CHAPTER 1 The World of Science

Chapter Outline

Have you ever experienced the thrill of an exciting fireworks display like this one? Fireworks were invented about 2000 years ago in China. But it wasn't until much later that people understood the science behind the technology.

Do you know why fireworks explode? Do you know what causes the brilliant bursts of light and the deep rumbling booms? In this FlexBook® digital resource, you'll find out the "hows" and "whys" of many things in the physical world around you—from the chemical reactions that cause fireworks to the waves of energy that travel through space from the sun.

Ghengis Fireworks (www.ghengisfireworks.com). www.flickr.com/photos/ghengisfireworks/9710103655/. CC BY 2.0.

1.1 What Is Science?

Lesson Objectives

- Define science.
- Explain how scientists use induction.
- Distinguish between scientific theories and laws.
- Describe milestones in the history of science.
- Identify contributions of women and minorities to science.

Lesson Vocabulary

- induction
- science
- scientific law
- scientific theory

Introduction

Understanding the "hows" and "whys" of the world is the goal of science. The term science comes from a Latin word that means "having knowledge." But science is as much about adding to knowledge as it is about having knowledge. Science is a way of thinking as well as a set of facts. **Science** can be defined as a way of learning about the natural world that is based on evidence and logic.

Thinking Like a Scientist

Are you like the teen in **Figure** 1.1? Do you ever wonder why things happen? Do you like to find out how things work? If so, then you are already thinking like a scientist. Scientists also wonder how and why things happen. They are curious about the world. To answer their questions, they make many observations. Then they use logic to draw general conclusions.

Induction

Drawing general conclusions from many individual observations is called **induction**. It is a hallmark of scientific thinking. To understand how induction works, think about this simple example. Assume you know nothing about gravity. In fact, pretend you've never even heard of gravity. Perhaps you notice that whenever you let go of an object it falls to the ground. For example, you drop a book, and it crashes to the floor. Your pencil rolls to the edge of the

FIGURE 1.1
Like a scientist, this teen wonders about how and why things happen. What do you wonder about?

desk and down it goes. You throw a ball into the air, and it falls back down. Based on many such observations (**Figure** 1.2), you conclude that all objects fall to the ground.

FIGURE 1.2
From skydivers in the air to kids on a playground slide, whatever goes up always comes back down. Or does it?

Now assume that someone gives you your first-ever helium balloon. You discover that it rises up into the air if you don't hold on to it. Based on this new observation, do you throw out your first idea about falling objects? No; you decide to observe more helium balloons and try to find other objects that fall up instead of down. Eventually, you come to a better understanding based on all your observations. You conclude that objects heavier than air fall to the ground but objects lighter than air do not. Your new conclusion is better because it applies to a wider range of observations. You can learn more about induction, including its limits, by watching the video at this link: http://www.youtube.com/watch?v=E1TpZ_HbK3M (5:39).

MEDIA
Click image to the left for more content.

How Science Advances

The above example shows how science generally advances. New evidence is usually used to improve earlier ideas rather than entirely replace them. In this way, scientists gradually refine their ideas and increase our understanding of the world. On the other hand, sometimes science advances in big leaps. This has happened when a scientist came up with a completely new way of looking at things. For example, Albert Einstein came up with a new view of gravity. He said it was really just a dent in the fabric of space and time.

Different conclusions can be drawn from the same observations, and it's not possible to tell which one is correct. For example, based on observations of the sun moving across the sky, people in the past couldn't tell whether the sun orbits Earth or Earth orbits the sun. Both models of the solar system are pictured in **Figure** 1.3. It wasn't until strong telescopes were invented that people could make observations that let them choose the correct idea. Not sure which idea is correct? You can learn more by watching the student-created video at this link: http://www.youtube.com/watch?v=JcqdUq16S28 .

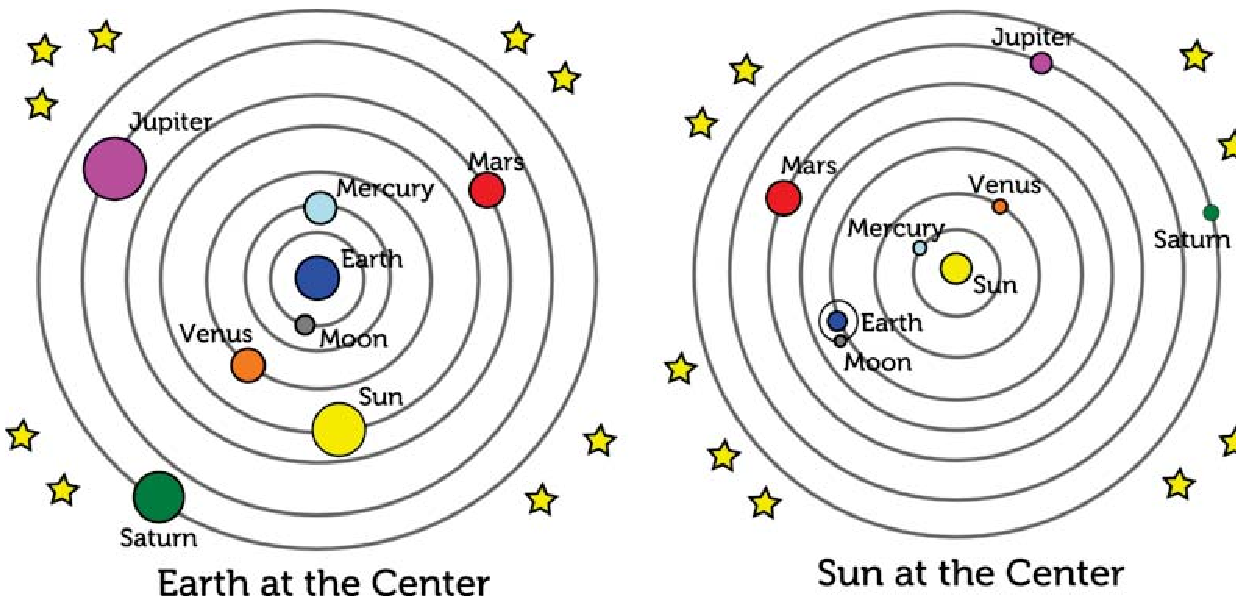


FIGURE 1.3
Both of these models could explain why the sun appears to move across the sky each day. Other observations were needed to decide which model is correct.

Theories and Laws

Some ideas in science gain the status of theories. Scientists use the term "theory" differently than it is used in everyday language. You might say, "I think the dog ate my homework, but it's just a theory." In other words, it's just one of many possible explanations for the missing work. However, in science, a theory is much more than that.

Scientific Theories

A **scientific theory** is a broad explanation that is widely accepted because it is supported by a great deal of evidence. An example is the kinetic theory of matter. According to this theory, all matter consists of tiny particles that are in constant motion. Particles move at different speeds in matter in different states. You can see this in **Figure** 1.4 and at the following URL: http://preparatorychemistry.com/Bishop_KMT_frames.htm . Particles in solids move the least; particles in gases move the most. These differences in particle motion explain why solids, liquids, and gases look and act differently. Think about how ice and water differ, or how water vapor differs from liquid water. The kinetic theory of matter explains the differences. You can learn more about this theory in the chapter *States of Matter*.

