph can represent the same data in a different format.	
	8	A circle graph represents parts of a whole.	
	9	The x- and y-axes on a graph must always start at zero.	

Description and Measurement

Measurement

How would you describe what you are wearing today? You might start with the colors of your outfit and perhaps you would even describe the style. Then you might mention sizes—size 7 shoes, size 14 shirt. Every day you are surrounded by numbers. **Measurement** is a way to describe the world with numbers. It answers questions such as how much, how long, or how far. Measurement can describe the amount of milk in a carton, the cost of a new compact disc, or the distance between your home and your school. It also can describe the volume of water in a swimming pool, the mass of an atom, or how fast a penguin's heart pumps blood.

The circular device in **Figure 1** is designed to measure the performance of an automobile in a crash test. Engineers use this information to design safer vehicles. In scientific endeavors, it is important that scientists rely on measurements instead of the opinions of individuals. You would not know how safe the automobile is if this researcher turned in a report that said, "Vehicle did fairly well in head-on collision when traveling at a moderate speed." What does "fairly well" mean? What is a "moderate speed"?

Figure 1 This device measures the range of motion of a seat-belted mannequin in a simulated accident.

Figure 2 Accurate measurement of distance and time is important for competitive sports like track and field.
Infer *Why wouldn't a clock that measured in minutes be precise enough for this race?*

Describing Events Measurement also can describe events such as the one shown in **Figure 2.** In the 1956 summer Olympics, sprinter Betty Cuthbert of Australia came in first in the women's 200-m dash. She ran the race in 23.4 s. In the 2000 summer Olympics, Marion Jones of the United States won the 100-m dash in a time of 10.75 s. In this example, measurements convey information about the year of the race, its length, the finishing order, and the time. Information about who competed and in what event are not measurements but help describe the event completely.

Estimation

What happens when you want to know the size of an object but you can't measure it? Perhaps it is too large to measure or you don't have a ruler handy. Estimation can help you make a rough measurement of an object. When you estimate, you can use your knowledge of the size of something familiar to estimate the size of a new object. Estimation is a skill based on previous experience and is useful when exact numbers are not required. Estimation is a valuable skill that improves with experience, practice, and understanding.

Reading Check *When should you not estimate a value?*

How practical is the skill of estimation? In many instances, estimation is used on a daily basis. A caterer prepares for each night's crowd based on an estimation of how many will order each entree. A chef makes her prize-winning chili. She doesn't measure the cumin; she adds "just that much." Firefighters estimate how much hose to pull off the truck when they arrive at a burning building.

INTEGRATE
Career

Precision and Accuracy
A pharmacist has a very important job: making sure that patients receive the right medication at the correct dosage. Any error in dosage or type of pill could harm the patient. Explain how precision and accuracy play a role in the pharmacist's job. If a patient receives the wrong medication or an extra pill, how could that affect their health? Research some other careers that rely on precision and accuracy. How could errors in a measurement affect the professional's finished product?

Figure 3 This student is about 1.5 m tall. **Estimate** *the height of the tree in the photo.*

Mini LAB

Measuring Temperature

Procedure

1. Fill a **400-mL beaker** with **crushed ice.** Add enough **cold water** to fill the beaker.
2. Make three measurements of the temperature of the ice water using a **computer temperature probe.** Remove the computer probe and dry it with a **paper towel.** Record the measurement in your **Science Journal.** Allow the probe to warm to room temperature between each measurement.
3. Repeat step two using an **alcohol thermometer.**

Analysis

1. Average each set of measurements.
2. Which measuring device is more precise? Explain. Can you determine which is more accurate? How?

Using Estimation You can use comparisons to estimate measurements. For example, the tree in **Figure 3** is too tall to measure easily, but because you know the height of the student next to the tree, you can estimate the height of the tree. When you estimate, you often use the word *about*. For example, doorknobs are about 1 m above the floor, a sack of flour has a mass of about 2 kg, and you can walk about 5 km in an hour.

Estimation also is used to check that an answer is reasonable. Suppose you calculate your friend's running speed as 47 m/s. You are familiar with how long a second is and how long a meter is. Think about it. Can your friend really run a 50-m dash in 1 s? Estimation tells you that 47 m/s is unrealistically fast and you need to check your work.

Precision and Accuracy

One way to evaluate measurements is to determine whether they are precise. **Precision** is a description of how close measurements are to each other. Suppose you measure the distance between your home and your school five times with an odometer. Each time, you determine the distance to be 2.7 km. Suppose a friend repeated the measurements and measured 2.7 km on two days, 2.8 km on two days, and 2.6 km on the fifth day. Because your measurements were closer to each other than your friend's measurements, yours were more precise. The term *precision* also is used when discussing the number of decimal places a measuring device can measure. A clock with a second hand is considered more precise than one with only an hour hand.

Degrees of Precision The timing for Olympic events has become more precise over the years. Events that were measured in tenths of a second 100 years ago are measured to the hundredth of a second today. Today's measuring devices are more precise. **Figure 4** shows an example of measurements of time with varying degrees of precision.

Accuracy When you compare a measurement to the real, actual, or accepted value, you are describing **accuracy**. A watch with a second hand is more precise than one with only an hour hand, but if it is not properly set, the readings could be off by an hour or more. Therefore, the watch is not accurate. However, measurements of 1.03 m, 1.04 m, and 1.06 m compared to an actual value of 1.05 m are accurate, but not precise. **Figure 5** illustrates the difference between precision and accuracy.

Reading Check *What is the difference between precision and accuracy?*

Figure 4 Each of these clocks provides a different level of precision. **Infer** *which of the three you could use to be sure to make the 3:35 bus.*

For centuries, analog clocks—the kind with a face—were the standard.

Before the invention of clocks, as they are known today, a sundial was used. As the Sun passes through the sky, a shadow moves around the dial.

Digital clocks are now as common as analog ones.

Figure 5

From golf to gymnastics, many sports require precision and accuracy. Archery— a sport that involves shooting arrows into a target—clearly shows the relationship between these two factors. An archer must be accurate enough to hit the bull's-eye and precise enough to do it repeatedly.

A The archer who shot these arrows is neither accurate nor precise—the arrows are scattered all around the target.

C Here we have a winner! All of the arrows have hit the bull's-eye, a result that is both precise and accurate.

B This archer's attempt demonstrates precision but not accuracy—the arrows were shot consistently to the left of the target's center.

Precision and accuracy are important in many medical procedures. One of these procedures is the delivery of radiation in the treatment of cancerous tumors. Because radiation damages cells, it is important to limit the radiation to only the cancerous cells that are to be destroyed. A technique called Stereotactic Radiotherapy (SRT) allows doctors to be accurate and precise in delivering radiation to areas of the brain. The patient makes an impression of his or her teeth on a bite plate that is then attached to the radiation machine. This same bite plate is used for every treatment to position the patient precisely the same way each time. A CAT scan locates the tumor in relation to the bite plate, and the doctors can pinpoint with accuracy and precision where the radiation should go.

Rounding a Measurement Not all measurements have to be made with instruments that measure with great precision like the scale in **Figure 6.** Suppose you need to measure the length of the sidewalk outside your school. You could measure it to the nearest millimeter. However, you probably would need to know the length only to the nearest meter or tenth of a meter. So, if you found that the length was 135.841 m, you could round off that number to the nearest tenth of a meter and still be considered accurate. How would you round this number? To round a given value, follow these steps:

1. Look at the digit to the right of the place being rounded to.

   - If the digit to the right is 0, 1, 2, 3, or 4, the digit being rounded to remains the same.

   - If the digit to the right is 5, 6, 7, 8, or 9, the digit being rounded to increases by one.

2. The digits to the right of the digit being rounded to are deleted if they are also to the right of a decimal. If they are to the left of a decimal, they are changed to zeros.

