Chapter 2
The Science Toolbox

Many tools are used in science. What is the most important tool? It's your brain! Among other things, your brain allows you to ask questions and make hypotheses. Other science tools allow you to make measurements and collect data. An experiment is also a science tool. Some science tools are big and heavy like huge telescopes. Some are small and easy to carry like a ruler. Let's go look in the science toolbox and see what else is in there.

Key Questions

1. *Why is your brain a good scientific tool?*
2. *Will a toy car go faster on a steeper ramp?*
3. *Can you design an experiment to find out the best tasting chocolate chip cookie?*

2.1 Measurement

An important step in the scientific method is collecting data. Measurements are one form of data. Measurements tell you how big or how small something is. Measurements also help you compare objects.

What is a measurement?

A number plus a unit

A **measurement** is a number that includes a *unit*. A **unit** is a specific quantity that is counted to make a measurement. The unit provides information about the type of measurement.

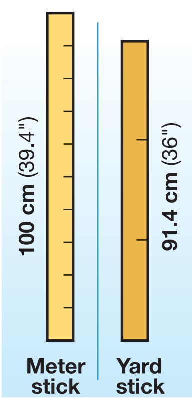
Why are units important?

Let's use an example. A basketball player might say, "I'm tall! I'm almost 2 high."

You might think "almost 2" doesn't sound very tall.

The basketball player is not tall if his height is almost 2 *feet*. A medium-sized dog is about two feet tall. However, the basketball player *is* tall if he is almost 2 *meters* tall. Two meters equals a height of about 6 feet 6 inches (Figure 2.1).

The words "meters" and "feet" are units. Always include a unit when making measurements. Do you see why this is important?



Activity: How tall are you in feet and meters?

Find a partner. You and your partner will need two measuring tools: a yardstick and a meter stick. Use the yardstick to measure height in feet and inches. Use the meter stick to measure height in meters and centimeters. Measure your partner's height. Your partner will measure your height.

How tall are you in feet and inches?
How tall are you in meters and centimeters?

VOCABULARY

measurement - a number that includes a unit.

unit - a specific quantity that is counted to make a measurement.

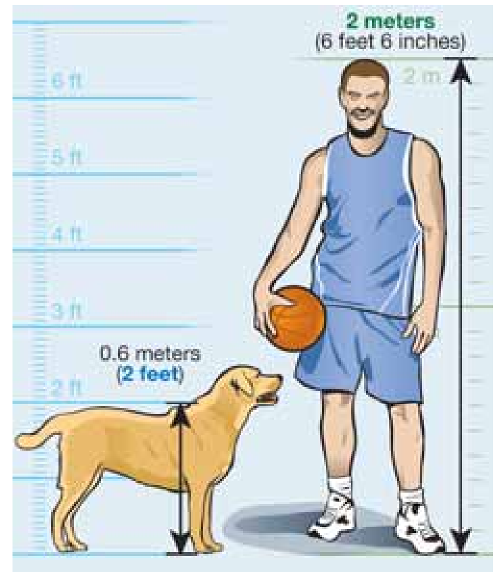


Figure 2.1: *A measurement includes a number and a unit. Two meters is much taller than two feet!*

A history of measuring systems

English System of measurement At one time, the English System of measurements included nearly a dozen units just for weight. For example, a pharmacist weighed medicine in *grains*, a jeweler weighed gold and gems in *carats*, and a carpenter weighed his nails in *kegs* (Figure 2.2). These units were hard to compare to each other.

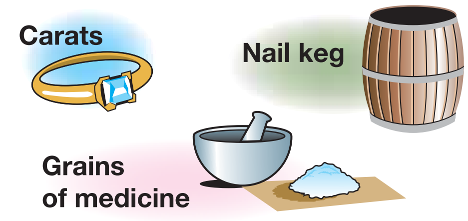
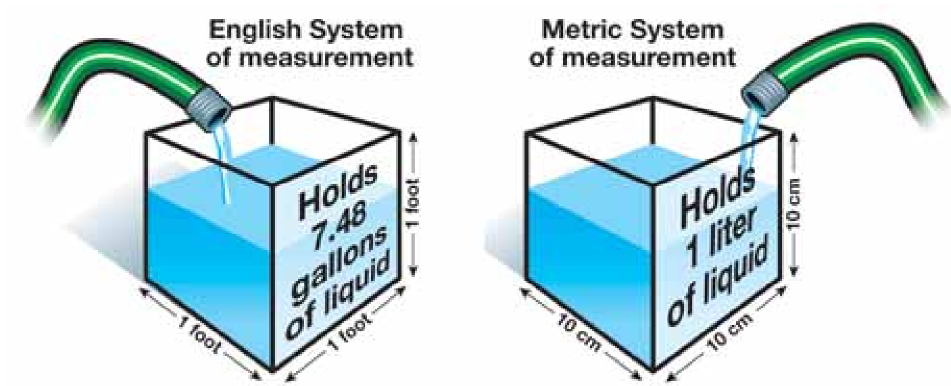


Figure 2.2: *Measurements in the early English system.*

The Metric System During the 1800s, a new system of measurement was developed in Europe and Great Britain—the Metric System. The goal of this system was for all units of measurement to be related to each other. It was a *base-10* system, meaning that all units were a factor of 10.

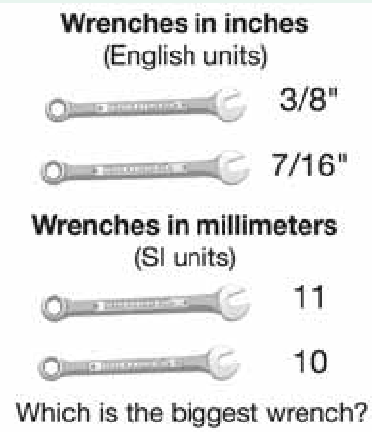
Comparing the systems Centimeters (cm) relate to liters in the Metric System. A 10 cm × 10 cm × 10 cm cube holds exactly 1 liter of liquid. However, in the English system, feet do not relate easily to gallons. A cube that is 1 foot × 1 foot × 1 foot holds about 7.48 gallons of liquid.



SI Units The General Conference on Weights and Measures changed the name of the Metric System to the International System of Units in 1960. Most people refer to it as SI units or SI measurements, from its official French name, Le Système International d'Unités. From now on, we will refer to this system as SI Units.

English and SI units

Imagine that you are working on your bicycle and find that the wrench that you have selected is one size too small. The graphic below shows that it is easier to pick the next bigger size if you use SI units than if you use English units.



More about SI units

The meter is the basic unit

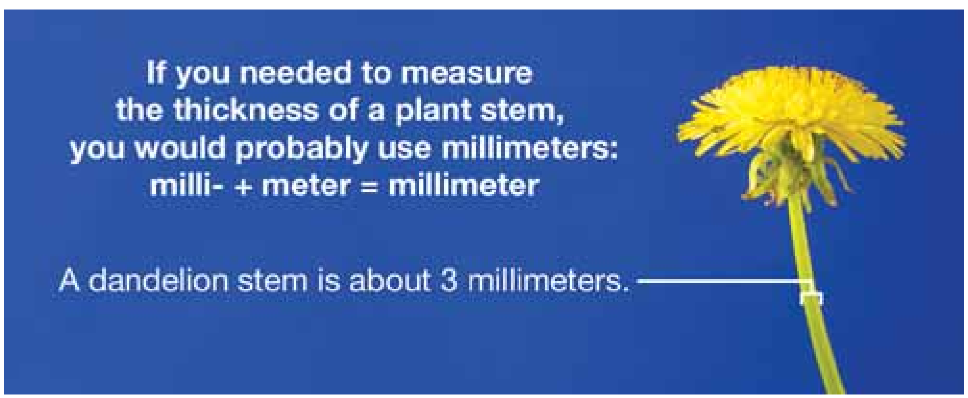
The **meter** is the basic distance unit for the SI Units system of measurement. The meter is also the basis for this system. It was decided that the meter would be equal to one ten-millionth of the distance from the North Pole to the equator, measured along a line that passed through Paris, France (Figure 2.3).

There is nothing special about the length of the meter or how it was chosen. However, the meter was a good starting place for developing the rest of the SI Units system of measurement.

Useful prefixes

Prefixes are added to the names of basic units in the SI Units system. Prefixes describe very small or large measurements. There are many SI units prefixes. The good news is that only three prefixes are needed most of the time, even in science.