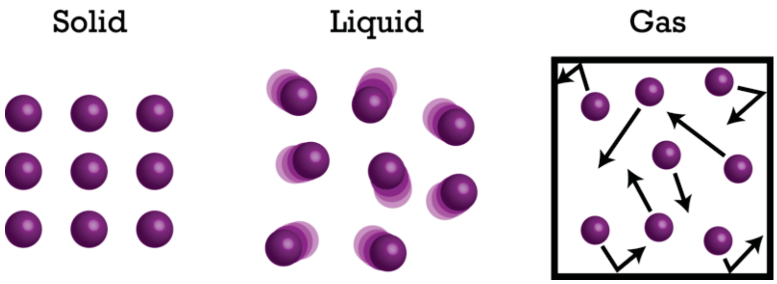


FIGURE 1.4
Why do you think particles move differently in different states of matter? (*Hint*: What causes ice to melt?)

Scientific Laws

Scientific laws are often confused with scientific theories, but they are not the same thing. A **scientific law** is a statement describing what always happens under certain conditions in nature. It answers "how" questions but not "why" questions. An example of a scientific law is Newton's law of gravity. It describes how all objects attract each other. It states that the force of attraction is greater for objects that are closer together or have more mass. However, the law of gravity doesn't explain why objects attract each other in this way. Einstein's theory of general relativity explains why. You can learn more about Newton's law of gravity and Einstein's theory in the chapter *Forces*, and at the following link: http://www.youtube.com/watch?v=O-p8yZYxNGc .

History of Science

People have wondered about the natural world for as long as there have been people. So it's no surprise that modern science has roots that go back thousands of years. The **Table** 1.1 describes just a few milestones in the history of science. A much more detailed timeline is available at the link below. Often, new ideas were not accepted at first because they conflicted with accepted views of the world. A good example is Copernicus' idea that the sun is the center of the solar system. This idea was rejected at first because people firmly believed that Earth was the center of the solar system and the sun moved around it.

http://www.sciencetimeline.net/

TABLE 1.1: Timeline of Scientific Discovery

Date	Scientific Discovery

TABLE 1.1: (continued)

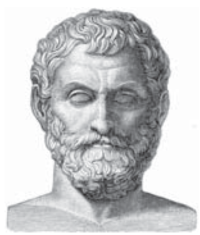
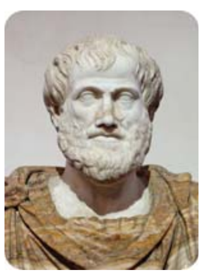
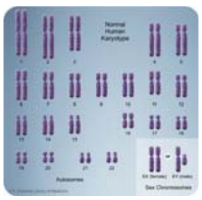
Date	Scientific Discovery
3500 BC  *Mesopotamian calendar*	Several ancient civilizations studied astronomy. They recorded their observations of the movements of stars, the sun, and the moon. We still use the calendar developed by the Mesopotamians about 5500 years ago. It is based on cycles of the moon.
600 BC  *Thales*	The ancient Greek philosopher Thales proposed that natural events, such as lightning and earthquakes, have natural causes. Up until then, people blamed such events on gods or other supernatural causes. Thales has been called the "father of science" for his ideas about the natural world.
350 BC  *Aristotle*	The Greek philosopher Aristotle argued that truth about the natural world can be discovered through observation and induction. This idea is called empiricism. Aristotle's empiricism laid the foundation for the methods of modern science.
400 AD to 1000 AD  *Early Chinese Seismograph*	When Europe went through the Dark Ages, European science withered. However, in other places, science still flourished. For example: • In North Africa, the scientist Alhazen studied light. He used experiments to test competing theories about light. • In China, scientists invented compasses. They also invented seismographs to measure earthquakes. They studied astronomy as well.

TABLE 1.1: (continued)

Date	Scientific Discovery
Mid-1500s to late 1600s  *Galileo*	The Scientific Revolution occurred in Europe. This was the beginning of modern Western science. Many scientific advances were made during this time. • Copernicus proposed that the sun, not Earth, is the center of the solar system. • Galileo improved the telescope and made important discoveries in astronomy. He discovered evidence that supported Copernicus' theory. • Newton proposed the law of gravity.
2001  *Human Chromosomes*	Many scientists around the world worked together to complete the genetic sequence of human chromosomes. This amazing feat will help scientists understand, and perhaps someday cure, genetic diseases.

Women and People of Color in Science

Throughout history, women and people of color have rarely had the same chances as white males for education and careers in science. But they have still made important contributions to science. The **Table** 1.2 gives just a few examples of their contributions to physical science. More contributions are described at these links:

- http://www.inventions.org/culture/science/women/index.html
- http://www1.umn.edu/ships/gender/giese.htm
- https://webfiles.uci.edu/mcbrown/display/faces.html
- http://library.thinkquest.org/20117/

TABLE 1.2: **A diversity of people has contributed to physical science.**

Contributor	Description
Marie Curie (1867-1934) 	Marie Curie was the first woman to win a Nobel Prize. She won the 1903 Nobel Prize in physics for the discovery of radiation. She won the 1911 Nobel Prize in chemistry for discovering the elements radium and polonium.

TABLE 1.2: (continued)

Contributor	Description
Lise Meitner (1878-1968) 	Lise Meitner was one of the scientists who discovered nuclear fission. This is the process that creates enormous amounts of energy in nuclear power plants.
Irene Joliot-Curie (1897–1956) 	Irene Joliot-Curie, daughter of Marie Curie, won the 1935 Nobel prize in chemistry, along with her husband, for the synthesis of new radioactive elements.
Maria Goeppert-Mayer (1906–1972) 	Maria Goeppert-Mayer was a co-winner of the 1963 Nobel prize in physics for discoveries about the structure of the nucleus of the atom.
Ada E. Yonath (1939–present) 	Ada E. Yonath was a co-winner of the 2009 Nobel prize in chemistry. She made important discoveries about ribosomes, the structures in living cells where proteins are made.

TABLE 1.2: (continued)

Contributor	Description
Shirley Ann Jackson (1946-present) 	Shirley Ann Jackson earned a doctoral degree in physics. She became the chair of the US Nuclear Regulatory Commission.
Ellen Ochoa (1958-present) 	Ellen Ochoa is an inventor, research scientist, and NASA astronaut. She has flown several space missions.

Lesson Summary

- Science is a way of learning about the natural world that is based on evidence and logic. The hallmark of scientific thinking is induction.
- A scientific theory is a broad explanation that is widely accepted because it is supported by a great deal of evidence. A scientific law is a statement describing what always happens under certain conditions in nature.
- Modern science has roots that go back thousands of years. Diverse people from around the world have contributed to the evolution of science.
- Women and minorities have rarely had the same chances in science as white males, but they still have made important contributions.

Lesson Review Questions

Recall

1. Define science.
2. What is induction?
3. State the contributions of Thales and Aristotle to the evolution of science.
4. What was the Scientific Revolution?

