Your Science Journal During this course, you will be keeping a science journal. You will write down what you do and see during your investigations. Your observations should be detailed enough that another person could read what you wrote and repeat the investigation exactly as you performed it. Instead of writing "the stuff changed color," you might say "the clear liquid turned to bright red when I added a drop of food coloring." Detailed observations written down during an investigation are more reliable than sketchy observations written from memory. Practice your observation skills by describing what you see in **Figure 26.**

Can the data be repeated? If your friend told you he could hit a baseball 100 m, but couldn't do it when you were around, you probably wouldn't believe him. Scientists also require repeatable evidence. When a scientist describes an investigation, as shown in **Figure 27,** other scientists should be able to do the investigation and get the same results. The results must be repeatable. When evaluating scientific data, look to see whether other scientists have repeated the data. If not, the data might not be reliable.

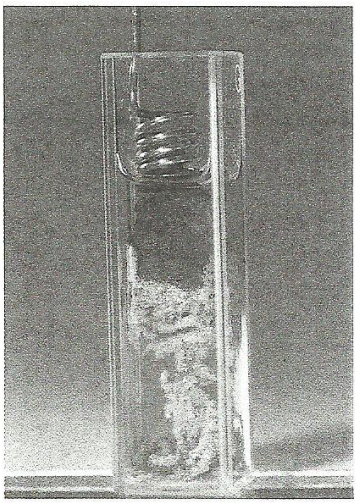


Figure 26 Detailed observations are important in order to get reliable data.
Observe *Use ten descriptive words to describe what you see happening in this photo.*

Evaluating the Conclusions

When you think about a conclusion that someone has made, you can ask yourself two questions. First, does the conclusion make sense? Second, are there any other possible explanations? Suppose you hear on the radio that your school will be running on a two-hour delay in the morning because of snow. You look outside. The roads are clear of snow. Does the conclusion that snow is the cause for the delay make sense? What else could cause the delay? Maybe it is too foggy or icy for the buses to run. Maybe there is a problem with the school building. The original conclusion is not reliable unless the other possible explanations are proven unlikely.

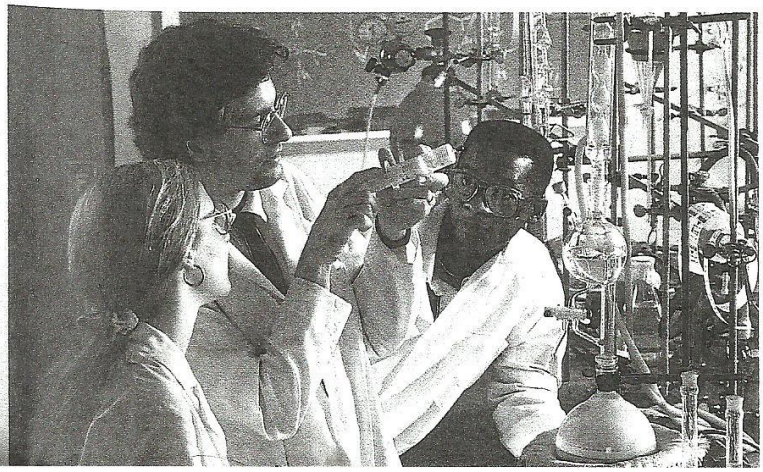


Figure 27 Working together is an important part of science. Several scientists must repeat an experiment and obtain the same results before data are considered reliable.

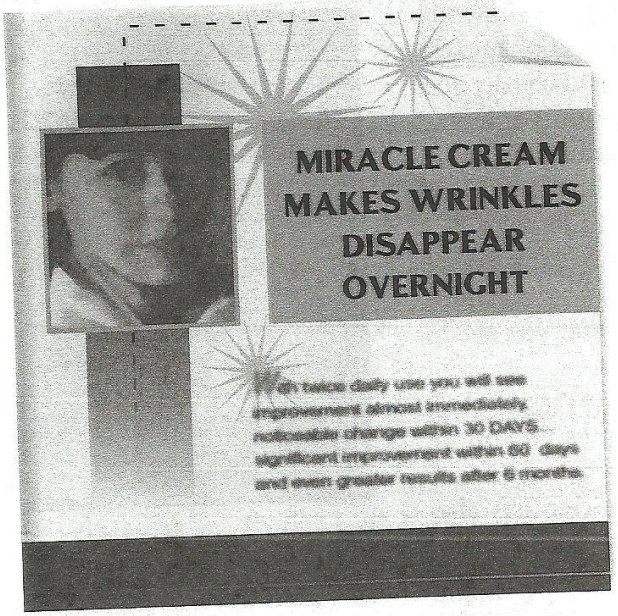


Figure 28 All material should be read with an analytical mind. **Explain** *what this advertisement means.*

Evaluating Promotional Materials

Scientific processes are not used only in the laboratory. Suppose you saw an advertisement in the newspaper like the one in **Figure 28.** What would you think? First, you might ask, "Does this make sense?" It seems unbelievable. You would probably want to hear some of the scientific data supporting the claim before you would believe it. How was this claim tested? How is the amount of wrinkling in skin measured? You might also want to know if an independent laboratory repeated the results. An independent laboratory is one that is not related in any way to the company that is selling the product or service. It has nothing to gain from the sales of the product. Results from an independent laboratory usually are more reliable than results from a laboratory paid by the selling company. Advertising materials are designed to get you to buy a product or service. It is important that you carefully evaluate advertising claims and the data that support them before making a quick decision to spend your money.

section 4 review

Summary

Believe it or not?