Look back at the sidewalk example. If you want to round the sidewalk length of 135.841 to the tenths place, you look at the digit to the right of the 8. Because that digit is a 4, you keep the 8 and round it off to 135.8 m. If you want to round to the ones place, you look at the digit to the right of the 5. In this case you have an 8, so you round up, changing the 5 to a 6, and your answer is 136 m.

Figure 6 This laboratory scale measures to the nearest hundredth of a gram.

Matt Meadows

Precision and Number of Digits When might you need to round a number? Suppose you want to divide a 2-L bottle of soft drink equally among seven people. When you divide 2 by 7, your calculator display reads as shown in **Figure 7.** Will you measure exactly 0.285 714 285 L for each person? No. All you need to know is that each person gets about 0.3 L of soft drink.

Using Precision and Significant Digits The number of digits that truly reflect the precision of a number are called the significant digits or significant figures. They are figured as follows:

- Digits other than zero are always significant.
- Final zeros after a decimal point (6.545 600 g) are significant.
- Zeros between any other digits (507.0301 g) are significant.
- Initial zeros (0.000 2030 g) are NOT significant.
- Zeros in a whole number (1650) may or may not be significant.
- A number obtained by counting instead of measuring, such as the number of people in a room or the number of meters in a kilometer, has infinite significant figures.

Applying Math   Rounding

ROUNDED VALUES The mass of one object is 6.941 g. The mass of a second object is 20.180 g. You need to know these values only to the nearest whole number to solve a problem. What are the rounded values?

Solution

1 *This is what you know:*
  - mass of first object = 6.941 g
  - mass of second object = 20.180 g

2 *This is what you need to find out:*
  - the number to the right of the one's place
  - first object: 9; second object: 1

3 *This is the procedure you need to use:*
  digits 0, 1, 2, 3, 4 remain the same
  for digits 5, 6, 7, 8, 9, round up

4 *Check your answer:*
  - first object: 9 makes the 6 round up = 7
  - second object: 1 makes the 0 remain the same = 20

Practice Problems

1. What are the rounded masses of the objects to the nearest tenth of a unit?

2. Round the following numbers: 25.643 to the ones place, 3.429 to the tenths place, 5.982 to the hundredths place, and 9.8210 to the tenths place.

Following the Rules In the soft drink example you have an exact number, seven, for the number of people. This number has infinite significant digits. You also have the number two, for how many liters of soft drink you have. This has only one significant digit.

There are also rules to follow when deciding the number of significant digits in the answer to a calculation. They depend on what kind of calculation you are doing.

- For multiplication and division, you determine the number of significant digits in each number in your problem. The significant digits of your answer are determined by the number with fewer digits.

$$6.14 \times 5.6 = \boxed{34}.384$$

3 digits   2 digits   2 digits

- For addition and subtraction, you determine the place value of each number in your problem. The significant digits of the answer are determined by the number that is least precise.

$$
\begin{array}{ll}
6.14 & \text{to the hundredths} \\
+\ 5.6 & \text{to the tenths} \\
\hline
\boxed{11.7}4 & \text{to the tenths}
\end{array}
$$

In the soft drink example you are dividing and the number of significant digits is determined by the amount of soft drink, 2 L. There is one significant digit there; therefore, the amount of soft drink each person gets is rounded to 0.3 L.

Figure 7 Sometimes considering the size of each digit will help you realize they are unneeded. In this calculation, the seven ten-thousandths of a liter represents just a few drops of soft drink.

section 1 review

Summary

Measurement
- Measurement is used to answer questions such as how much, how long, or how far.

Estimation
- When making an estimate, rely on previous knowledge to make an educated guess about the size of an object.

Precision and Accuracy
- Precision is the ability to remain consistent. Accuracy compares a measurement to the real value of an object.
- Significant digits affect precision when calculating an answer and are determined by rules based on calculation.

Self Check

1. **Estimate** the distance between your desk and your teacher's desk. Explain the method you used.
2. **Infer** John's puppy has chewed on his ruler. Will John's measurements be accurate or precise? Why?
3. **Think Critically** Would the sum of 5.7 cm and 6.2 cm need to be rounded? Why or why not? Would the sum of 3.28 cm and 4.1 cm need to be rounded? Why or why not?

Applying Math

4. **Calculate** Perform the following calculations and express the answer using the correct number of significant digits: 42.35 + 214; 225/12. **For more help, refer to the Math Skill Handbook.**

Mark Burnett

SI Units

The International System

Can you imagine how confusing it would be if people used different measuring systems? Sharing data would be complicated. To avoid confusion, scientists established the International System of Units, or **SI**. It was designed to provide a worldwide standard of physical measurement for science, industry, and commerce. SI base units are shown in **Table 1.** All other SI units can be created from these seven units.

Reading Check *Why was SI established?*

The SI units are related by multiples of ten. Any SI unit can be converted to a smaller or larger SI unit by multiplying by a power of 10. For example, to rewrite a kilogram measurement in grams, you multiply by 1,000.

$$\text{Ex. } 5.67 \text{ kg} \times 1000 = 5670 \text{ grams}$$

The new unit is renamed by changing the prefix, as shown in **Table 2.** For example, one millionth of a meter is one *micro*meter. One thousand grams is one *kilo*gram. **Table 3** shows some common objects and their measurements in SI units.

Table 1 SI Base Units		
Quantity	**Unit**	**Symbol**
length	meter	m
mass	kilogram	kg
temperature	kelvin	K
time	second	s
electric current	ampere	A
amount of substance	mole	mol
intensity of light	candela	cd

Table 2 SI Prefixes	
Prefix	**Multiplier**
giga-	1,000,000,000
mega-	1,000,000
kilo-	1,000
hecto-	100
deka-	10
[unit]	1
deci-	0.1
centi-	0.01
milli-	0.001
micro-	0.000 001
nano-	0.000 000 001

Length

Length is defined as the distance between two points. Lengths measured with different tools can describe a range of things from the distance from Earth to Mars to the thickness of a human hair. In your laboratory activities, you usually will measure length with a metric ruler or meterstick.

The **meter** (m) is the SI unit of length. One meter is about the length of a baseball bat. The size of a room or the dimensions of a building would be measured in meters. For example, the height of the Washington Monument in Washington, D.C. is 169 m.

Smaller objects can be measured in centimeters (cm) or millimeters (mm). The length of your textbook or pencil would be measured in centimeters. A twenty-dollar bill is 15.5 cm long. You would use millimeters to measure the width of the words on this page. To measure the length of small things such as blood cells, bacteria, or viruses, scientists use micrometers (millionths of a meter) and nanometers (billionths of a meter).

A Long Way Sometimes people need to measure long distances, such as the distance a migrating bird travels or the distance from Earth to the Moon. To measure such lengths, you use kilometers. Kilometers might be most familiar to you as the distance traveled in a car or the measure of a long-distance race, as shown in **Figure 8.** The course of a marathon is measured carefully so that the competitors run 42.2 km. When you drive from New York to Los Angeles, you cover 4,501 km.

Figure 8 These runners have just completed a 10-kilometer race—known as a 10K. **Estimate** *how many kilometers is the distance between your home and your school.*


Measurement Accuracy How important are accurate measurements? In 1999, the *Mars Climate Orbiter* disappeared as it was to begin orbiting Mars. NASA later discovered that a unit system error caused the flight path to be incorrect and the orbiter to be lost. Research the error and determine what systems of units were involved. How can using two systems of units cause errors?