Apply Concepts

5. Use induction to draw a logical conclusion based on **Table** 1.3.

TABLE 1.3: Freezing Point of Substances

Substance	Temperature at Freezing (°C)
Pure water (1 cup water)	0
Salt water (1 cup water + 5 grams table salt)	-4
Sugar water (1 cup water + 6 grams sugar)	-5

6. What observation would require you to revise your conclusion in question 5?

Think Critically

7. Compare and contrast scientific theories and scientific laws. Give an example of each.

Points to Consider

Most of the scientists mentioned in this lesson are physical scientists.

- Based on their work, what do you think is the subject matter of physical science?
- What are some questions that physical scientists might investigate?

1.2 The Scope of Physical Science

Lesson Objectives

- Define physical science.
- Explain the relevance of physical science to everyday life.
- Describe examples of careers in physical science.

Lesson Vocabulary

- chemistry
- physical science
- physics

Introduction

Physical science covers a lot of territory. It's easier to describe by what it is not than by what it is. Basically, it's all science that is not life science.

Defining Physical Science

Physical science can be defined as the study of matter and energy. Matter refers to all the "stuff" that exists in the universe. It includes everything you can see and many things that you cannot see, including the air around you. Energy is what gives matter the ability to move and change. Energy can take many forms, such as electricity, heat, and light. Physical science can be divided into chemistry and physics. Chemistry focuses on matter and energy at the scale of atoms and molecules. Physics focuses on matter and energy at all scales, from atoms to outer space.

Chemistry

Chemistry is the study of the structure, properties, and interactions of matter. Important concepts in chemistry include physical changes, such as water freezing, and chemical reactions, such as fireworks exploding. Chemistry concepts can answer all the questions on the left page of the notebook in **Figure** 1.5. Do you know the answers?

Physics

Physics is the study of energy and how it interacts with matter. Important concepts in physics include motion, forces such as magnetism and gravity, and different forms of energy. Physics concepts can answer all the questions on the right page of the notebook in **Figure** 1.5.

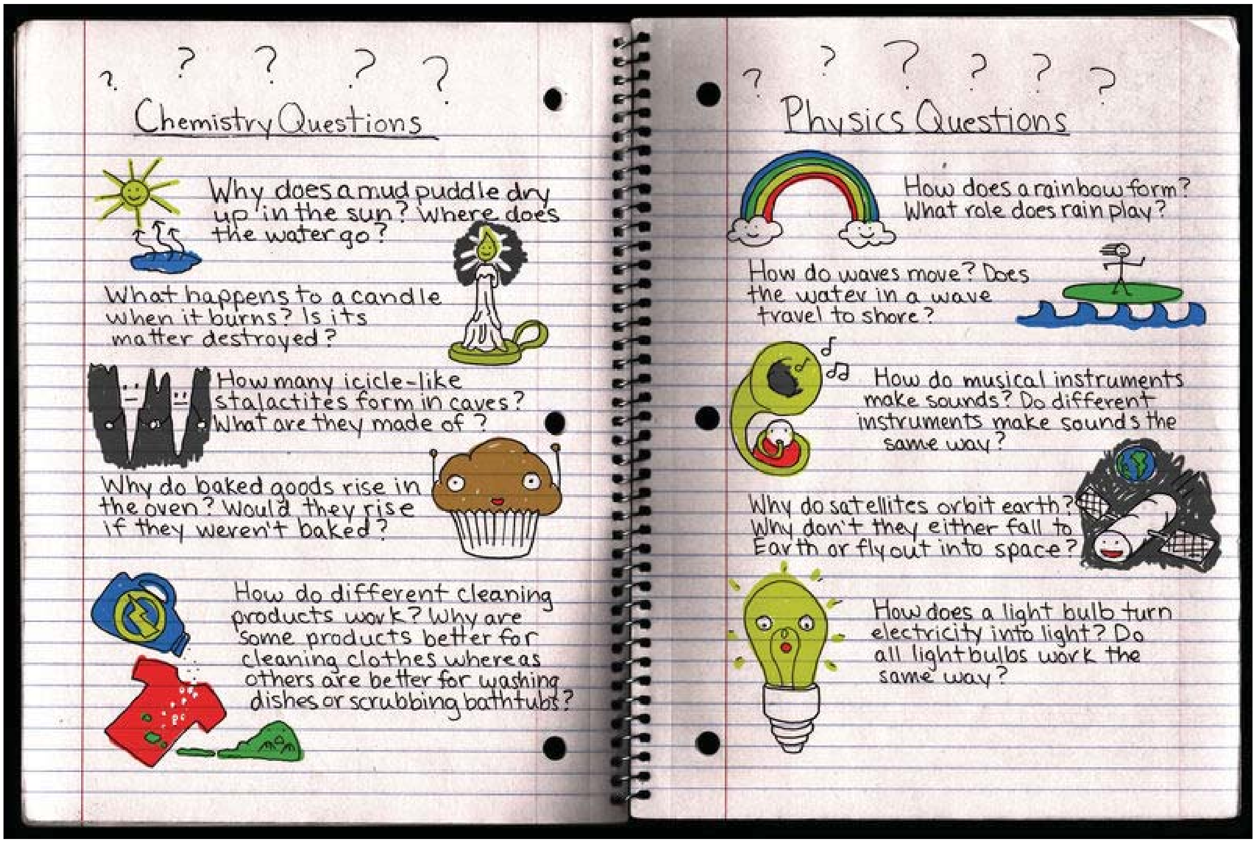


FIGURE 1.5

Using what you already know, try to answer each of these questions. Revisit your answers after you read about the relevant concepts in later chapters.

Physical Science and You

Physical science explains much of what you observe and do in your daily life. In fact, you depend on physical science for almost everything that makes modern life possible. You couldn't drive a car, text message, or send a tweet without decades of advances in chemistry and physics. You wouldn't even be able to turn on a light. **Figure** 1.6 shows some other examples of common activities that depend on advances in physical science. You'll learn the "hows" and "whys" about them as you read the rest of this book.

Careers in Physical Science

People with training in physical science are employed in a variety of places. There are many career options. Just four are described in **Figure** 1.7. Many more are described at the URL below. Do any of these careers interest you?

- http://diplomaguide.com/article_directory/sh/page/Physical%20Science/sh/Job_Titles_and_Careers_List.html
  .

FIGURE 1.6
All these activities involve matter and energy. Can you explain how or why?

Lesson Summary

- Physical science is the study of matter and energy. It includes chemistry, which focuses on matter, and physics, which focuses on energy.
- Physical science explains everyday observations and actions. Its advances make modern life possible.
- There are many career options in physical science. Examples include pharmacist and surveyor.

Lesson Review Questions

Recall

1. Define physical science.
2. What is the focus of chemistry?
3. Describe an example of a career in physical science.

FIGURE 1.7
How might chemistry or physics be involved in each of these careers?

Apply Concepts

4. What practical question might be answered with physics concepts?

Think Critically

5. Energy is needed to make matter move. Explain how you use energy to ride a bike uphill. What force allows you to coast downhill without peddling?

Points to Consider

Figure 1.7 describes several careers in physical science. Other careers in physical science include research scientist and engineer.

- What do you think research scientists do?
- How do you think the work of engineers differs from that of research scientists?