Prefixes	Prefix + meter	Compared to a meter
milli-	millimeter	1,000 times smaller
centi-	centimeter	100 times smaller
kilo-	kilometer	1,000 times bigger



VOCABULARY

meter - the basic distance unit for the SI Units system of measurement.

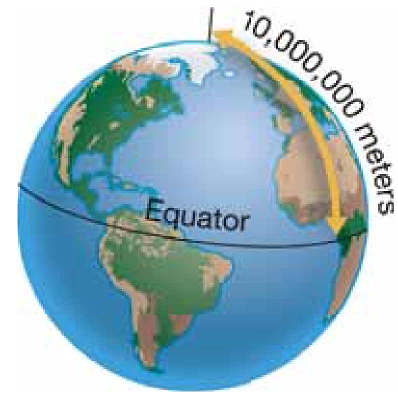


Figure 2.3: *In 1791, a meter was defined as 1/10,000,000 of the distance from the North Pole of Earth to its equator. Today a meter is defined more accurately using the speed of light.*

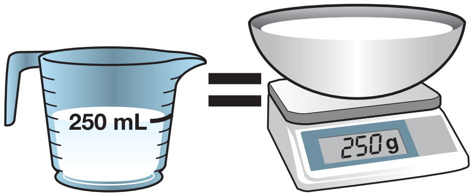
Volume and mass

Volume **Volume** measures how much space is occupied by an object. One way to think of a volume measurement is as a measure with three distance measurements. The formula for the volume of a rectangular solid is length × width × height.

The liter The basic SI unit of volume is the **liter**. The liter is based on the centimeter. The prefix *centi-* means 1/100. A centimeter is one-hundredth of a meter—about the width of a pencil. A liter of volume is equal to the volume of a cube-shaped box that is 10 centimeters on each side (Figure 2.4).

The gram A **gram** is the basic unit of *mass* in the SI Units measuring system. Water, a common substance, was wisely chosen as the material to define the gram. The water used to determine the mass of a gram must be pure, and the temperature and pressure have to be just right. A gram is defined as the mass of one-thousandth of a liter of pure water. Using prefixes, this means a gram is the mass of a *milliliter* of water. You will learn more about mass in Section 2.2.

Cooking with grams Around the world, many cooks measure the volume of ingredients in a mixing bowl using grams. They use a small electronic scale and weigh dry and wet ingredients in grams in the same bowl on the scale. This is possible because many wet ingredients are mostly water. Rather than measure 250 mL of milk into a cup, the cook adds 250 grams of milk to the bowl on the scale. This technique makes for a fast cleanup since only one bowl is needed for measuring all of the ingredients!



250 milliliters of milk equals 250 grams of milk

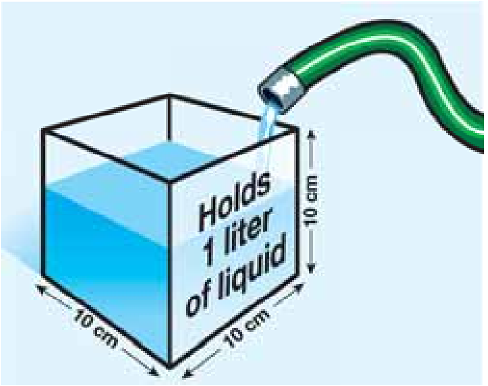


Figure 2.4: *A liter of volume is equal to the volume of a cube-shaped box that is 10 centimeters on each side.*

VOCABULARY

volume - a measurement of how much space is occupied by an object.

liter - the basic unit of volume in the SI Units measuring system.

gram - the basic unit of mass in the SI Units measuring system; one-thousandth of a liter.

Measuring volume with SI units

Measuring volume with distance

If an object is a solid cube or rectangle, you can measure its length, width, and height in SI units. These measurements are multiplied to find the volume in cubic SI units. If the measurements are taken in centimeters, the result of the multiplication will be in cubic centimeters or cm^3. This way of measuring SI volume is best suited for solid objects with parallel sides, but is also used for large volumes. For example, the volume of a lake may be measured in cubic meters (m^3) (Figure 2.5).

Measuring small volumes of liquid

The volume of liquids can be measured by pouring them into containers like beakers or graduated cylinders (Figure 2.6). Volume found this way is reported in milliliters (mL). This way of measuring SI volumes is best suited for small volumes of liquid.

The graphic below illustrates the two ways to measure volume in SI units. Regardless of the method chosen, the result is the same!

A liter is a cube that measures 10 cm on each side.

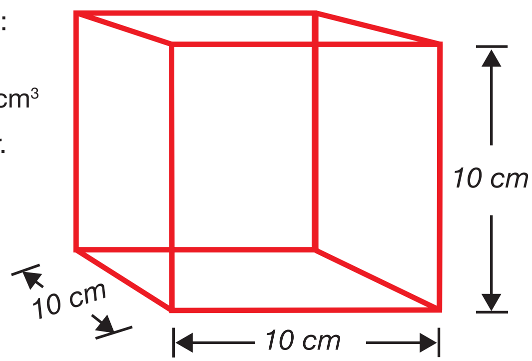
The volume of this 1-liter cube is:

Length × width × height
10 cm × 10 cm × 10 cm = 1000 cm^3

There are 1000 milliliters in a liter.

1000 milliliters = 1000 cm^3

1 milliliter = 1 cm^3



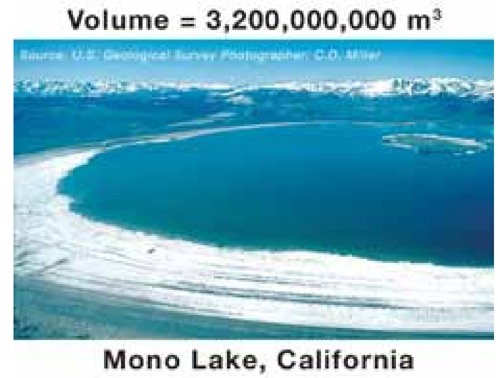


Figure 2.5: *Large volumes are measured in cubic meters. The volume of Mono Lake in California is about 3,200,000,000 cubic meters (measurement made in 2002).*

Figure 2.6: *A beaker and a graduated cylinder are used to measure small volumes.*

2.1 Section Review

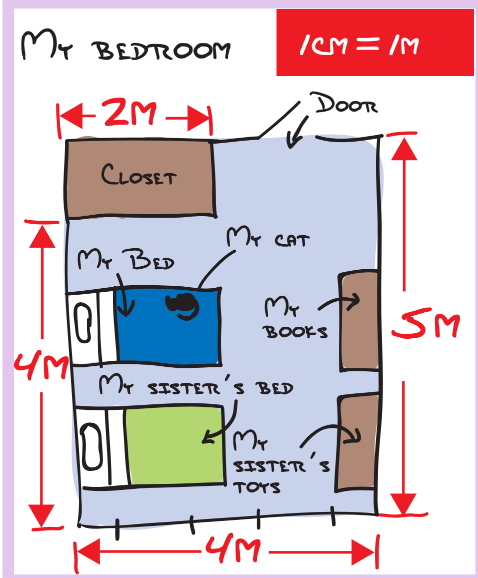
Answer the following questions. For questions 3, 8, 9, and 10, assume that the water meets the special conditions that makes the mass of one milliliter of water equal to one gram.

1. What is the main difference between the SI Units measuring system and the English System of measurement?
2. What is the relationship between a cubic centimeter and a milliliter?
3. What is the mass of a cubic centimeter of pure water?
4. How many milliliters are in a liter?
5. What is the mass of a liter of water in grams? in kilograms?
6. What prefix increases an SI unit 1,000 times?
7. If you were going to measure the length of your foot, would you use millimeters, centimeters, or meters? Explain your answer.
8. How many liters of water are in a cubic meter?
9. What is the mass of a cubic meter of water in kilograms?
10. A metric ton equals 1,000 kilograms. What is the mass of a cubic meter of water in metric tons?
11. A room is 8 meters wide and 5 meters long. This room is 4 meters high. What is the volume of this room?
12. **Challenge:** Write a short story or describe a real-life story that illustrates why units are important.

SOLVE IT!

Use a metric ruler or a meter stick to measure the dimensions of your room at home. Record your measurements on a piece of paper. Then use a scale of 1 meter = 1 centimeter to make a map of your room on another piece of paper. Once you have drawn the shape of your room on the piece of paper, make the map. Where is your bed? Where do you keep your clothes? Where are your favorite things?