Table 3 Common Objects in SI Measurements		
Object	**Type of Measurement**	**Measurement**
can of soft drink	volume	355 mL
bag of potatoes	mass	4.5 kg
fluorescent tube	length	1.2 m
refrigerator	temperature	276 K

Figure 9 A cubic meter equals the volume of a cube 1 m by 1 m by 1 m.
Infer *how many cubic centimeters are in a cubic meter.*
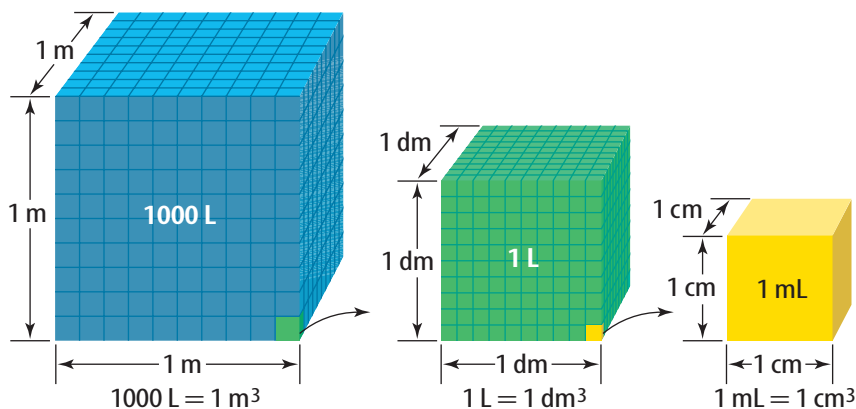
1 m
1 m
1 m
1000 L
1 m
1000 L = 1 m³

1 dm
1 dm
1 dm
1 L
1 dm
1 L = 1 dm³

1 cm
1 cm
1 cm
1 mL
1 cm
1 mL = 1 cm³

Volume

The amount of space an object occupies is its **volume.** Units of volume are created by multiplying units of length. Therefore, they are not base units and are not listed in **Table 1.** The cubic meter (m³), shown in **Figure 9,** is the SI unit of volume. You can measure smaller volumes with the cubic centimeter (cm³ or cc). To find the volume of a square or rectangular object, such as a brick or your textbook, measure its length, width, and height and multiply them together. What is the volume of a compact disc case?

You are probably familiar with a 2-L bottle. A liter is a measurement of liquid volume. A cube 10 cm by 10 cm by 10 cm holds 1 L (1,000 cm³) of water. A cube 1 cm on each side holds 1 mL (1 cm³) of water.

Volume by Immersion Not all objects have an even, regular shape. How can you find the volume of something irregular like a rock or a piece of metal?

Have you ever added ice cubes to a nearly full glass of water only to have the water overflow? Why did the water overflow? Did you suddenly have more water? The volume of water did not increase at all, but the water was displaced when the ice cubes were added. Each ice cube takes up space or has volume. The difference in the volume of water before and after the addition of the ice cubes equals the volume of the ice cubes that are under the surface of the water.

The ice cubes took up space and caused the total volume in the glass to increase. The volume of an irregular object can be measured the same way. Start with a known volume of water and drop in, or immerse, the object. The increase in the volume of water is equal to the volume of the object.
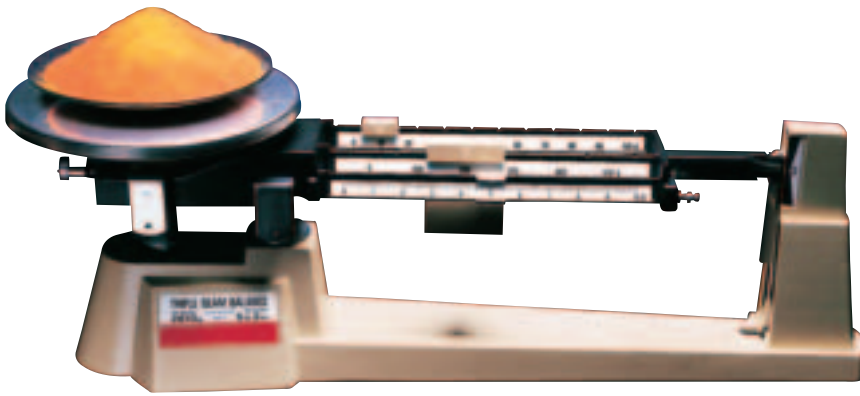
Figure 10 A triple beam balance compares an unknown mass to known masses.

Mass

The **mass** of an object measures the amount of matter in the object. The **kilogram** (kg) is the SI unit for mass. One liter of water has a mass of about 1 kg. Smaller masses are measured in grams (g). One gram is about the mass of a large paper clip.

You can determine mass with a triple-beam balance, shown in **Figure 10.** The balance compares an object to a known mass. It is balanced when the known standard mass of the slides on the balance is equal to the object on the pan.

Why use the word *mass* instead of *weight?* Weight and mass are not the same. Mass depends only on the amount of matter in an object. If you ride in an elevator in the morning and then ride in the space shuttle later that afternoon, your mass is the same. Mass does not change when only your location changes.

Weight **Weight** is a measurement of force. The SI unit for weight is the newton (N). Weight depends on gravity, which can change depending on where the object is located. A spring scale measures how a planet's gravitational force pulls on objects. Several spring scales are shown in **Figure 11.**

If you were to travel to other planets, your weight would change, even though you would still be the same size and have the same mass. This is because gravitational force is different on each planet. If you could take your bathroom scale, which uses a spring, to each of the planets in this solar system, you would find that you weigh much less on Mars and much more on Jupiter. A mass of 75 pounds, or 34 kg, on Earth is a weight of 332 N. On Mars, the same mass is 126 N, and on Jupiter it is 782 N.
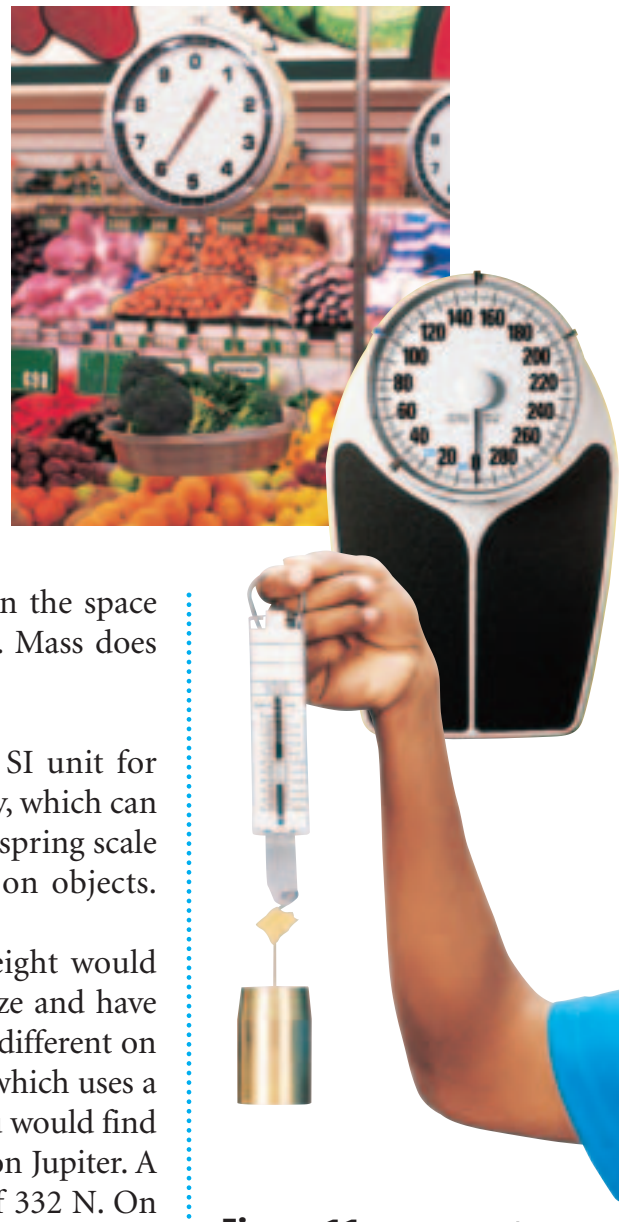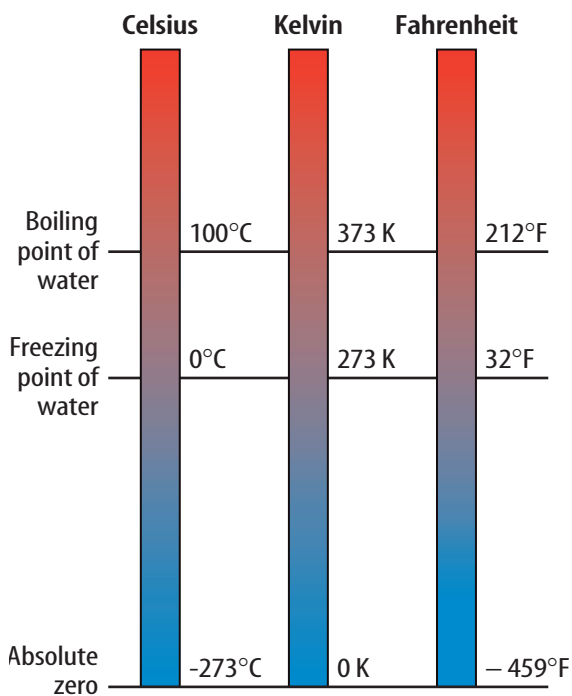
Reading Check *What does weight measure?*