For **Table** 1.1, from top to bottom:

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For **Table** 1.2, from top to bottom:

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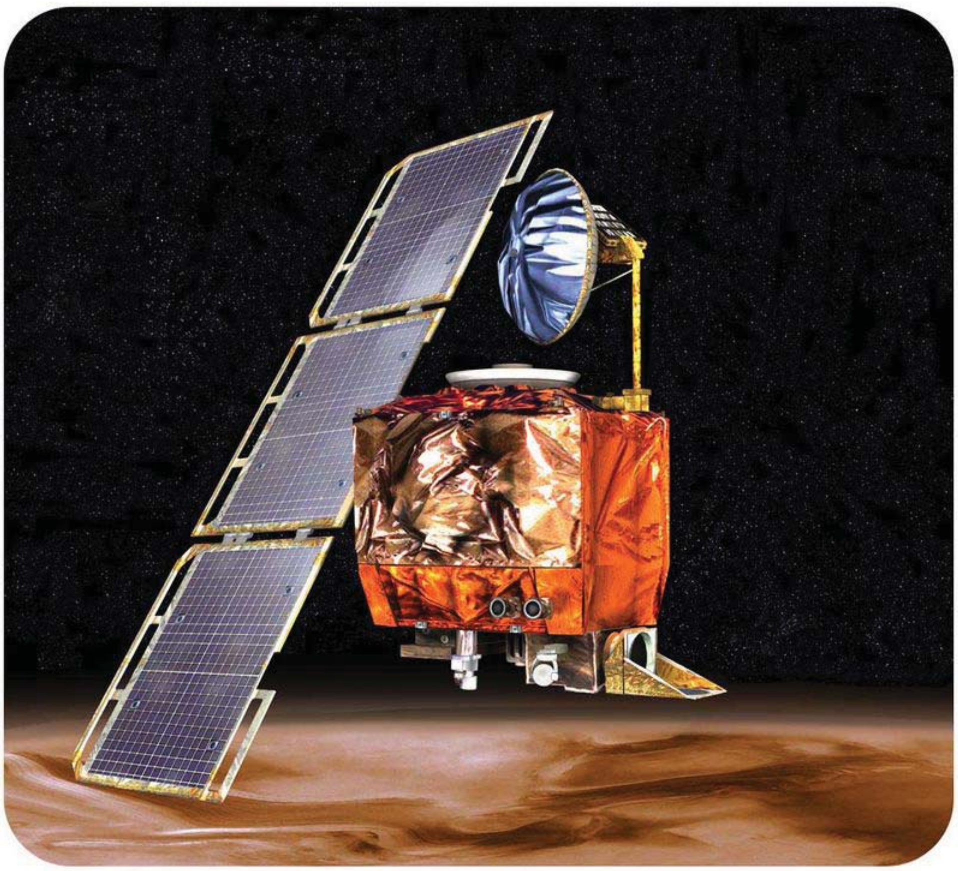
1.3 References

1. Vinay Shivakumar, modified by CK-12 Foundation. http://www.flickr.com/photos/vinayshivakumar/3280705941/ . CC BY 2.0
2. Skydiver: Philip Leara; Slide: Jacky W. (Flickr: Mediatejack). Skydiver: http://www.flickr.com/photos/philleara/7046670573/; Slide: http://www.flickr.com/photos/mediatejack/2075620374/ . CC BY 2.0
3. Joy Sheng. CK-12 Foundation . CC BY-NC 3.0
4. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0
5. Laura Guerin. CK-12 Foundation . CC BY-NC 3.0
6. Bike: Flickr:andy_c; Thermostat: Robert Lopez; Microwave: Chris Kelly; Glasses: Camera Eye Photography; Paint: Jill. Bike: http://www.flickr.com/photos/11276503@N00/1262355794; Thermostat: CK-12 Foundation; Microwave: http://www.flickr.com/photos/ckelly/4846654926; Glasses: http://www.flickr.com/photos/22605449@N06/6628934195; Paint: http://www.flickr.com/photos/lij/5869676745 . Bike: CC BY 2.0; Thermostat: CC BY-NC 3.0; Microwave: CC BY 2.0; Glasses: CC BY 2.0; Paint: CC BY 2.0
7. Pharmacist: Courtesy of Rhoda Baer, National Cancer Institute; Forensic scientist: Courtesy of National Cancer Institute; Mechanic: User:Interiot/Wikipedia; Surveyor: Courtesy of Photographers Mate 1st Class Brien Aho, U.S. Navy. Pharmacist: http://commons.wikimedia.org/wiki/File:Woman_consults_with_pharmacist_-%281%29.jpg; Forensic scientist: http://commons.wikimedia.org/wiki/File:Scientist_looking_thorugh_microscope.jpg; Mechanic: http://commons.wikimedia.org/wiki/File:Auto_Mechanic.jpg; Surveyor: http://commons.wikimedia.org/wiki/File:Us_land_survey_officer.jpg . Public Domain

CHAPTER 2 Scientific Research and Technology

Chapter Outline



In 1999, NASA's Mars Climate Orbiter, pictured here, burned up as it passed through Mars' atmosphere. The satellite was programmed to orbit Mars at high altitude and gather climate data. Instead, the Orbiter flew too low and was lost almost as soon as it reached the red planet. What happened to the Orbiter? The answer is human error. The flight system software on the Orbiter was written using scientific units of measurement. The ground crew was entering data using the common English system of units.

The example of the Mars Climate Orbiter shows the importance of using a standard system of measurement in science and technology. Measurement is just one of the basic skills needed in these fields. What other skills are needed? In this chapter, you'll find out.

Image courtesy of NASA. commons.wikimedia.org/wiki/File:Mars_Climate_Orbiter_2.jpg. Public Domain.

2.1 Scientific Investigation

Lesson Objectives

- List the steps of a scientific investigation.
- Describe the relationship of ethics to scientific research.

Lesson Vocabulary

- control
- ethics
- experiment
- field study
- hypothesis
- manipulated variable
- observation
- replication
- responding variable

Introduction

Investigation is at the heart of science. It is how scientists do research. Scientific investigations produce evidence that helps answer questions and solve problems. If the evidence cannot provide answers or solutions, it may still be useful. It may lead to new questions or problems for investigation. As more knowledge is discovered, science advances.

Steps of a Scientific Investigation

Scientists investigate the world in many ways. In different fields of science, researchers may use different methods and be guided by different theories and hypotheses. However, most scientists, including physical scientists, usually follow the general approach shown in **Figure** 2.1. This approach typically includes the following steps:

- Identify a research question or problem.
- Form a hypothesis.
- Gather evidence, or data, to test the hypothesis.
- Analyze the evidence.
- Decide whether the evidence supports the hypothesis
- Draw conclusions.
- Communicate the results.

Scientists may follow these steps in a different sequence. Or they may skip or repeat some of the steps. Which steps are repeated in **Figure** 2.1?

Asking Questions

A scientific investigation begins with a question or problem. Often, the question arises because a scientist is curious about something she has observed. An **observation** is any information that is gathered with the senses. People often have questions about things they see, hear, or observe in other ways. For example, a teen named Tara has a bracelet with a magnetic clasp, like the one shown in **Figure** 2.2. Tara has noticed that the two magnets in the clasp feel harder to pull apart on cold days than on warm days. She wonders whether temperature affects the strength of a magnet.