Example:



2.2 More Measurements

In this section you will learn more about measuring and measuring tools. You will learn the difference between measurements of mass and weight. And you will learn about measuring temperature and time.

Mass and weight

Matter Everything is made of **matter**. Your body, a book, an apple, a duck, water, and the air are all forms of matter. All matter is made of particles called **atoms**. Atoms are too small to see with your eyes. An atom is 10 million times smaller than a grain of sand.

Mass The **mass** of an object equals the amount of matter it has. A nutrition label includes measurements for the mass of carbohydrates, protein, and fat in the food. The “g” on the nutrition label stands for “gram.”

Mass stays the same Mass and weight are not the same thing. One apple has a mass of about 150 grams. If you flew in a space ship to Mars, the apple would still have a mass of 150 grams. However, the weight of the apple would be different!

Weight **Weight** is a measure of the force of gravity. The more mass an object has, the greater the force of gravity on that object. Say you bought 15 apples. On Earth, 15 apples weigh about 5 pounds. On Mars, the force of gravity is less. Those same 15 apples would weigh only about 2 pounds (Figure 2.7)!

In science class, we will use the terms “grams” and “mass” instead of “pounds” and “weight.”

pound = unit of weight	gram or kilogram = unit of mass
2.2 pounds on Earth = 1,000 grams = 1 kilogram	

VOCABULARY

matter - the substance of all objects; all matter is made of atoms and has mass.

atom - a particle of matter.

mass - the amount of matter that an object has.

weight - a measure of mass and the force of gravity on an object.

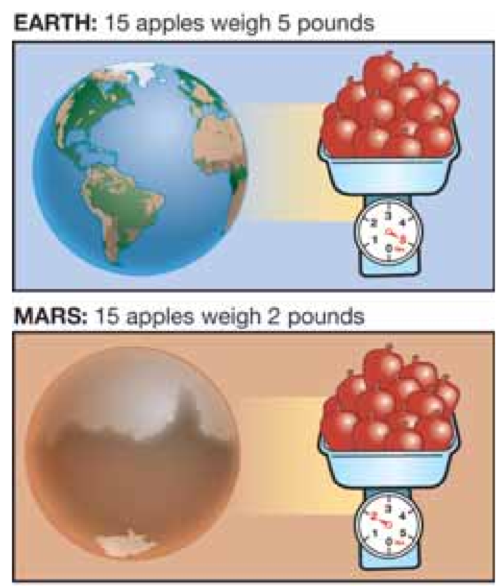


Figure 2.7: *Fifteen apples on Earth weigh 5 pounds. The same 15 apples weigh 2 pounds on Mars! This is because the force of gravity is less on Mars.*

Measuring time

What time is it? What time does your school start in the morning? What time does school end? These questions ask about one moment in time. For example, one important moment each day is the start of lunch time. Many people are ready to eat lunch at 12:00 p.m. each day (Figure 2.8).

Figure 2.8: *12:00 p.m. is lunchtime.*

Measuring time It is often important to measure time in experiments. For example, it is important to know how long it takes for something to move or grow. It might take one hour for a car to travel 80 kilometers on a highway. It takes about 156 days from the time you plant a pumpkin seed until you have a big orange pumpkin (Figure 2.9).

Units for measuring time You are probably familiar with the common units for measuring time: seconds, hours, minutes, days, and years. But you may not know how these units relate to each other. The table below gives some useful relationships between units of time.

Time relationships
1 minute = 60 seconds
1 hour = 60 minutes
1 day = 24 hours
1 year = 365 days
1 century = 100 years

Figure 2.9: *156 days is about the amount of time it takes to grow a pumpkin from a seed.*

Measuring temperature

Two temperature scales

There are two commonly used temperature scales. If the temperature in England is 21 degrees Celsius, you can wear shorts and a T-shirt. If the temperature in the United States is 21 degrees Fahrenheit, you will need to wear a heavy coat, gloves, and a hat. The United States is one of few countries that still use the Fahrenheit scale. For this reason, it is useful to know both of these temperature scales (Figure 2.10).

Fahrenheit

On the Fahrenheit scale, water freezes at 32 degrees and boils at 212 degrees. A comfortable room temperature is 68°F. The normal temperature for a human body is 98.6°F.

Celsius

On the Celsius scale, water freezes at 0°C and boils at 100°C. The normal human body temperature on the Celsius scale is 37°C. Most science and engineering temperature measurements are in Celsius because 0° and 100° are easier to remember than 32° and 212°. Most other countries use the Celsius scale for descriptions of temperature, including weather reports.

Converting between the scales

You can convert between Fahrenheit and Celsius using these formulas.

CONVERTING BETWEEN FAHRENHEIT AND CELSIUS

$$T_{Fahrenheit} = (\tfrac{9}{5} \times T_{Celsius}) + 32 \qquad T_{Celsius} = \tfrac{5}{9}(T_{Fahrenheit} - 32)$$

$T_{Fahrenheit}$ = Temperature in °F

$T_{Celsius}$ = Temperature in °C

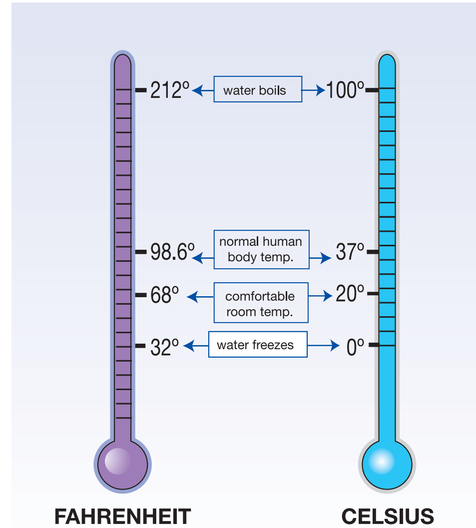


Figure 2.10: *The Celsius and Fahrenheit temperature scales.*

SOLVE IT!

You are doing a science experiment with a Fahrenheit thermometer. Your data must be in degrees Celsius. If you measure a temperature of 86°F, what is this temperature in degrees Celsius?

How do you measure temperature?

Thermometers Humans can sense warmth or cold, but not very accurately. Accurate measurement of temperature requires a *thermometer*, an instrument that measures temperature. A thermometer that contains liquid alcohol uses the expansion of the alcohol to measure temperature changes (Figure 2.11).

When temperature increases As you have learned, matter is made of particles called *atoms*. Groups of atoms are called *molecules*. The volume of alcohol in a thermometer contains huge numbers of alcohol molecules. As temperature increases, the alcohol molecules move faster and bounce off each other. As a result, the liquid alcohol expands and takes up more space in the thermometer. For an alcohol thermometer, temperature is a measure of how much the alcohol expands. Even a small increase in volume inside the tube makes a visible change in the amount that the alcohol rises up the tube.

Different thermometers Thermometers are based on a physical property (such as color or volume) that changes with temperature. Alcohol thermometers measure temperature as a change in volume of the alcohol. Digital thermometers sense temperature by measuring the ability of electricity to pass through a part of the thermometer called a *probe*. Aquarium "sticker" thermometers use a chemical that changes color at different temperatures. The "sticker" thermometers like the one below are placed on the aquarium tank.

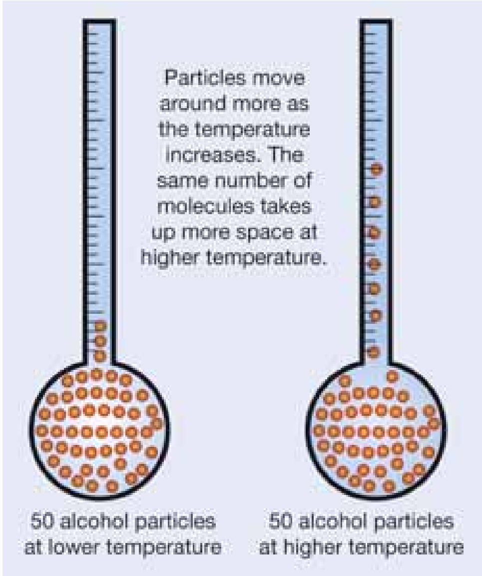


Figure 2.11: *Alcohol particles move faster at higher temperatures and spread out. The volume of alcohol expands, or takes up more space.*

STUDY SKILLS

A mathematical formula is easier to use the more you practice using it. Practice converting Celsius degrees to Fahrenheit degrees at least once a day. Pretty soon this conversion formula will be easy to use!