Figure 11 A spring scale measures an object's weight by how much it stretches a spring.

Figure 12 The kelvin scale starts at 0 K. In theory, 0 K is the coldest temperature possible in nature.

	Celsius	Kelvin	Fahrenheit
Boiling point of water	100°C	373 K	212°F
Freezing point of water	0°C	273 K	32°F
Absolute zero	-273°C	0 K	− 459°F

Temperature

The physical property of temperature is related to how hot or cold an object is. Temperature is a measure of the kinetic energy, or energy of motion, of the particles that make up matter.

Temperature is measured in SI with the **kelvin** (K) scale. The Fahrenheit and Celsius temperature scales are the two most common scales used on thermometers and in classroom laboratories. These two scales do not start at zero, as shown in **Figure 12.** A 1 K difference in temperature is the same as a 1°C difference in temperature.

Time and Rates

Time is the interval between two events. The SI unit of time is the second (s). Time also is measured in hours (h). Can you imagine hearing that a marathon was run in 7,620 s instead of 2 h and 7 min?

A **rate** is the amount of change of one measurement in a given amount of time. One rate you are familiar with is speed, which is the distance traveled in a given time. Speeds often are measured in kilometers per hour (km/h).

The unit that is changing does not necessarily have to be an SI unit. For example, you can measure the number of cars that pass through an intersection per hour in cars/h.

section 2 review

Summary

The International System

- The International System of Units, SI, was established to provide a standard of physical measurement and to reduce international confusion when comparing measurements.

Measurement

- Length is the distance between two points.
- Volume is the amount of space an object occupies.
- To calculate volume, multiply length by width by height.
- The amount of matter in an object is its mass.
- Weight is determined by gravitational pull.
- Celsius temperature scales are more common in laboratories than kelvin scales.

Self Check

1. **Describe** a situation in which different units of measure could cause confusion.
2. **Define** what type of quantity the cubic meter measures.
3. **Explain** how you would change a measurement in centimeters to kilometers.
4. **Identify** what SI unit replaces the pound. What does this measure?
5. **Think Critically** How would you find the mass of a metal cube?

Applying Math

6. **Measure** A block of wood is 0.2 m by 0.1 m by 0.5 m. Find its dimensions in centimeters. Then find its volume in cubic centimeters.

Scale Drawing

A scale drawing is used to represent something that is too large or too small to be drawn at its actual size. Blueprints for a house are a good example of a scale drawing.

▶ Real-World Question

How can you represent your classroom accurately in a scale drawing?

Goals
- **Measure** using SI.
- **Make** a data table.
- **Calculate** new measurements.
- **Make** an accurate scale drawing.

Materials
1-cm graph paper   metric ruler
pencil   meterstick

▶ Procedure

1. Use your meterstick to measure the length and width of your classroom. Note the locations and sizes of doors and windows.
2. **Record** the lengths of each item in a data table similar to the one below.
3. Use a scale of 2 cm = 1 m to calculate the lengths to be used in the drawing. Record them in your data table.
4. **Draw** the floor plan. Include the scale.

Room Dimensions		
Part of Room	Distance in Room (m)	Distance on Drawing (cm)
Do not write in this book.		

▶ Conclude and Apply

1. How did you calculate the lengths to be used on your drawing? Did you put a scale on your drawing?
2. **Infer** what your scale drawing would look like if you chose a different scale?
3. **Sketch** your room at home, estimating the distances. Compare this sketch to your scale drawing of the classroom. When would you use each type of illustration?
4. What measuring tool simplifies this task?

Communicating Your Data

Measure your room at home and compare it to the estimates on your sketch. Explain to someone at home what you did and how well you estimated the measurements. **For more help, refer to the Science Skill Handbook.**

Drawings, Tables, and Graphs

What You'll Learn

- **Describe** how to use pictures and tables to give information.
- **Identify** and use three types of graphs.
- **Distinguish** the correct use of each type of graph.

Why It's Important

Illustrations, tables, and graphs help you communicate data about the world around you in an organized and efficient way.

Review Vocabulary

model: a representation of an object or event used as a tool for understanding the natural world

New Vocabulary

- table
- graph
- line graph
- bar graph
- circle graph

Scientific Illustrations

Most science books include pictures. Photographs and drawings model and illustrate ideas and sometimes make new information clearer than written text can. For example, a drawing of an airplane engine shows how all the parts fit together much better than several pages of text could describe it.

Drawings A drawing is sometimes the best choice to show details. For example, a canyon cut through red rock reveals many rock layers. If the layers are all shades of red, a drawing can show exactly where the lines between the layers are. A drawing can emphasize only the things that are necessary to show.

A drawing also can show things you can't see. You can't see the entire solar system, but drawings show you what it looks like. Also, you can make quick sketches to help model problems. For example, you could draw the outline of two continents to show how they might have fit together at one time.

Drawings can show hidden things, as well. A drawing can show the details of the water cycle, as in **Figure 13.** Architects use drawings to show what the inside of a building will look like. Biologists use drawings to show where the nerves in your arm are found.