Forming Hypotheses and Making Predictions

Tara is curious. She decides to investigate. She begins by forming a hypothesis. A **hypothesis** is a potential answer to a question that can be tested by gathering information. If it isn't possible to gather evidence to test an answer, then it cannot be used as a scientific hypothesis. In fact, the question it addresses may not even be answerable by science. For example, in the children's television show *Sesame Street*, there was a large Snuffalufagus (kind of like an elephant). But Snuffy would disappear whenever people came around. So if someone said "Is there a Snuffy on Sesame Street?," that question would be unanswerable by science, since there isn't any test that can be performed –because Snuffy would disappear as soon as a scientist showed up. Can you think of other examples of questions outside the realm of science?

This important distinction, that evidence taken in by observation is experimented on by a scientist, is what separates legitimate science from other things which may pretend to be science. Fields which claim to be scientific but don't use the scientific method are called "pseudoscience." If a person can't gather data through some sort of instrument or sense information, they can't form a scientific conclusion. If there is no way to prove the hypothesis false, there is no scientific claim either. For example, if a friend told you that Snuffy visited him every day, but he was invisible whenever anyone walked into the room, this claim is not scientific, *since there is no way to prove him false*.

Developing a hypothesis may require creativity as well as reason. However, in Tara's case, the hypothesis is simple. She hypothesizes that a magnet is stronger at lower temperatures. Based on her hypothesis, Tara makes a prediction. If she cools a magnet, then it will pick up more metal objects, such as paper clips. Predictions are often phrased as "if-then" statements like this one. Is Tara's prediction correct? She decides to do an experiment.

Doing Experiments

An **experiment** is a controlled scientific study of specific variables. A variable is a factor that can take on different values. There must be at least two variables in an experiment. They are called the manipulated variable and the responding variable.

- The **manipulated variable** (also called the "independent variable") is a factor that is changed by the researcher. For example, Tara will change the temperature of a magnet. Temperature is the manipulated variable in her experiment.
- The **responding variable** (also called the "dependent variable") is a factor that the researcher predicts will change if the manipulated variable changes. Tara predicts the number of paper clips attracted by the magnet will be greater at lower temperatures. Number of paper clips is the responding variable in her experiment.

Tara wonders what other variables might affect the strength of a magnet. She thinks that the size and shape of a magnet might affect its strength. These are variables that must be controlled. A **control** is a variable that is held constant so it won't influence the outcome of an experiment. By using the same magnet at different temperatures,

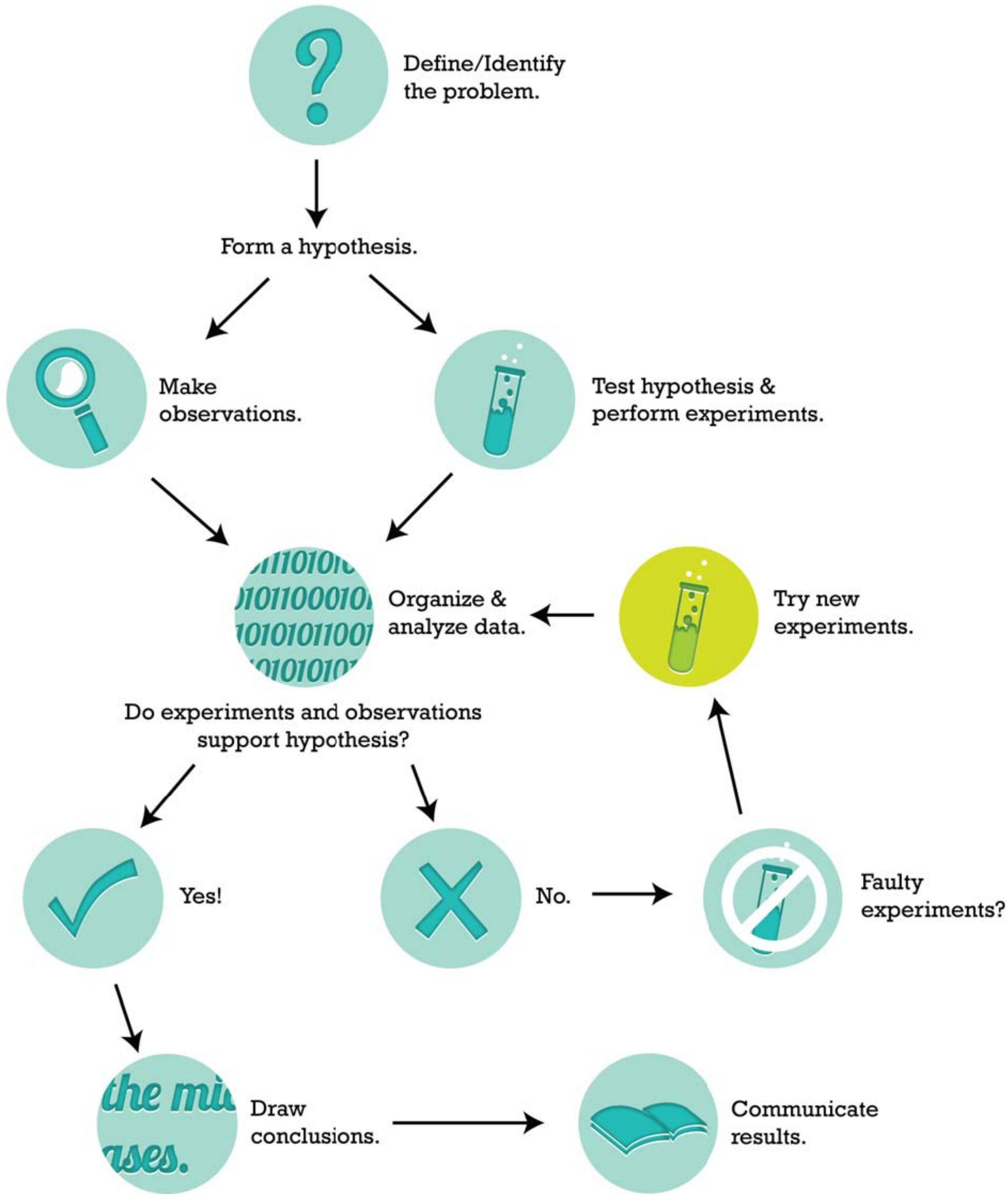


FIGURE 2.1

This diagram shows the steps of a scientific investigation. Other arrows could be added to the diagram. Can you think of one? (*Hint*: Sometimes evidence that does not support one hypothesis may lead to a new hypothesis to investigate.)

FIGURE 2.2
Each end of this bracelet contains a small magnet. The magnets attract each other and hold together the two ends.

Tara is controlling for any magnet variables that might affect the results. What other variables should Tara control? (*Hint*: What about the paper clips?)