- By combining what you already know with new information as it becomes available, you can decide whether something is fact or fiction.
- Explanations should be evaluated by looking at both the observations and the conclusions the explanation is based on.

Evaluating the Data

- It is important to take thorough notes during any investigation.

Evaluating the Conclusions

- In order for a conclusion to be reliable, it must make sense.

Evaluating Promotional Materials

- Independent laboratories test products in order to provide more reliable results.

Self Check

1. **Describe** why it is important that scientific experiments be repeated.
2. **List** what types of scientific claims should be verified.
3. **Explain** how vague claims in advertising can be misleading.
4. **Think Critically** An advertisement on a food package claims it contains Glistain, a safe taste enhancer. Make a list of ten questions you would ask when evaluating this claim.

Applying Skills

5. **Classify** Watch three television commercials and read three magazine advertisements. Record the claims that each advertisement made. Classify each claim as being vague, misleading, reliable, and/or scientific.

ScienceOnline red.msscience.com/self_check_quiz

section 1

Description and Measurement

as you read

What You'll Learn

- **Determine** how reasonable a measurement is by estimating.
- **Identify** and use the rules for rounding a number.
- **Distinguish** between precision and accuracy in measurements.

Why It's Important

Measurement helps you communicate information and ideas.

Review Vocabulary

description: an explanation of an observation

New Vocabulary

- measurement
- precision
- estimation
- accuracy

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"?

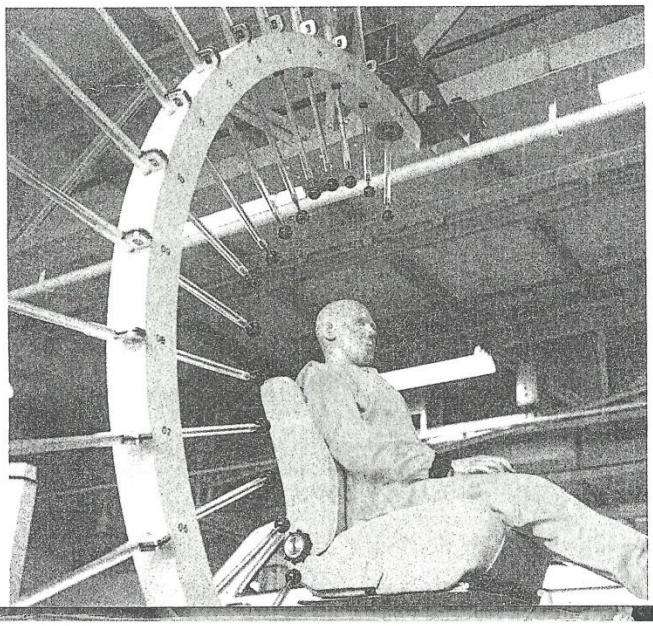


Figure 1 This device measures the range of motion of a seat-belted mannequin in a simulated accident.

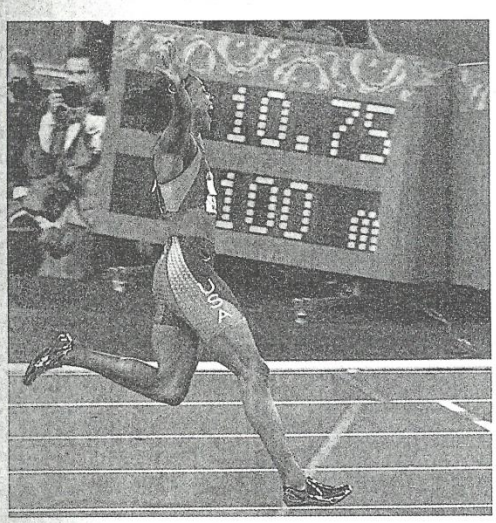


Figure 2 Accurate measurement of distance and time is important for competitive sports like track and field.
Infer *Why wouldn't a clock that measured in minutes be precise enough for this race?*

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.

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?