Figure 13 This drawing shows details of the water cycle that can't be seen in a photograph.
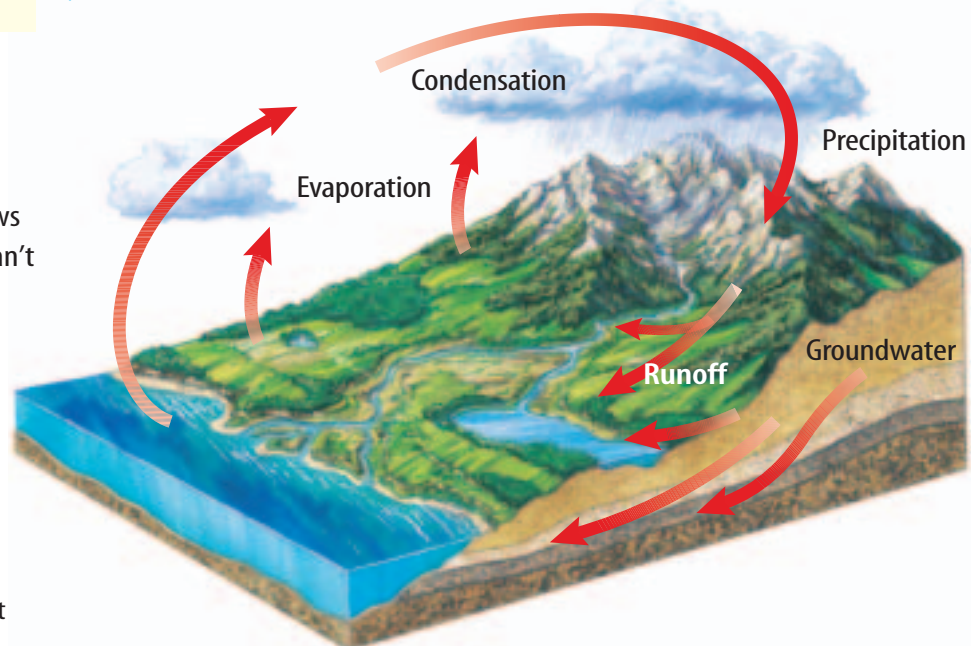
Photographs A still photograph shows an object exactly as it is at a single moment in time. Movies show how an object moves and can be slowed down or sped up to show interesting features. In your schoolwork, you might use photographs in a report. For example, you could show the different types of trees in your neighborhood for a report on ecology.

Tables and Graphs

Everyone who deals with numbers and compares measurements needs an organized way to collect and display data. A *table* displays information in rows and columns so that it is easier to read and understand, as seen in **Table 4.** The data in the table could be presented in a paragraph, but it would be harder to pick out the facts or make comparisons.

A **graph** is used to collect, organize, and summarize data in a visual way. The relationships between the data often are seen more clearly when shown in a graph. Three common types of graphs are line, bar, and circle graphs.

Line Graph A **line graph** shows the relationship between two variables. A variable is something that can change, or vary, such as the temperature of a liquid or the number of people in a race. Both variables in a line graph must be numbers. An example of a line graph is shown in **Figure 14.** One variable is shown on the horizontal axis, or *x*-axis, of the graph. The other variable is placed along the vertical axis, or *y*-axis. A line on the graph shows the relationship between the two variables.

Table 4 Endangered Animal Species in the United States

Year	Number of Endangered Animal Species
1984	192
1986	213
1988	245
1990	263
1992	284
1994	321
1996	324
1998	357
2000	379
2002	389

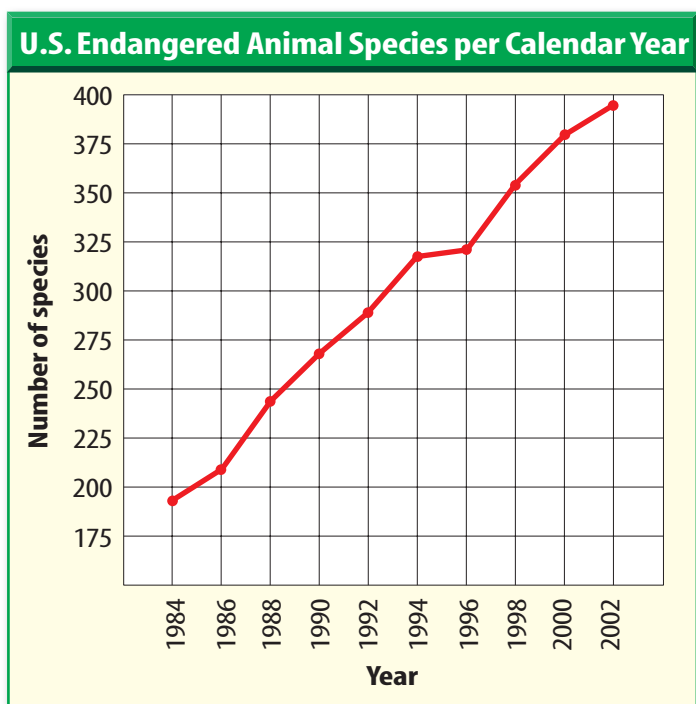U.S. Endangered Animal Species per Calendar Year

Figure 14 To find the number of endangered animal species in 1992, find that year on the *x*-axis and see what number corresponds to it on the *y*-axis.
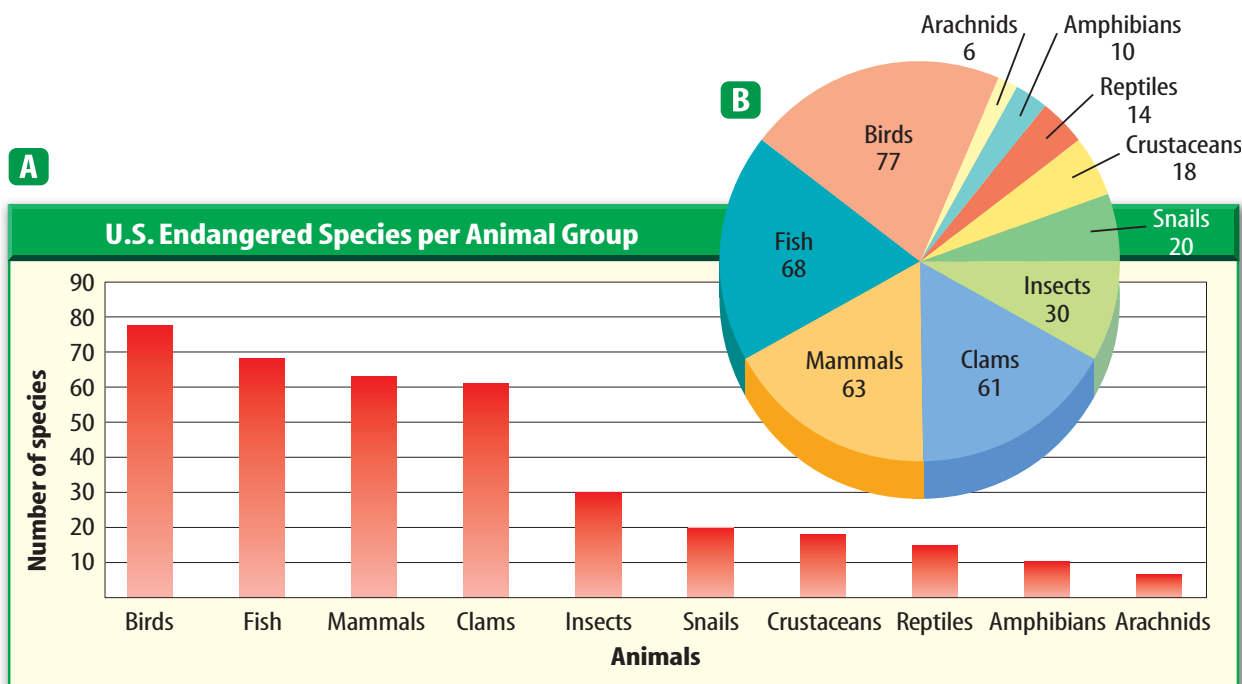**Interpret Data** *How many species were endangered in 1998?*

U.S. Endangered Species per Animal Group

A Bar graph: Number of species vs Animals (Birds, Fish, Mammals, Clams, Insects, Snails, Crustaceans, Reptiles, Amphibians, Arachnids)

B Circle graph: Birds 77, Arachnids 6, Amphibians 10, Reptiles 14, Crustaceans 18, Snails 20, Insects 30, Clams 61, Mammals 63, Fish 68

Figure 15 **A** Bar graphs allow you to picture the results easily. **B** On this circle graph, you can see what part of the whole each animal represents.
Infer *Which category of animals has the most endangered species?*

Bar Graph A **bar graph** uses rectangular blocks, or bars, of varying sizes to show the relationships among variables. One variable is divided into parts. It can be numbers, such as the time of day, or a category, such as an animal. The second variable must be a number. The bars show the size of the second variable. For example, if you made a bar graph of the endangered species data from **Figure 14,** the bar for 1990 would represent 263 species. An example of a bar graph is shown in **Figure 15A.**

Circle Graph Suppose you want to show the relationship among the types of endangered species. A **circle graph** shows the parts of a whole. Circle graphs are sometimes called pie graphs. Each piece of pie visually represents a fraction of the total. Looking at the circle graph in **Figure 15B,** you see quickly which animals have the highest number of endangered species by comparing the sizes of the pieces of pie.