Doing Other Types of Studies

Not everything in physical science is as easy to study as magnets and paper clips. Sometimes it's not possible or desirable to do experiments. There are some things with which a person simply cannot experiment. A distant star is a good example. Scientists study stars by making observations with telescopes and other devices. Often, it's important to investigate a problem in the real world instead of in a lab. Scientists do **field studies** to gather real-world evidence. You can see an example of a field study in **Figure** 2.3.

FIGURE 2.3
This scientist is investigating the effects farming practices have on the water quality. He is collecting and analyzing samples of river water. How might the evidence he gathers in the field help him solve the problem?

Communicating Results

Researchers should always communicate their results. By sharing their results, they may be able to get helpful feedback from other scientists. Reporting on research also lets other scientists repeat the investigation to see whether they get the same results. Getting the same results when an experiment is repeated is called **replication**. If results can be replicated, it means they are more likely to be correct. Replication of investigations is one way that a hypothesis may eventually become a theory.

Scientists can share their results in various ways. For example, they can write articles for peer-reviewed science journals. Peer review means that the work is analyzed by peers, in this case other scientists. This is the best way to ensure that the results are accurate and reported honestly. Another way to share results with other scientists is with presentations at scientific meetings (see **Figure** 2.4). Creating websites and writing articles for newspapers and magazines are ways to share research with the public. Why might this be important?

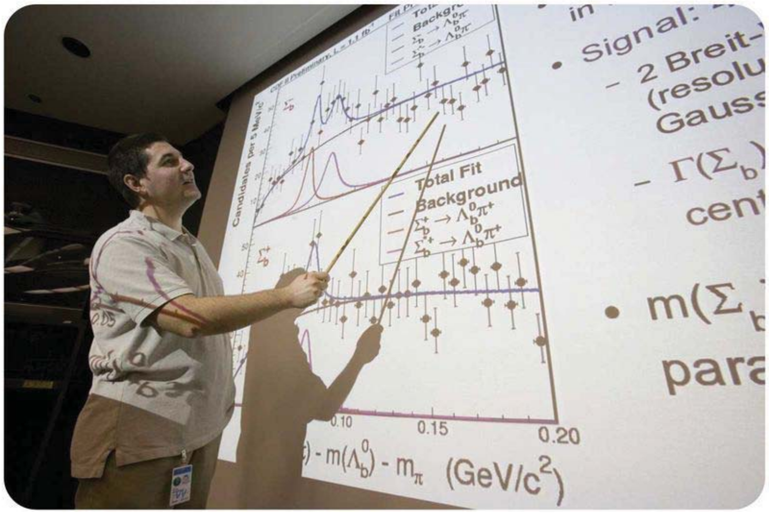


FIGURE 2.4
This researcher is presenting his results to a group of other scientists in his field.

Ethics and Scientific Research

Ethics refers to rules for deciding between right and wrong. Ethics is an important issue in science. Scientific research must be guided by ethical rules, including those listed below. The rules help ensure that the research is done safely and the results are reliable. Following the rules furthers both science and society. You can learn more about the role of ethics in science by following the links at this URL: http://www.files.chem.vt.edu/chem-ed/ethics/index.html#resources .

Ethical Rules for Scientific Research

- Scientific research must be reported honestly. It is wrong and misleading to make up or change research results.
- Scientific researchers must try to see things as they really are. They should avoid being biased by the results they expect or want to get.
- Researchers must be careful. They should take pains to avoid errors in their data.
- Researchers studying human subjects must tell their subjects about any potential risks of the research. Subjects also must be told that they can refuse to participate in the research.
- Researchers must inform coworkers, students, and members of the community about any risks of the research. They should proceed with the research only if they have the consent of these groups.
- Researchers studying living animals must treat them humanely. They should provide for their needs and do what they can to avoid harming them (see **Figure** 2.5).

Sometimes, science can help people make ethical decisions in their own lives, although science is unlikely to be the only factor involved. For example, scientific evidence shows that human actions are affecting Earth's climate. Actions such as driving cars are causing Earth to get warmer. Does this mean that it is unethical to drive a car to work or school? What if driving is the only way to get there? As this example shows, ethical decisions are likely to be influenced by many factors, not just science. Can you think of other factors that might affect ethical decisions such as this one?

FIGURE 2.5
This scientist is studying lab rats. He keeps them in comfortable cages and provides them with plenty of food and water.

Lesson Summary

- Steps of a scientific investigation include identifying a research question or problem, forming a hypothesis, gathering evidence, analyzing evidence, deciding whether the evidence supports the hypothesis, drawing conclusions, and communicating the results.
- Scientific research must be guided by ethical rules. They help ensure that the research is done safely and the results are reliable.

Lesson Review Questions

Recall

1. List the steps of a typical scientific investigation.
2. State why communication is important in scientific research.
3. Identify three ethical rules for scientific research.

Apply Concepts

4. Write a hypothesis based on this question: Do vinegar and water freeze at the same temperature? Make a prediction based on your hypothesis.
5. Describe an experiment you could do to test your prediction in question 4. Identify the variables and controls in your experiment. Include a list of materials. With your teacher's approval, conduct your investigation.

Think Critically

6. In Tara's experiment with the magnet, she measured and recorded the data in the **Table** 2.1.

TABLE 2.1: Tara's Data Table

Magnet Temperature (°C)	Number of Paper Clips Picked up by Magnet
24	8
4	6
3	6

Based on these data, Tara wrote this conclusion:

Magnets get stronger at cooler temperatures, but only down to 4°C. Below 4°C, the strength of magnets does not change.

Do you agree with Tara's conclusion? Why or why not? Suggest an alternative explanation for the data.

7. Describe a better experiment to test Tara's original hypothesis. (*Hint*: You might include more measurements, a wider range of temperatures, and more than one magnet.)

Points to Consider

Scientific investigations often involve measuring. For example, Tara measured the temperature of a magnet with a thermometer. Thermometers may have different scales. You may be most familiar with the Fahrenheit and Celsius scales.

- Do you know how the Fahrenheit and Celsius scales differ? For example, what are the freezing and boiling points of water on each scale?
- Do you know how to convert a temperature from one scale to the other?

2.2 Science Skills

Lesson Objectives

- Explain how measurements are made in scientific research.
- Describe how to keep good records in scientific investigations.
- Demonstrate how to use significant figures and scientific notation.
- Calculate descriptive statistics and use data graphs.
- Identify the role of models in science.
- Describe how to stay safe when doing scientific research.

Lesson Vocabulary

- accuracy
- Kelvin scale
- mean
- model
- precision
- range
- scientific notation
- SI
- significant figures

Introduction

Measuring is an important science skill. Other skills needed to do science include keeping records, doing calculations, organizing data, and making models. Knowing how to stay safe while doing scientific investigations may be the most important skill of all. You will read about all these science skills in this lesson.

Measuring

One of the most important aspects of measuring is the system of units used for measurement. Remember the Mars Climate Orbiter that opened this chapter? It shows clearly why a single system of measurement units is needed in science.

Using SI Units

The measurement system used by most scientists is the International System of Units, or **SI**. **Table** 2.2 lists common units in this system. SI is easy to use because everything is based on the number 10. Basic units are multiplied or divided by powers of ten to arrive at bigger or smaller units. Prefixes are added to the names of the basic units to indicate the powers of ten. For example, the meter is the basic unit of length. The prefix *kilo-* means 1000, so a kilometer is 1000 meters. Can you infer what the other prefixes in the table mean? If not, you can find out at this URL: http://physics.nist.gov/cuu/Units/prefixes.html .