2.2 Section Review

1. Why is your brain a good scientific tool?
2. Describe three measuring tools that are used in science. The sidebar box at the right lists some of these tools.
3. A mathematical formula is one kind of tool. Use the temperature conversion formula below to fill in the following table. The first one is done for you.

	Celsius degrees	Converting	Fahrenheit degrees
a.	25°C	$(^9/_5 \times 25°C) + 32 =$ Multiply: $(9 \times 25) = 225$ Divide: $225 \div 5 = 45$ Add: $45 + 32 = 77°F$	77°F
b.	100°C		
c.	5°C		
d.			40°F
e.			100°F
f.			200°F

4. What is the difference between mass and weight?

CONVERTING BETWEEN FAHRENHEIT AND CELSIUS

$$T_{Fahrenheit} = (\tfrac{9}{5} \times T_{Celsius}) + 32 \qquad T_{Celsius} = \tfrac{5}{9}(T_{Fahrenheit} - 32)$$

$T_{Fahrenheit}$ = Temperature in °F

$T_{Celsius}$ = Temperature in °C

MY JOURNAL

Write a short story about making an important scientific discovery. Include tools from the “science toolbox” in your story. Here is a list of important science tools:

- Your brain
- The scientific method
- An experiment
- Ruler, meter stick, tape measure
- Triple beam balance
- Beakers or graduated cylinders
- Thermometer
- Stopwatch
- Clock
- Calculator
- Graph paper
- Computer

2.3 Systems and Variables

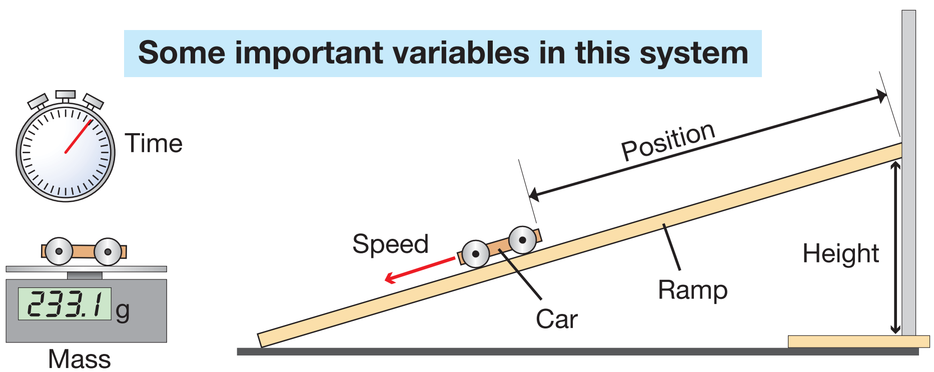
The universe is huge and complex. Therefore, it is useful to think about only a small part at a time. A toy car rolling down a ramp is a small part of the universe. In science, a group of objects, like a car and a ramp, is called a *system*.

What is a system?

A group of objects A **system** is a group of objects and the factors that affect these objects. Some systems are listed below:

- The respiratory system in the human body
- Bacteria in a petri dish
- A fish aquarium
- A car engine
- A car and ramp (see diagram below)

Variables A factor that affects an object is called a **variable**. A system can be affected by many variables. In an experiment, only a few variables are studied. Figure 2.12 lists variables that are part of the car and ramp system. Additional variables include color, light, the table and floor, and friction. These variables either stay constant or they do not affect the system.



VOCABULARY

system - a group of objects and the factors that affect the objects.

variable - a factor that affects an object; examples include mass, temperature, speed, and time.

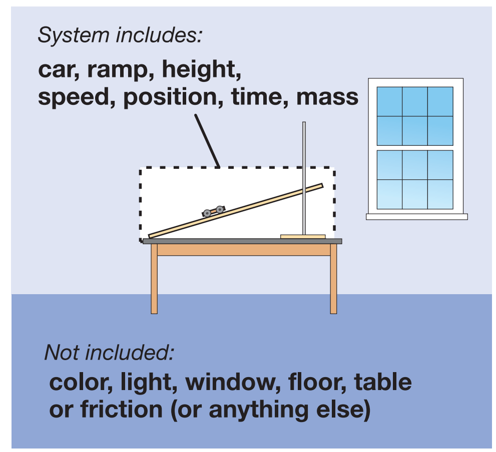


Figure 2.12: *A system includes objects and variables. Friction refers to how two objects interact. In the car and ramp system there is very little friction between the car and the ramp, so the car rolls very easily.*

Systems and experiments

Start with a question An experiment is an activity that follows the scientific method. An experiment can also be described as an activity that investigates the relationship between variables in a system. Experiments usually start with a question. An example is, "How does the height of a ramp affect the speed of a car?" (Figure 2.13)

An experiment is a tool An experiment is a good scientific tool for answering the question, "How does ramp height affect speed?" An example of an experiment you could do would be to change the ramp height three times and measure the car's speed at the three different heights.

Independent and dependent variables The variable that is changed in an experiment is the **independent variable**. The variable that is affected by the change to the independent variable is the **dependent variable**. In Figure 2.13, the height of the ramp is the independent variable and the speed of the car is the dependent variable.

Change one variable at a time There should only be one independent variable in an experiment. All of the other variables should stay the same so you know that your results are due to changes made to the independent variable.

Control variable For example, to study height, you keep the other variables the same. A variable that is kept the same in an experiment is called a **control variable**. The mass of the car is a control variable. If you changed the height of the ramp *and* the mass of the car you would not know which variable affected the speed.

State a hypothesis A hypothesis is a statement describing how the independent variable will affect the dependent variable. (Note: The hypothesis is not necessarily correct. It must be tested.) One hypothesis is, "As height of the ramp increases, the car's speed increases." The hypothesis is made before the experiment takes place.

VOCABULARY

independent variable - a variable that is changed in an experiment. The independent variable is sometimes called the *manipulated variable*.

dependent variable - a variable that is affected by the change to the independent variable. The dependent variable is sometimes called the *responding variable*.

control variable - a variable that is held constant in an experiment.

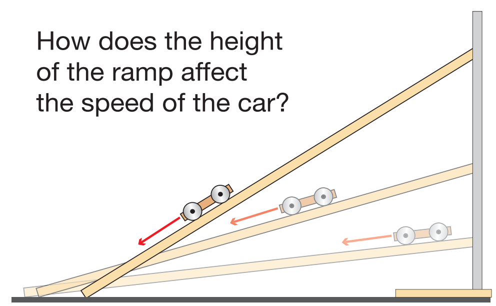


Figure 2.13: *State a hypothesis that answers this question. You will be able to test this hypothesis in your science lab class.*

Energy in systems

Energy Energy is an important variable in all systems. **Energy** is a measure of a system's ability to change or create change in other systems. Energy has many forms. Some examples of energy are heat, motion, light, height, pressure, electricity, and calories. Here are examples of energy and the resulting changes in the systems:

- Boiling (heat) changes the appearance of an egg.
- Kicking a ball (motion) moves it into a goal.
- Moving a book from a low to a high shelf (height) changes its position.
- Increasing the amount of air in a tire (pressure) makes it firm and able to support a car.
- Turning on a TV (electricity) causes an image to appear on a blank screen.
- Eating food provides energy (calories) to your body.

Energy in systems Systems tend to move from high to low energy (Figure 2.14). A system at higher energy is unstable, while a system at lower energy is stable. The car is unstable at the top of the ramp where its energy of position (height) is greatest. It naturally rolls to a more stable position at the bottom of the ramp. Likewise, a child has more energy at the top of a playground slide. Once the child slides down, she is more stable and has less energy.

Friction Energy is liberated due to *friction* when two objects rub against each other (Figure 2.15). The more friction there is between objects, the more energy builds up between them as they try to move past each other. Some of this energy is converted to heat. You can generate heat due to friction by rubbing your hands together really fast. If you wet your hands, it will be harder to generate heat. This is because the water reduces friction between your hands.

VOCABULARY

energy - a measure of a system's ability to change.