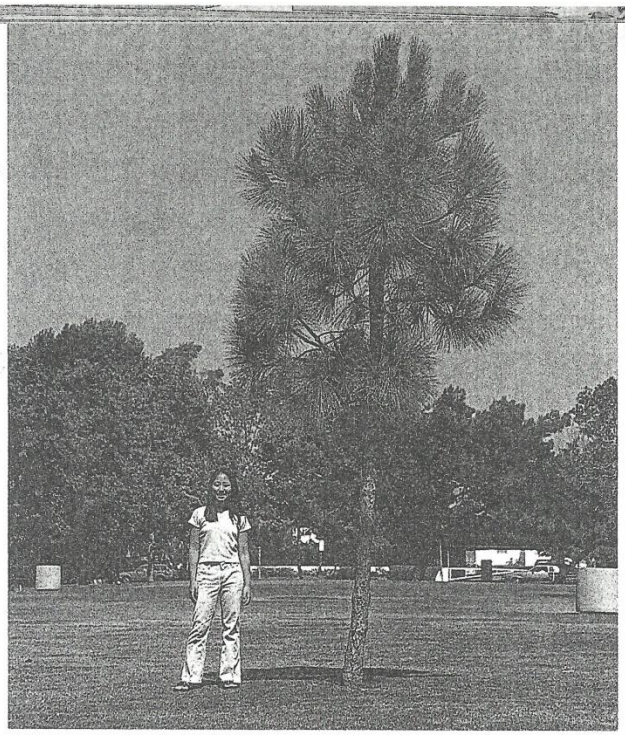


Figure 3 This student is about 1.5 m tall. **Estimate** *the height of the tree in the photo.*

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.

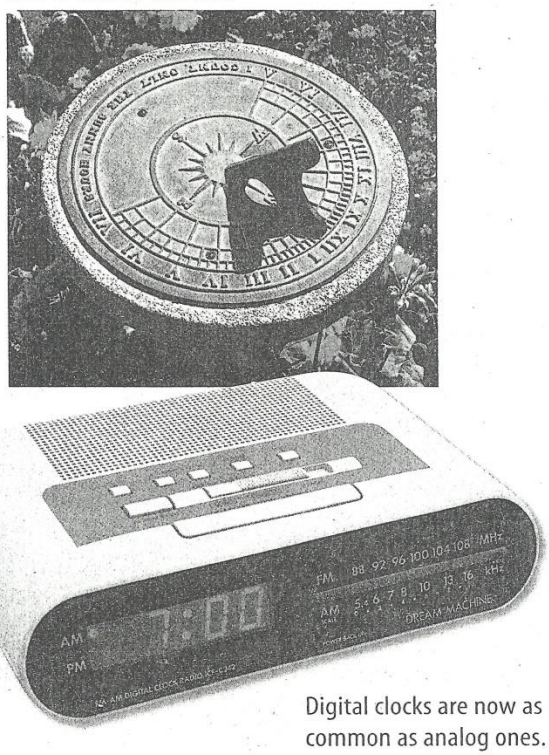
Accuracy When you compare a measurement to the real, actual, or accepted value, you are describing **accuracy.** A watch with a second hand is more precise than one with only an hour hand, but if it is not properly set, the readings could be off by an hour or more. Therefore, the watch is not accurate. 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.

INTEGRATE Health

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.

Science Online

Topic: Measurement

Visit red.msscience.com for Web links to information about the importance of accuracy and precision in the medical field.

Activity Research a topic of interest on the Internet and present the topic and numeric data to your class. How might your classmates' understanding of the topic be affected if you presented crucial information inaccurately?

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

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.

Science Online — For more practice, visit red.msscience.com/math_practice

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.

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

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.

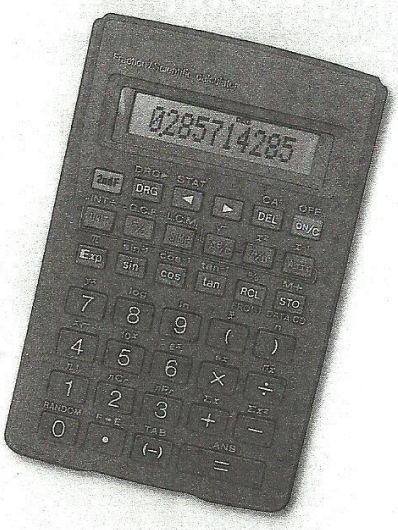


Figure 7 Sometimes considering the size of each digit will help you realize they are unneeded. In this calculation, the seven ten-thousandths of a liter represents just a few drops of soft drink.

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.**

section 2

SI Units

as you read

What You'll Learn

- **Identify** the purpose of SI.
- **Identify** the SI units of length, volume, mass, temperature, time, and rate.

Why It's Important

The SI system is used throughout the world, allowing you to measure quantities in the exact same way as other students around the world.

Review Vocabulary

variable: factors that can be changed in an experiment

New Vocabulary

- SI
- meter
- volume
- mass
- kilogram
- weight
- kelvin
- rate

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.

Ex. 5.67 kg × 1000 = 5670 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