TABLE 2.2: Common SI Units

Variable	Basic SI Unit (English Equivalent)	Related SI Units	Equivalent Units
Length	meter (m) (1 m = 39.37 in)	kilometer (km) decimeter (dm) centimeter (cm) millimeter (mm) micrometer (μm) nanometer (nm)	= 1000 m = 0.1 m = 0.01 m = 0.001 m = 0.000001 m = 0.000000001 m
Volume	cubic meter (m^3) (1 m^3 = 1.3 yd^3)	liter (L) milliliter (mL)	= 1 dm^3 = 1 cm^3
Mass	gram (g) (1 g = 0.04 oz)	kilogram (kg) milligram (mg)	= 1000 g = 0.001 g

The SI system has units for other variables in addition to the three shown here in **Table** 2.2. Some of these other units are introduced in later chapters.

Problem Solving

Problem: Use information in **Table** 2.2 to convert 3 meters to inches.

Solution: 3 m = 3 $\times$ 39.37 in = 118.11 in

You Try It!

Problem: Rod needs to buy 1 m of wire for a science experiment. The wire is sold by the yard, not the meter. If he buys 1 yd of wire, will he have enough? (*Hint*: How many inches are there in 1 yd? In 1 m?)

Measuring Temperature

The SI scale for measuring temperature is the **Kelvin scale**. However, some scientists use the Celsius scale instead. If you live in the U.S., you are probably more familiar with the Fahrenheit scale. **Table** 2.3 compares all three temperature scales. What is the difference between the boiling and freezing points of water on each of these scales?

TABLE 2.3: Temperature Scales

Scale	Freezing Point of Water	Boiling Point of Water
Kelvin	273 K	373 K
Celsius	0°C	100°C
Fahrenheit	32°F	212°F

Each 1-degree change on the Kelvin scale is equal to a 1-degree change on the Celsius scale. This makes it easy to convert measurements between Kelvin and Celsius. For example, to go from Celsius to Kelvin, just add 273. How would you convert a temperature from Kelvin to Celsius?

Converting between Celsius and Fahrenheit is more complicated. The following conversion factors are used:

- Celsius $\rightarrow$ Fahrenheit : $(°C \times 1.8) + 32 = \ °F$
- Fahrenheit $\rightarrow$ Celsius : $(°F - 32) \div 1.8 = \ °C$

Problem Solving

Problem: Convert 10°C to Fahrenheit.

Solution: (10°C × 1.8) + 32 = 50°F

You Try It!

Problem: The weather forecaster predicts a high temperature today of 86°F. What will the temperature be in Celsius?

Using Measuring Devices

Measuring devices must be used correctly to get accurate measurements. **Figure** 2.6 shows the correct way to use a graduated cylinder to measure the volume of a liquid.

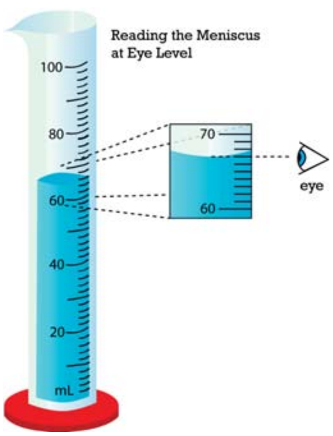


FIGURE 2.6
This cylinder contains about 66 mL of liquid. What would the measurement be if you read the top of the meniscus by mistake?

Follow these steps when using a graduated cylinder to measure liquids:

- Place the cylinder on a level surface before adding liquid.
- Move so your eyes are at the same level as the top of the liquid in the cylinder.
- Read the mark on the glass that is at the lowest point of the curved surface of the liquid. This is called the meniscus.

At the URLs below, you can see the correct way to use a metric ruler to measure length and a beam balance to measure mass.

- http://www.wsd1.org/waec/math/Consumer%20Math%20Advanced/Unit%202%20Design%20and%20Measurement/Ruler%20Meas/measmain.htm (metric ruler)
- http://www.youtube.com/watch?v=C9howXG7LUY (beam balance) (5:14)

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Click image to the left for more content.

Accuracy and Precision

Measurements should be both accurate and precise.

- **Accuracy** is how close a measurement is to the true value. For example, 66 mL is a fairly accurate measurement of the liquid in **Figure** 2.6.
- **Precision** is how exact a measurement is. A measurement of 65.5 mL is more precise than a measurement of 66 mL. But in **Figure** 2.6, it is not as accurate.

You can think of accuracy and precision in terms of a game like darts. If you are aiming for the bull's-eye and get all of the darts close to it, you are being both accurate and precise. If you get the darts all close to each other somewhere else on the board, you are precise, but not accurate. And finally, if you get the darts spread out all over the board, you are neither accurate nor precise.

Keeping Records

Record keeping is very important in scientific investigations. Follow the tips below to keep good science records.

- Use a bound laboratory notebook so pages will not be lost. Write in ink for a permanent record.
- Record the steps of all procedures.
- Record all measurements and observations.
- Use drawings as needed.
- Date all entries, including drawings.

Calculating

Doing science often requires calculations. Converting units is just one example. Calculations are also needed to find derived quantities.

Calculating Derived Quantities

Derived quantities are quantities that are calculated from two or more different measurements. Examples include area and volume. It's easy to calculate these quantities for a simple shape. For a rectangular solid, like the one in **Figure** 2.7, the formulas are:

$$\text{Area (of each side)} = \text{length} \times \text{width } (l \times w)$$
$$\text{Volume} = \text{length} \times \text{width} \times \text{height } (l \times w \times h)$$

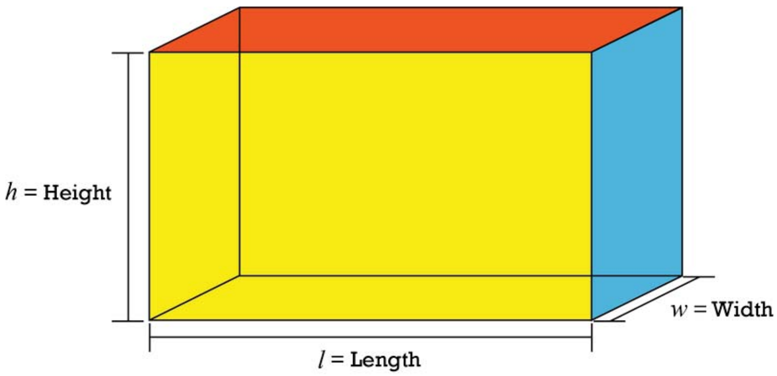


FIGURE 2.7
Dimensions of a rectangular solid include length (l), width (w), and height (h). The solid has six sides. How would you calculate the total surface area of the solid?

Helpful Hints

When calculating area and volume, make sure that:

- all the measurements have the same units.
- answers have the correct units. Area should be in squared units, such as cm^2; volume should be in cubed units, such as cm^3. Can you explain why?