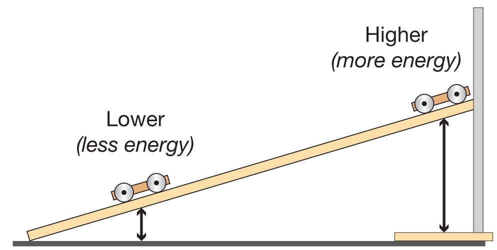


Figure 2.14: *A car at the top of a ramp has more height energy than a car at the bottom of the ramp.*

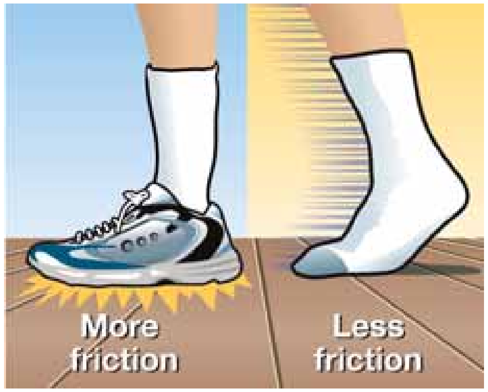


Figure 2.15: *There is more friction between a sneaker and a gym floor than between a sock and the gym floor.*

The scale of a system

An example of different scales

One characteristic of all systems is their scale. The word *scale* here refers to size. Figure 2.16 shows a road at three different scales. The bottom box shows a map, which is a system of roads shown at a large scale. You can see many roads in this large-scale model. The center box shows a road and a car at a human-scale, one road and one car, at the size that you see every day. The top box, showing a crack in the road, is using a smaller scale. Small scale is a close-up view, allowing you to see more detail than you'd see with a larger scale. The smallest scale involves atoms and molecules.

Large scale

Variables are on a large scale when you can see them with the naked eye, or measure them directly. The mass of a car and the temperature of a pot of water are large-scale variables. Most of the things you measure in classroom experiments are large-scale, or *macroscopic.*

The scale of atoms

Some variables are so small that they are not visible to the eye or readily measured. Temperature and energy are related variables, but it is not possible to understand how they are related using a macroscopic scale. To understand the connection between temperature and energy we must look using the *atomic scale,* the scale of atoms and molecules.

Atoms

Atoms are tiny particles, far too small to see without powerful magnification tools. Many of the large-scale properties of matter that you can observe depend on the behavior of atoms. To understand certain aspects of the world (such as temperature) we need to understand the behavior of atoms.

Figure 2.16: *Three different scales for looking at a road.*

Models

What is a model? Explanations in science typically come in the form of models. A *model* is an explanation that connects the variables in a system through cause and effect relationships. For example, if you increase the height of the ramp, the car's speed will increase. A model is a good science tool because it helps you think about how two variables are related. There are many types of models.

Mental models If you wanted to kick a soccer ball into a goal, you could come up with a mental model. You imagine the ball going into the goal and that helps you know how hard to kick the ball (Figure 2.17).

Physical models A physical model (or scale model) is a small version of something big. Engineers make small model bridges to learn how to make an actual bridge for a city. A scale model has to be proportional to the real object. For example, a scale of 1 centimeter = 10 meters means that an object 100 meters long in real life would be 10 centimeters long in a small-scale model.

Conceptual models A conceptual model is a way of using your existing knowledge to understand or remember a new concept. Earth scientists use a conceptual model called *theory of plate tectonics* to explain why earthquakes occur (see sidebar box). Comparing the Earth's plates to puzzle pieces makes the concept easier to understand.

Mathematical models An example of a mathematical model is $\mathbf{E = mc^2}$. This was a model that Albert Einstein discovered. **E** stands for energy, **m** stands for mass, and **c** stands for the speed of light. This mathematical model states that energy equals mass times the square of the speed of light. Graphs are another type of mathematical model that you'll learn about in the next section. A **graph** is a picture that shows how two variables are related.

Energy
Mass
$E = mc^2$
Speed of light

Figure 2.17: *Imagining how to kick a soccer ball to make a goal is a mental model.*

A conceptual model: The theory of plate tectonics

Earth's surface is like a giant puzzle with huge pieces called plates. The theory of plate tectonics describes how the plates move on Earth's surface. You will learn more about plate tectonics in Unit 3.

VOCABULARY

graph - a picture that shows how two variables are related.

2.3 Section Review

1. In Section 2.3, you learned that systems, experiments, and models are types of scientific tools. Explain why each of these things can be considered to be a scientific tool.
2. You read about an experiment that related the height of a ramp to the speed of a toy car. In the experiment, what kind of variables are the height of the ramp and the mass of the car?
3. Will a toy car go faster if the height of the ramp is raised from 20 centimeters to 50 centimeters? Explain your answer.
4. Refer to page 17 to answer these questions about energy:
   a. What kind of energy is involved in turning on a TV set?
   b. Your foot kicks a soccer ball into a goal. List the parts of this system. What kind of energy is involved in this system?
   c. Using an oven, you can turn cake batter into a delicious cake. What kind of energy is involved in this change?
5. You know that a toy car at the top of a ramp will always roll *down* the ramp. Why doesn't the car ever roll *up* the ramp?
6. Is the car and ramp system a macroscopic scale system or an atomic scale system?
7. Physical models are proportional to a real object. Imagine that you wanted to make a model of a car. The length of a real car is about 4 meters long. If the physical model has a scale of 10 centimeters = 1 meter, how long would the model car have to be?
8. What kind of model is a graph?
9. What kind of model is a globe of Earth?

CHALLENGE

Do an experiment

Below are two experiments for you to try. Be sure to state a hypothesis before you do your experiment, and follow the steps of the scientific method.

(1) Use the car and ramp to answer the following question: Does mass affect a car's speed on the ramp? Be very detailed in how you design your experiment and collect your data.

(2) Do an experiment to answer the following question: Does salty water freeze at a lower temperature than tap water? Here are some tips for this experiment. Place containers of salty water and tap water in a freezer. Use equal volumes of water. Observe the water samples at regular intervals and measure the temperature of each. Record the temperature at which ice forms on each sample.

2.4 Graphs

An experiment is an important scientific tool. One of the reasons it's a good tool is that it produces information or data. A graph is a mathematical model that helps you interpret the data you collect.

What is a graph?

A graph is a picture A *graph* is a picture that shows how two variables are related. Graphs are easier to read than tables of numbers, so they are often used to display data collected during an experiment.

Independent variable Graphs are drawn with the *independent variable* on the horizontal or x-axis. Independent variables are controlled by the experimenter. The independent variable in Graph A is the amount of gas in the car (Figure 2.18).

Dependent variable The *dependent variable* goes on the vertical or y-axis. A dependent variable is affected by an independent variable. Distance is a good example of a dependent variable because distance traveled often depends on other things such as speed, type of vehicle, terrain, and amount of gas the vehicle has (Graph A).

Types of graphs Types of graphs include line, bar, and pie graphs. A line graph is used when one variable causes a second variable to increase or decrease in value. For example, the more gas you put in a car, the farther it travels (Graph A). A bar graph compares categories of information. Graph B compares five places and their distances from home. A pie graph is a circular graph that also compares categories of information. The data in a pie graph is usually written in percentages. Graph C shows how a student spends her time during 24 hours. What would the graph look like if the student spent half her day in school and half her day asleep?