A circle has a total of 360°. To make a circle graph, you need to determine what fraction of 360 each part should be. First, determine the total of the parts. In **Figure 15B,** the total of the parts, or endangered species, is 367. One fraction of the total, *Mammals,* is 63 of 367 species. What fraction of 360 is this? To determine this, set up a ratio and solve for *x:*

$$\frac{63}{367} = \frac{x}{360°} \qquad x = 61.8°$$

Mammals will have an angle of 61.8° in the graph. The other angles in the circle are determined the same way.

Reading Check *What is another name for a circle graph?*

A U.S. Endangered Animal Species per Year

B U.S. Endangered Animal Species per Year
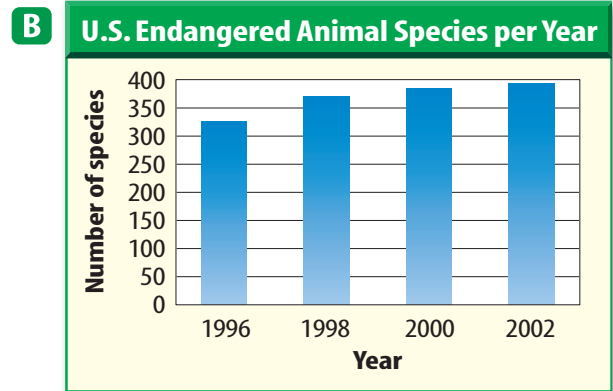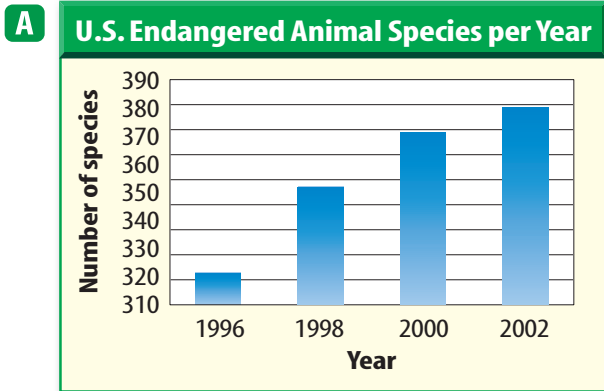
Reading Graphs When you are using or making graphs to display data, be careful—the scale of a graph can be misleading. The way the scale on a graph is marked can create the wrong impression, as seen in **Figure 16A.** Until you see that the *y*-axis doesn't start at zero, it appears that the number of endangered species has quadrupled in just six years.

This is called a broken scale and is used to highlight small but significant changes, just as an inset on a map draws attention to a small area of a larger map. **Figure 16B** shows the same data on a graph that does not have a broken scale. The number of species has only increased 20 percent from 1996 to 2002. Both graphs have correct data, but must be read carefully. Always analyze the measurements and graphs that you come across. If there is a surprising result, look closer at the scale.

Figure 16 Careful reading of graphs is important. **A** This graph does not start at zero, which makes it appear that the number of species has more than quadrupled from 1996–2002. **B** The actual increase is about 20 percent, as you can see from this full graph. The broken scale must be noted in order to interpret the results correctly.

section 3 review

Summary

Scientific Illustrations

- Drawings and illustrations can help people visualize complex concepts.
- A drawing can include details you see and those that are hidden.
- Photographs are an exact representation of an object at a single moment in time.

Tables and Graphs

- Tables display information while graphs are used to summarize data.
- A line graph shows the relationship between two variables, a bar graph shows the relationship among variables, and a circle graph shows the parts of a whole.
- It is important to pay close attention to the scale on graphs in order to analyze the information.

Self Check

1. **Explain** how to use **Figure 16** to find the number of endangered species in 1998.
2. **Infer** what type of graph you would use to display data gathered in a survey about students' after-school activities.
3. **Think Critically** Why is it important to be careful when making or using graphs?
4. **Describe** a time when an illustration would be helpful in everyday activities.
5. **Identify** when you would use a broken scale.

Applying Skills

6. **Use a Spreadsheet** Make a spreadsheet to display how the total mass of a 500-kg elevator changes as 50-kg passengers are added one at a time.

PACE YOURSELF

▶ Real-World Question

Track meets and other competitions require participants to walk, run, or wheel a distance that has been precisely measured. Officials make sure all participants begin at the same time, and each person's time is stopped at the finish line. If you are practicing for a local marathon or 10K, you need to know your speed or pace in order to compare it with those of other participants. How can your performance be measured accurately? How will you measure the speed of each person in your group? How will you display these data?

▶ Form a Hypothesis

Think about the information you have learned about precision, measurement, and graphing. In your group, make a hypothesis about a technique that will provide you with the most precise measurement of each person's pace.

▶ *Test Your Hypothesis*

Make a Plan

1. As a group, decide what materials you will need.

2. How far will you travel? How will you measure that distance? How precise can you be?

3. How will you measure time? How precise can you be?

4. List the steps and materials you will use to test your hypothesis. Be specific. Will you try any part of your test more than once?

5. Before you begin, create a data table. Your group must decide on its design. Be sure to leave enough room to record the results for each person's time. If more than one trial is to be run for each measurement, include room for the additional data.

Follow Your Plan

1. Make sure that your teacher approves your plan before you start.

2. Carry out the experiment as planned and approved.

3. Be sure to record your data in the data table as you proceed with the measurements.

▶ *Analyze Your Data*

1. **Graph** your data. What type of graph would be best?

2. Are your data table and graph easy to understand? Explain.

3. How do you know that your measurements are precise?

4. Do any of your data appear to be out of line with the rest?

▶ *Conclude and Apply*

1. **Explain** how it is possible for different members of a group to find different times while measuring the same event.

2. **Infer** what tools would help you collect more precise data.

3. What other data displays could you use? What are the advantages and disadvantages of each?

Communicating Your Data

Make a larger version of your graph to display in your classroom with the graphs of other groups. **For more help, refer to the Science Skill Handbook.**

Richard Hutchings

SCIENCE Stats

Biggest, Tallest, Loudest

Did you know...

... The world's most massive flower belongs to a species called *Rafflesia* (ruh FLEE zhee uh) and has a mass of up to 11 kg. The diameter, or the distance across the flower's petals, can measure up to 1 m.

... The world's tallest building is the Petronus Towers in Kuala Lumpur, Malaysia. It is 452 m tall. The tallest building in the United States is Chicago's Sears Tower, shown here, which measures 442 m.

Applying Math How many of the largest rafflesia petals would you have to place side by side to equal the height of the Sears Tower?

...One of the loudest explosions on Earth was the 1883 eruption of Krakatau (krah kuh TAHEW), an Indonesian volcano. It was heard from more than 3,500 km away.

Write About It

Visit **ips.msscience.com/science_stats** to find facts that describe some of the shortest, smallest, or fastest things on Earth. Create a class bulletin board with the facts you and your classmates find.

(t)Fletcher & Baylis/Photo Researchers, (b)Charles O'Rear/CORBIS

Reviewing Main Ideas

Section 1 — Description and Measurement

1. Length, volume, mass, temperature, and rates are used to describe objects and events.

2. Estimation is used to make an educated guess at a measurement.

3. Accuracy describes how close a measurement is to the true value. Precision describes how close measurements are to each other.