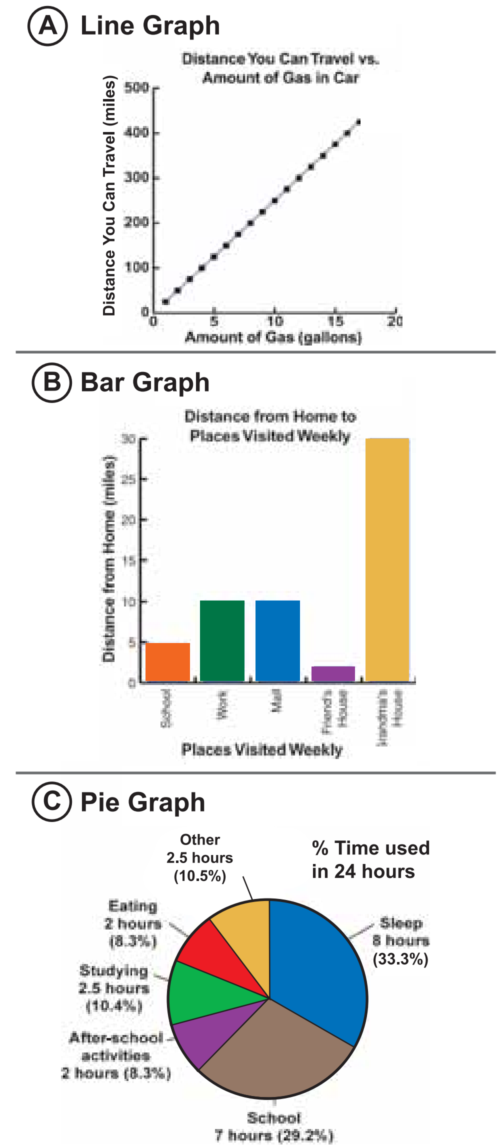
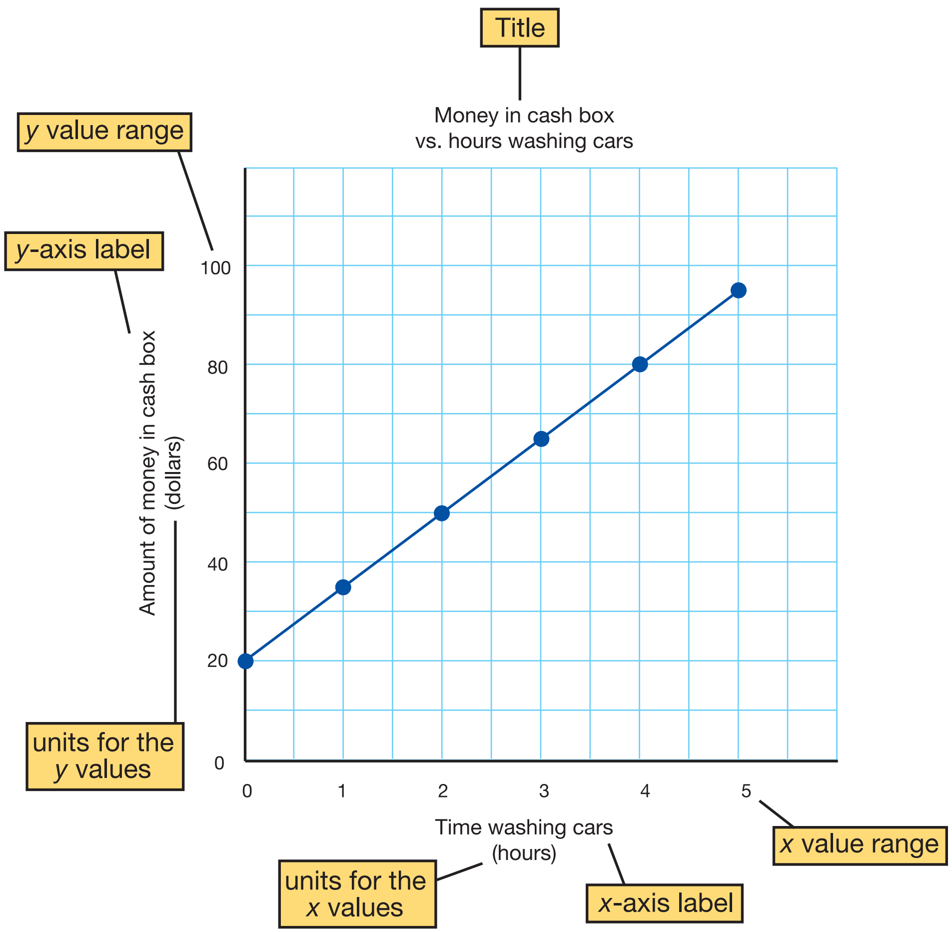


Figure 2.18: *Examples of graphs*

Parts of a graph

A picture of information A graph is a picture of information. All of the space on the graph should be used so that the data "picture" is easy to understand.

Example A car wash is being held to raise money for a school trip. The data set (Table 2.1) and the line graph below show the relationship between the amount of money in the cash box and the number of hours spent washing cars.



Data for a line graph

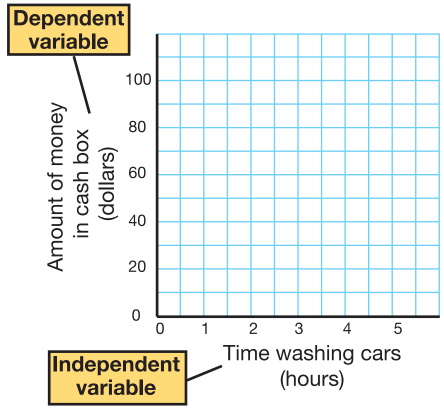
Table 2.1 contains a data set. A data set is organized into pairs of values. For every value in the "*x*" column, there is a value in the "*y*" column. Each pair of values can be represented by writing (*x*, *y*). A pair of values (*x*, *y*) represents a certain location or point on a graph. The *x* and *y* values are the *coordinates* of the point. The "picture" of points for this data set is the graph to the left.

Table 2.1: Money in cash box vs. number of hours washing cars.

x # of hours washing cars	*y* Amount of money in cash box	(*x*, *y*) Coordinates
0	20	(0, 20)
1	35	(1, 35)
2	50	(2, 50)
3	65	(3, 65)
4	80	(4, 80)
5	95	(5, 95)

How to make a line graph

Step 1 After you have collected your data, you compare independent and dependent variables. The independent variable always goes on the x-axis of a graph. The dependent variable always goes on the y-axis. Be sure to label each axis (see graph at right).



Step 2 The next step is to make a scale for each axis of the graph. Remember that the word *scale* refers to the size of something. When talking about a graph, scale refers to how each axis is divided up to fit the range of data values. For example, let's say we have a piece of graph paper that is 12 boxes by 12 boxes. The range of values for the x-axis is 0 to 5. The range of values for the y-axis is 20 to 95. To make a graph of this data, we need to figure out the value for each box on each axis.

To do this, you can use a formula:

Data range ÷ Number of boxes on the axis = Value per box

SOLVE IT!

Make a bar graph and pie graph

1) A bar graph compares categories of information. Use the following data set to make a bar graph.

Number of students who bring lunch to school each day

Day	Number of Students
Mon	30
Tue	30
Wed	30
Thurs	30
Fri	5

2) A pie graph also compares categories of information. Use the following data set to make a pie graph.

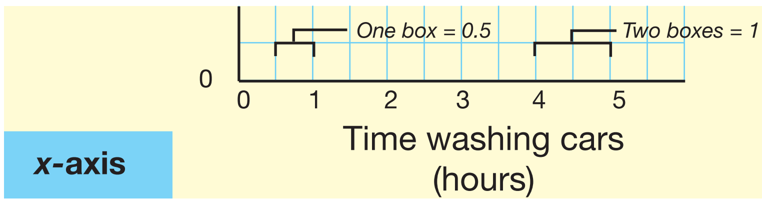
Percent of students in afterschool activities

Activity	% of Students
Soccer	25%
Dance	25%
Karate	25%
Drama Club	12.5%
Math Team	12.5%

The scale for the *x*-axis is easier to determine. You have 12 boxes and values from 0 to 5 hours. The data range is 5 hours.

Data range ÷ Number of boxes on the axis = Value per box
5 hours ÷ 12 boxes = 0.42 hour/box

One box equals 0.42 hour per box. Round 0.42 to 0.5. This means every two boxes equals 1 hour.



For the *y*-axis, the data range is \$20 to \$95. To more easily calculate the scale, choose \$0 to \$100 as the data range. Calculate the scale this way:

Data range ÷ Number of boxes on the axis = Value per box
\$100 ÷ 12 boxes = \$8.3/box

Round \$8.3 to \$10. One box on the *y*-axis equals \$10 (Figure 2.19).

Now, write the numbers of the data range on each axis at evenly spaced intervals. Label each axis with its corresponding variable and unit.

Step 3 Plot each point by finding the *x*-value and tracing the graph upward until you get to the correct *y*-value. Make a dot for each point. Draw a smooth curve that shows the pattern of the points (Figure 2.20).

Step 4 Create a title for your graph.

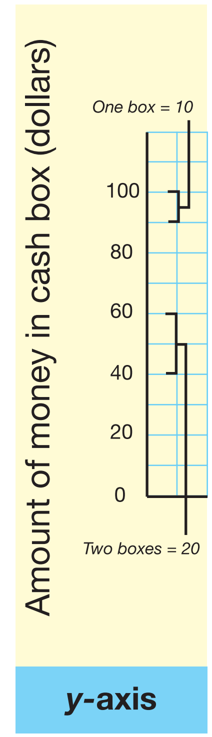


Figure 2.19: *The scale of the y-axis for the graph.*

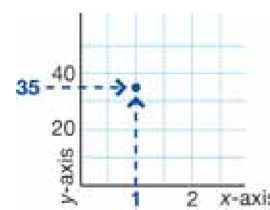


Figure 2.20: *Plot each point by finding the x-value and tracing the graph upward until you get to the correct y-value.*

2.4 Section Review

1. Why is it a good idea to make a graph of the data in a data table?
2. Questions and variables for different experiments are listed below. For each, determine which variable is independent and which is dependent.

	Question	Variables	Independent or dependent?
a.	Does getting more sleep help you do better on tests?	Test scores	
		Hours of sleep	
b.	Does the mass of a toy car affect its speed?	Mass	
		Speed of the car	
c.	Does the amount of sunshine increase the number of pieces of fruit per fruit tree?	Amount of sunshine	
		Pieces of fruit per tree	

3. Below is a list of data sets. State what kind of graph you would use for each.
   a. Favorite foods of a group of 100 students: 10% prefer steak, 20% prefer french fries, 20% prefer spaghetti, 25% prefer ice cream, and 25% prefer pizza
   b. Speed of a toy car on a ramp versus the height of the ramp
   c. Books in a library: 2,000 non-fiction books, 1,500 fiction books, 500 children's books
4. A blank graph is 10 boxes by 10 boxes (Figure 2.21). You want to plot a data set on this graph. The range of values for the *x*-axis is 0 to 20. The range of values for the *y*-axis is 0 to 10. Make a sketch that shows the scale that you would use for each axis.

CHALLENGE

Design three experiments to determine which of three chocolate chip cookie manufacturers makes the best cookie.

- One experiment should result in data that you can plot on a line graph.
- The second experiment should result in data that you can plot on a bar graph.
- And the third experiment should result in data that you can plot on a pie graph (or cookie graph)!

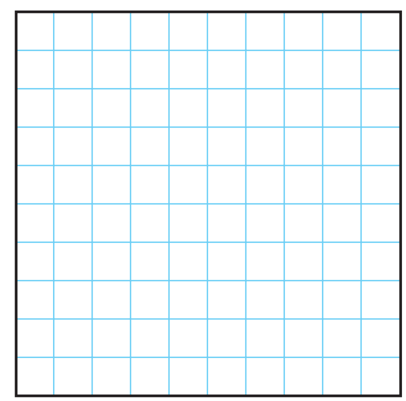


Figure 2.21: *A blank graph that is 10 boxes by 10 boxes.*

TECHNOLOGY CONNECTION

Modern Map-Making

Can you imagine trying to sail around the world without a map? The first Europeans to reach North America did just that. According to archaeologists, the history of mapmaking dates all the way back to early humans. They had the ability to produce a rough, but amazingly accurate drawing of their surroundings. Some of the first maps showed hunting and fishing areas with detailed drawings. A picture is really worth a thousand words when it comes to finding your way.


Library of Congress, Geography and Map Division

Mapmaking is known as *cartography*. The early European cartographers were often painters and artists. It was considered more of an art than a science.

How Things Have Changed

The first maps were probably drawn on animal skins. Later maps were made using brushes and parchment paper and then with pens and paper. Early maps were based on what people saw and what they were told. They were not nearly as accurate as they are today. Early map makers did not know the size or the shape of Earth. They were able to measure distances between points on Earth's surface, but not with great accuracy.

Now, thanks to sophisticated measuring devices, computers and satellites, mapmaking is truly a science. One thing that hasn't changed is the importance and the need for cartography.

Geographic Information System

The Geographic Information System (GIS) is a computer system that automates the production of mapmaking. GIS has the ability to measure distances. It can also calculate the area and borders of features.

The GIS technology is more than a computer system; it is a large collection of people, software, computers, information, and organizations. Every part of the system collects, stores, analyzes, and displays information about Earth. Every day, it seems, data about Earth's surface is added to GIS. It includes natural features, such as mountains, rivers, lakes, and streams. It also includes things people have built, such as roads, buildings, and bridges.

CAD and Cartography

Maps today are drawn on computers, often using CAD, a computer-aided design system. CAD systems are designed to show geographical features as drawings in a computer. Line thicknesses and colors can be changed easily. For example, a blue line might indicate water. These drawings are handled as separate layers that can easily be found and displayed for viewing alone or together. Because there are “layers” in the computer’s files, they can be changed separately as well.

Technology Moves Mapping Forward

The use of aerial and satellite photography is one of the many ways maps are evolving. The earliest maps were made by measuring positions of latitude and longitude on Earth. Today remote sensing is used to gather information about Earth from a distance. Remote sensing devices can be used on airplanes as they fly above Earth’s surface. Satellites are also used to gather information as they orbit around Earth.

Now, the view from the air or even from space gives map makers the ability to make every map exact, right down to the centimeter. Modern maps can be interactive and are easily updated. The best maps are just a mouse click away. In fact you can view The National Map at: *http://nmviewogc.cr.usgs.gov/viewer.htm*

A few clicks of the mouse allow you to interactively view, customize, and print a map of your choice. The National Map is a topographical map of the nation that provides the public with high quality data and information.

Where To Go For Answers

The National Map, maintained by the United States Geological Survey (USGS), provides critical up to date and accurate data. The USGS works with other federal, state, academic, and private mapmaking agencies. Maps are essential tools in the field of geology in that they are records of natural resources such as water, minerals, wildlife, and natural hazards such as earthquakes and volcanic activity.

Questions:

1. What is cartography?
2. Explain what the Geographic Information System is.
3. In what ways are GIS and CAD systems different?
4. What are the advantages of the National Map?

CHAPTER ACTIVITY

Measurement Olympics!

During the Measurement Olympics you and a partner will practice measurement and conversion skills.

Procedure

You will have 4 minutes at each event station. Your teacher will instruct you when it is time to move to a new station. Your partner will measure and record the results for you while you compete. Then, you will do the same for him/her.

Description of Events

- **Straw Javelin:** During this event, you will be throwing a straw as far as you can, like it is a javelin. Your front foot may not cross the start line, and you must throw the straw like a javelin with only one hand. Measure the distance of your throw in meters and centimeters.
- **Paper Cup Challenge:** How much water can you move from a tank to a beaker in 10 seconds using just one paper cup? Use a graduated cylinder to measure the volume of water you successfully transferred. Be careful so you don't spill any water!
- **Pebble Grab:** Who can grab the greatest mass of pebbles? Use ONLY ONE HAND to grab as many pebbles as you can out of a container. Transfer them to a triple beam balance to measure the mass. Be sure the balance is zeroed before you begin!
- **Side Step:** How far is your leg span? From a starting point step as far as you can to the side. Your partner will measure the length of your step in meters and centimeters.
- **Hoppity Hop:** Who can hop 10 meters the fastest on one foot? Your teacher has marked 10 meters on the floor. Using the timers provided, time how long it takes your partner to hop 10 meters on one foot!

Olympic Results

1. Record your results below. Any result with missing or incorrect units will be automatically disqualified from the Measurement Olympics!
2. After you have recorded your results there will be a class discussion about the winners. Record the winner's results for each event!

Olympic Event	My Results	Winners Results
Straw Javelin		
Paper Cup Challenge		
Pebble Grab		
Side Step		
Hoppity Hop		

Questions

a. Calculate the difference between the winner's results and your results for each event. (Don't forget units!)

Olympic Event	Difference
Straw Javelin	
Paper Cup Challenge	
Pebble Grab	
Side Step	
Hoppity Hop	

b. Which measurement were you most familiar with before The Olympics? Why?

c. Which measurement did you find easiest to do during The Olympics? Why was it so easy for you?

d. Which measurement did you find to be the most difficult during the Olympics? Why?

Chapter 2 Assessment

Vocabulary

Select the correct term to complete the sentences.

measurement	unit	atom
mass	gram	weight
dependent variable	variable	control variable
liter	energy	graph
meter	independent variable	system
volume		

Section 2.1

1. A(n) _____ includes a number and a unit.
2. My dog is 2 feet tall. The word "feet" in this sentence is an example of a _____.
3. A(n) _____ is a distance measurement that is a little longer than a yard.
4. The _____ is the basic unit of volume in the SI system of measurement.
5. A formula for _____ is length × width × height.
6. One _____ is the mass of one milliliter of pure water.

Section 2.2

7. A(n) _____ is a particle of matter.
8. Your _____ is the same on Earth and on Mars.
9. Your _____ is less on Mars than it is on Earth.