Section 2 — SI Units

1. The international system of measurement is called SI. It is used throughout the world for communicating data.

2. The SI unit of length is the meter. Volume— the amount of space an object occupies— can be measured in cubic meters. The mass of an object is measured in kilograms.
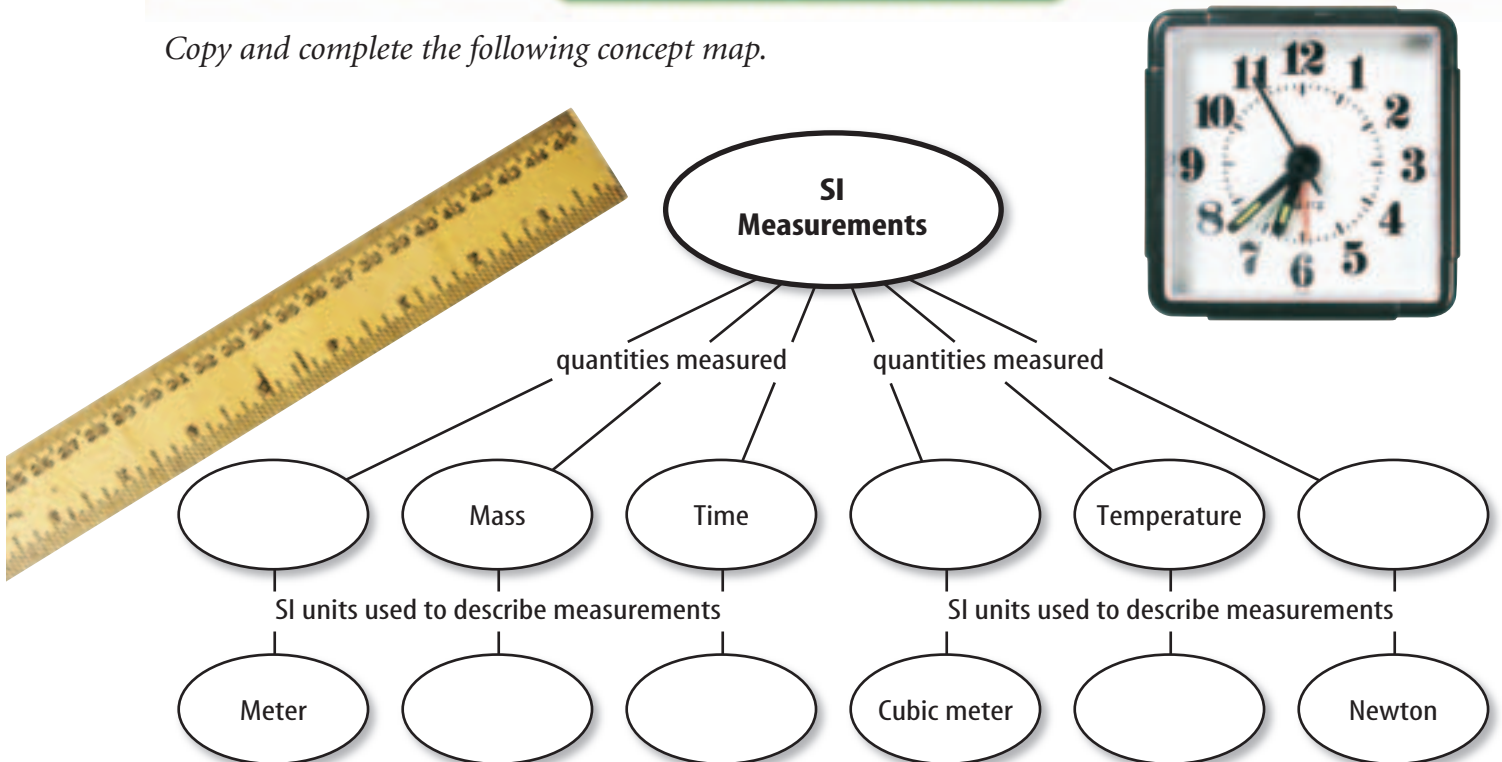
Section 3 — Drawings, Tables, and Graphs

1. Tables, photographs, drawings, and graphs are tools used to collect, organize, summarize, and display data in a way that is easy to use and understand.

2. Line graphs show the relationship between two variables that are numbers on an *x*-axis and a *y*-axis. Bar graphs divide a variable into parts to show a relationship. Circle graphs show the parts of a whole like pieces of a pie.

Visualizing Main Ideas

Copy and complete the following concept map.

SI Measurements

quantities measured   quantities measured

(   )   Mass   Time   (   )   Temperature   (   )

SI units used to describe measurements   SI units used to describe measurements

Meter   (   )   (   )   Cubic meter   (   )   Newton

Using Vocabulary

accuracy p. 45
bar graph p. 58
circle graph p. 58
estimation p. 43
graph p. 57
kelvin p. 54
kilogram p. 53
line graph p. 57
mass p. 53

measurement p. 42
meter p. 51
precision p. 44
rate p. 54
SI p. 50
table p. 57
volume p. 52
weight p. 53

Each phrase below describes a vocabulary word. Write the word that matches the phrase describing it.

1. the SI unit for length

2. a description with numbers

3. a method of making a rough measurement

4. the amount of matter in an object

5. a graph that shows parts of a whole

6. a description of how close measurements are to each other

7. the SI unit for temperature

8. an international system of units

9. the amount of space an object occupies

Checking Concepts

Choose the word or phrase that best answers the question.

10. The measurement 25.81 g is precise to the nearest
    A) gram.
    B) kilogram.
    C) tenth of a gram.
    D) hundredth of a gram.

11. What is the SI unit of mass?
    A) kilometer   C) liter
    B) meter   D) kilogram

12. What would you use to measure length?
    A) graduated cylinder
    B) triple beam balance
    C) meterstick
    D) spring scale

13. The cubic meter is the SI unit of what?
    A) volume   C) mass
    B) weight   D) distance

14. Which term describes how close measurements are to each other?
    A) significant digits
    B) estimation
    C) accuracy
    D) precision

15. Which of the following is a temperature scale?
    A) volume   C) Celsius
    B) mass   D) Mercury

16. Which of the following is used to organize data?
    A) table   C) precision
   B) rate   D) meterstick

17. To show the number of wins for each football team in your district, which of the following would you use?
    A) photograph   C) bar graph
    B) line graph   D) SI

18. To show 25 percent on a circle graph, the section must measure what angle?
    A) 25°   C) 180°
    B) 90°   D) 360°

Science**Online** ips.msscience.com/vocabulary_puzzlemaker

Thinking Critically

19. Infer How would you estimate the volume your backpack could hold?

20. Explain Why do scientists in the United States use SI rather than the English system (feet, pounds, pints, etc.) of measurement?

21. List the following in order from smallest to largest: 1 m, 1 mm, 10 km, 100 mm.

22. Describe Give an example of an instance when you would use a line graph. Could you use a bar graph for the same purpose?

23. Compare and contrast volume, length, and mass. How are they similar? Different? Give several examples of units that are used to measure each quantity. Which units are SI?

24. Infer Computer graphics artists can specify the color of a point on a monitor by using characters for the intensities of three colors of light. Why was this method of describing color invented?

Use the photo below to answer question 25.
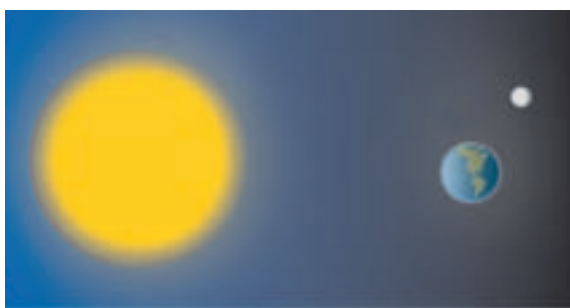
25. Interpreting Scientific Illustrations What does the figure show? How has this drawing been simplified?