Section 2.3

10. In my experiment I studied a _____ that included a car, a ramp, and the height of the ramp.
11. The color of the car is an example of a _____ that I did not study in my experiment.
12. A(n) _____ is the variable that scientists change on purpose in an experiment.
13. The _____ is the variable in an experiment that changes as a result of how another variable is changed.
14. When doing an experiment it is important to keep one variable constant. This kind of variable is called a _____.
15. Systems tend to move from high to low _____.
16. A _____ is a picture that allows you to see how two variables relate to one another.

Concepts

Section 2.1

1. What is a unit? In your answer, give an example of an SI unit and an example of a unit from the English System of measurement.
2. Which statement is correct? Explain why it is the only correct statement?

   (a) I am 2 tall. (c) I am 2 meters tall.

   (b) I am 2 kilograms tall. (d) I weigh 30 milliliters.

3. You learned about two systems of measurement. Which of these systems is based on the number 10?

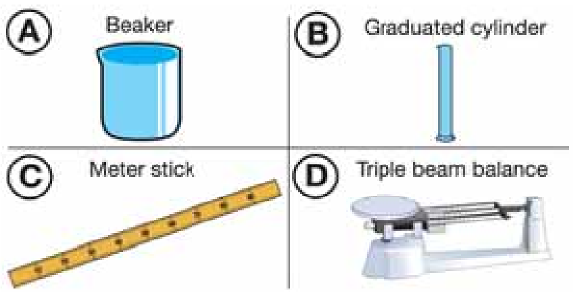
Section 2.2

4. An apple on the moon has the same mass as an apple on Earth, but the same apple weighs more on Earth than it does on the moon? Why?

5. The force of gravity on the moon is less than it is on Earth. Therefore, the weight of your body on Earth is ______________ it is on the moon. Which statement goes in the blank: greater than, the same as, or less than?

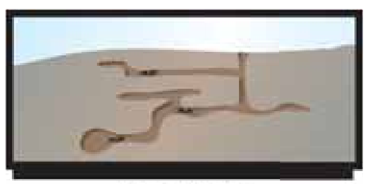
6. You want to do an experiment to find out how long it takes for a bean plant to grow from a seed. What units of time would you use?

7. Below are pictures of different measurement tools. Identify whether the tool is used to measure length, volume or mass.



Section 2.3

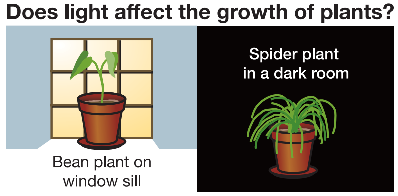
8. Is an ant farm in an aquarium an example of a system? Use the definition of a system from the chapter to answer this question. Explain your answer in paragraph form.



An ant farm

9. You want to find out if light affects the growth of plants. To do your experiment, you use two plants. One plant is a bean plant and the other is a spider plant. Both plants are in the same size pot and the same type of soil. You put the bean plant in a window, and you put the spider plant in a closet, where the light will be turned off for the duration of the experiment. The experiment lasts one week. Each day at 9:00 am you measure the height of each plant and record your data using centimeters in your science notebook. At the same time, you water each of the plants with 500 mL of water.
Is your experiment a good scientific experiment? Why or why not?

Does light affect the growth of plants?



10. Identify the independent variable, dependent variable, and the control variable(s) in this experiment. Explain your reasoning.

Question: How does wheel size affect the speed of carts moving down a ramp?

In the experiment, there are 5 carts that are all identical, except for the wheels. Each cart had a different size wheel with diameters as follows: 5 cm, 7 cm, 9 cm, 11 cm and 13 cm. The carts were placed one at a time on a ramp and released. The carts were released from the same starting point. The time for each cart to roll 2 meters down the ramp was recorded. There were 3 trials for each cart, and the same ramp was used for the entire experiment.

11. You are doing a presentation about The Golden Gate Bridge in your social studies class. Since you can't bring the bridge to class, you want to make a model of the bridge for your classmates. In a paragraph, describe the best model you could use. What type of model is this? What is one essential component to your model, so your classmates get an accurate depiction of the bridge?

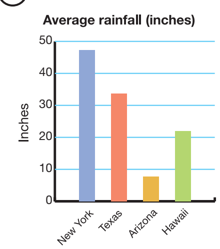
12. Friction is known to:

a. increase the amount of energy in a system.
b. cause a loss of energy in a system through heat.
c. do nothing to the energy in a system.
d. None of the above. There is little known about friction.

Section 2.4

13. There are 3 graphs below. Identify each type of graph:

Ⓐ



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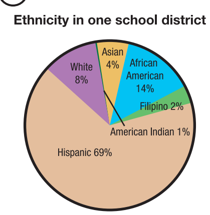

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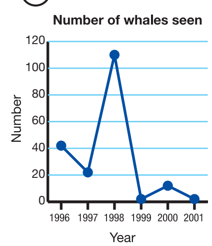


14. When graphing you should always:
    a. put the independent variable on the x-axis.
    b. put the dependent variable on the x-axis.
    c. put the independent variable on the y-axis.
    d. put the control variable on the y-axis.

15. Below are three data sets. What kind of graph would you use to plot each data set? Explain your answer.
    a. Student grades on a science test

Grade	Percent of students who earned this grade
A	25%
B	35%
C	35%
D	5%
F	0%

b. **The favorite foods of students in a 6th grade class**

Favorite food	Number of students who say that this food is their favorite
Pizza	10
Ice cream	3
Tacos	5
Chocolate	2
Spaghetti	3

c. The height of a plant each day

Day number	Height (cm)
1	3
2	3.2
3	4
4	4.5
5	6

Math and Writing Skills

Section 2.1

1. How many meters does each value represent?
    a. 1,000 millimeters
    b. 300 centimeters
    c. 2 kilometers

2. A book is on a shelf that is 2.5 meters high. How high is the book in centimeters?

3. How long is this wrench in centimeters?

4. You have a box that measures 5 cm × 5 cm × 3 cm. How many milliliters of water would fit in this box?

5. Which box would hold 100 milliliters of water?
   a. A box that measures 2 cm × 2 cm × 2 cm
   b. A box that measures 4 cm × 5 cm × 5 cm
   c. A box that measures 20 cm × 2 cm × 1 cm
6. Your mother gives you 1000 mL of your favorite soda and says "You are only allowed to drink half of a liter of that soda." How many milliliters are you allowed to drink? How much soda will be left over after you drink half a liter?

Section 2.2

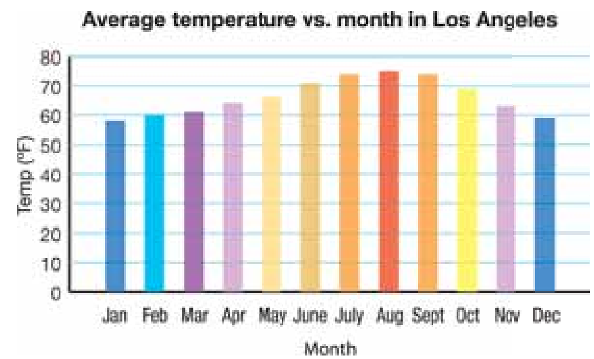
7. A grocery store wants to sell 100 pounds of bananas. What is the mass of these bananas in kilograms?
8. Calculate how many seconds are in 2 hours and 5 minutes.
9. What is the typical body temperature of the human body in Fahrenheit? Now, convert this to Celsius and report typical human body temperature in Celsius.

Section 2.3

10. Here are some examples of systems: the Earth and moon system, the digestive system in your body, and a fish in an aquarium. Choose one of these systems and write a paragraph about it that answers these questions:
    What are the different parts of the system?
    Why is it a system?
    What variables affect the function of the system?

Section 2.4

11. Make 3 graphs of the data that were reported in Concept question #15. Make one graph for each data set, and be sure it has all of the proper components.
12. Below is a bar graph for climate data in Los Angeles over one year. Answer the following questions about the graph.



   a. When was the highest average temperature?
   b. When was the lowest average temperature?
   c. What does the graph show about the trends in temperature in Los Angeles over one year?
   d. What do you predict the average temperature will be in May of the following year?

Chapter Project—Conduct an Experiment

Design and conduct your own scientific experiment. What do you want to find out? The experiment can take up to one week to perform, or can take only a couple of hours to perform. Here is what you need to keep in mind:

- Ask a question about which you are curious.
- Your hypothesis must be testable.
- You need an independent and a dependent variable.
- Are all other variables controlled?
- How are you going to collect data, make measurements, and record results?

Be sure to check with your teacher about your question and your hypothesis before continuing with your experiment.