Performance Activities

26. Newspaper Search Look through a week's worth of newspapers and evaluate any graphs or tables that you find.

Applying Math

Use the table below to answer question 27.

Areas of Bodies of Water	
Body of Water	**Area (km²)**
Currituck Sound (North Carolina)	301
Pocomoke Sound (Maryland/Virginia)	286
Chincoteague Bay (Maryland/Virginia)	272
Core Sound (North Carolina)	229

27. Make and Use Graphs The table shows the area of several bodies of water. Make a bar graph of the data.

Use the illustration below to answer question 28.

Distance = 2,859.85 km
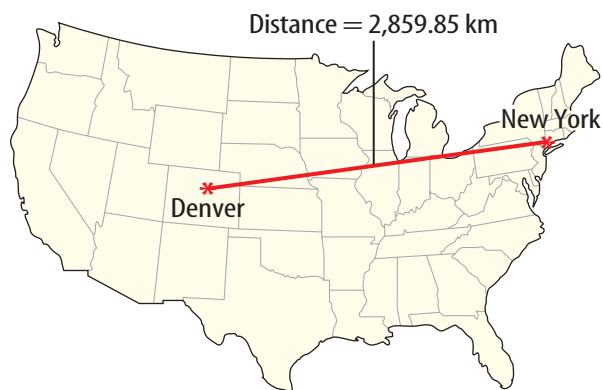
New York

Denver

28. Travel Distances The map above shows the driving distance from New York City to Denver, Colorado in kilometers. Convert the distance to meters and then find out how many meters are in a mile and convert the distance to miles.

29. Round Digits Round the following numbers to the correct number of significant digits.

$$42.86 \text{ kg} \times 38.703 \text{ kg}$$

$$10 \text{ g} \times 25.05 \text{ g}$$

$$5.8972 \text{ nm} \times 34.15731 \text{ nm}$$

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which best describes measurements that are accurate?
   A. They are very close to an accepted value.
   B. They are based on an estimate.
   C. They are very close to each other.
   D. They are not based on numbers.

2. The mass of a sample of calcium chloride is 33.755 grams. Round to the nearest hundredth of a gram.
   A. 33.8 g
   B. 34 g
   C. 33.76 g
   D. 33.75 g

Use the illustration below to answer questions 3 and 4.
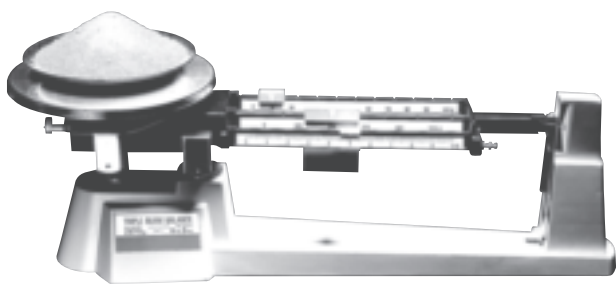
3. Which quantity is measured using this tool?
   A. weight   **C.** volume
   B. mass   **D.** length

4. Which measurement does this balance show?
   A. about 315 g   **C.** about 325 g
   B. about 326 g   **D.** about 215 g

Use the graph below to answer questions 5 and 6.

Phase Changes of H$_2$O
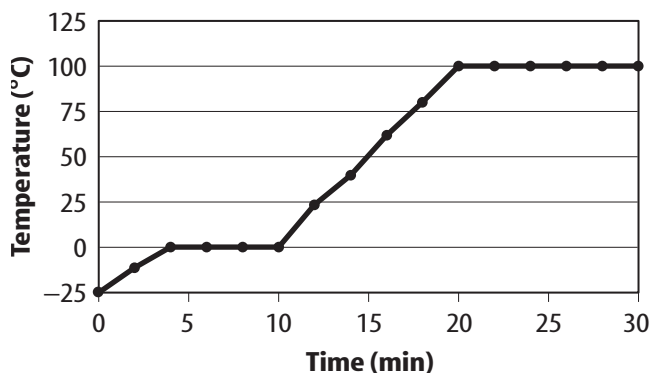
5. The graph shows data from an experiment in which ice was heated until it melted, then became steam. In what phase is the H$_2$O at 16 minutes?
   A. solid   **C.** gas
   B. liquid   **D.** plasma

6. Which statement describes the trend evident in the data?
   A. Temperature continually increased as time increased.
   B. Temperature did not change as time increased.
   C. Temperature increases were divided by plateaus as time increased.
   D. Temperature continually decreased as time increased.

**7.** Which of these represents 1/1000th of a meter?
   A. mm   **C.** ms
   B. km   **D.** dm

8. Which is NOT a unit of volume?
   A. milliliter
   B. cubic centimeter
   C. deciliter
   D. kelvin

Test-Taking Tip

Take Your Time Read carefully and make notes of the units used in any measurement.

Part 2 | Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

9. 35.77 g of Solid A are mixed with 95.3 g of Solid B. Write the mass of the mixture with the correct number of significant digits. Explain your answer.

10. Arrange these measuring tools in order from least to most precise: stopwatch measuring to 1/100ths of a second, atomic clock, sundial, wall clock with 2 hands.

Use the illustration below to answer questions 11 and 12.

4.0 cm
4.0 cm
4.0 cm
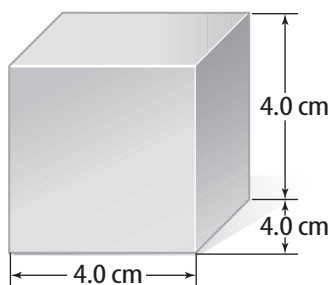
11. Define the term volume. Calculate the volume of the cube shown above. Give your answer in cm^3 and mL.

12. Describe how you would find the volume of the cube using the immersion method.

13. Create a table which shows the differences between mass and weight.

14. How do graphs make it easier to analyze data?

15. Why are drawings an effective way to communicate information?

16. Explain the difference between precision and accuracy.

Part 3 | Open Ended

Record your answers on a sheet of paper.

17. A recipe calls for 1 cup sugar, 1 cup flour, and 1 cup milk. Define the term precision, and explain how to measure these ingredients precisely using kitchen tools.

18. While shopping, you find a rug for your room. Without a ruler, you must estimate the rug's size to determine if it will fit in your room. How will you proceed?

19. Identify the most appropriate SI length unit to measure the following: your height, the distance between two cities, the width of a computer screen, the radius of a coin, the length of a muscle cell. How are units converted in the SI system?

Use the figure below to answer questions 20 and 21.

Composition of Earth's Atmosphere

Nitrogen 78%

Oxygen 21%

Water vapor, carbon dioxide, other gases 1%
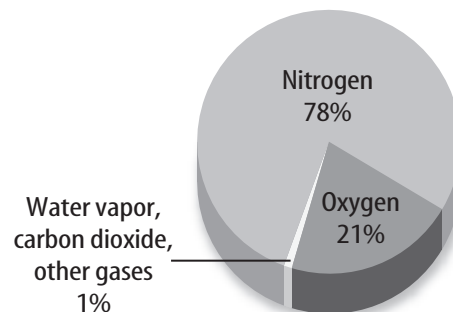
20. Calculate the angle of each section in this circle graph.

21. Create a bar graph using this data.

22. Measurement is a part of everyday life. Describe measurements someone might make as part of his or her normal activities.

23. You must decide what items to pack for a hiking trip. Space is limited, and you must carry all items during hikes. What measurements are important in your preparation?