Naturally, not all derived quantities will have the same types of units. In the examples above, the only fundamental unit used was meters for the length of one of the sides of the box. However, if you had a quantity like speed (a derived quantity), it would be equal to distance traveled (which is meters) divided by the amount of time you spent traveling that distance (which is in seconds). Therefore your speed would be measured in meters per second.

Using Significant Figures

Assume you are finding the area of a rectangle with a length of 6.8 m and a width of 6.9 m. When you multiply the length by the width on your calculator, the answer you get is 46.92 m^2. Is this the correct answer? No; the correct answer is 46.9 m^2. The correct answer must be rounded down so there is just one digit to the right of the decimal point. That's because the answer cannot have more digits to the right of the decimal point than any of the original measurements. Using extra digits implies a greater degree of precision than actually exists. The correct number of digits is called the number of **significant figures**. To learn more about significant figures and rounding, you can watch the videos at the URLs below.

- http://www.youtube.com/watch?v=ZbTxK6-1fDg (3:20)
- http://www.youtube.com/watch?v=MuVyoqz5lxM (8:30)

Using Scientific Notation

Quantities in science may be very large or very small. This usually requires many zeroes to the left or right of the decimal point. Such numbers can be hard to read and write accurately. That's where scientific notation comes in. **Scientific notation** is a way of writing very large or small numbers that uses exponents. Numbers are written in this format:

$$a \times 10^b$$

The letter *a* stands for a decimal number. The letter *b* stands for an exponent, or power, of 10. For example, the number 300 is written as 3.0×10^2. The number 0.03 is written as 3.0×10^{-2}. **Figure** 2.8 explains how to convert numbers to and from scientific notation. For a review of exponents, watch: http://www.youtube.com/watch?v=8htcZca0JIA .

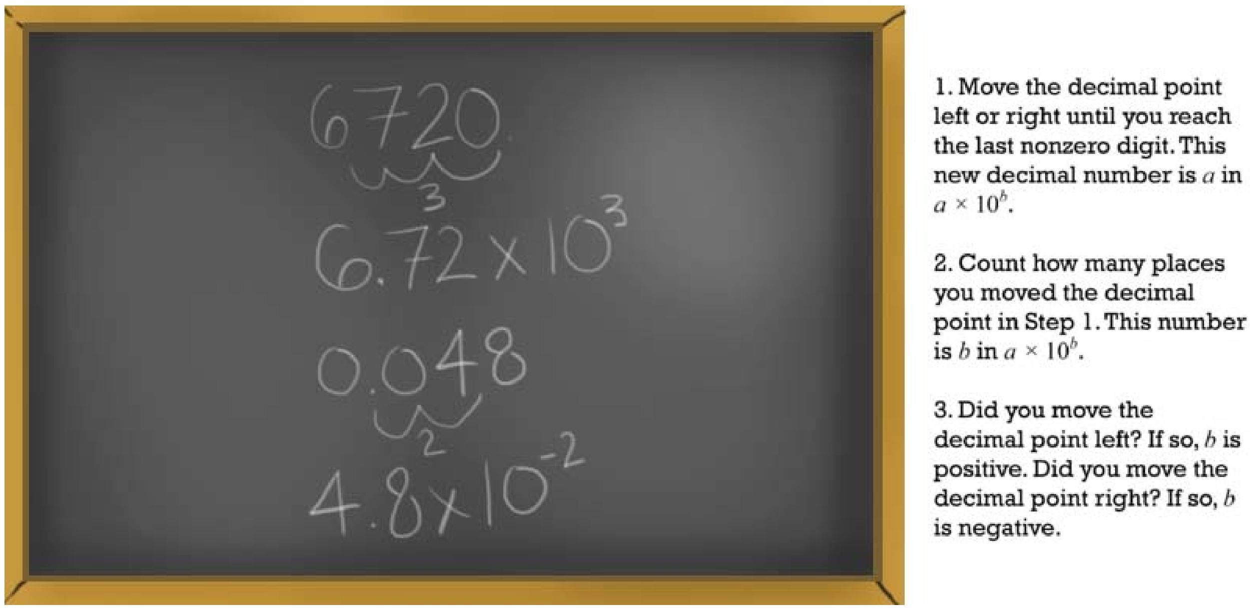


FIGURE 2.8

Follow the steps in reverse to convert numbers from scientific notation.

You Try It!

Problem: Write the number 46,000,000 in scientific notation.

Organizing Data

In a scientific investigation, a researcher may make and record many measurements. These may be compiled in spreadsheets or data tables. In this form, it may be hard to see patterns or trends in the data. Descriptive statistics and graphs can help organize the data so patterns and trends are easier to spot.

Example: A vehicle checkpoint was set up on a busy street. The number of vehicles of each type that passed by the checkpoint in one hour was counted and recorded in **Table** 2.4. These are the only types of vehicles that passed the checkpoint during this period.

TABLE 2.4: **Data Table**

Type of Vehicle	Number
4-door cars	150
2-door cars	50
SUVs	80

TABLE 2.4: (continued)

Type of Vehicle	Number
vans	50
pick-up trucks	70

Descriptive Statistics

A descriptive statistic sums up a set of data in a single number. Examples include the mean and range.

- The **mean** is the average value. It gives you an idea of the typical measurement. The mean is calculated by summing the individual measurements and dividing the total by the number of measurements. For the data in **Table** 2.4, the mean number of vehicles by type is: (150 + 50 + 80 + 50 + 70) ÷ 5 = 80. (There are two other words people can sometimes use when they use the word "average." They might be referring to a quantity called the "median" or the "mode." You'll see these quantities in later courses, but for now, we'll just say the average is the same thing as the mean.)
- The **range** is the total spread of values. It gives you an idea of the variation in the measurements. The range is calculated by subtracting the smallest value from the largest value. For the data in **Table** 2.4, the range in numbers of vehicles by type is: 150 - 50 = 100.

Graphs

Graphs can help you visualize a set of data. Three commonly used types of graphs are bar graphs, circle graphs, and line graphs. **Figure** 2.9 shows an example of each type of graph. The bar and circle graphs are based on the data in **Table** 2.4, while the line graph is based on unrelated data. You can see more examples at this URL: http://www.beaconlearningcenter.com/weblessons/kindsofgraphs/default.htm .

- Bar graphs are especially useful for comparing values for different types of things. The bar graph in **Figure** 2.9 shows the number of vehicles of each type that passed the checkpoint.
- Circle graphs are especially useful for showing percents of a whole. The circle graph in **Figure** 2.9 shows the percent of all vehicles counted that were of each type.
- Line graphs are especially useful for showing changes over time. The line graph in **Figure** 2.9 shows how distance from school changed over time when some students went on a class trip.

Helpful Hints

Circle graphs show percents of a whole. What are percents?

- Percents are fractions in which the denominator is 100. *Example:* 30% = 30/100
- Percents can also be expressed as decimal numbers. *Example:* 30% = 0.30

You Try It!

Problem: Show how to calculate the percents in the circle graph in **Figure** 2.9.

Need a refresher on percents, fractions, and decimals? Go to this URL: http://www.mathsisfun.com/decimal-fraction-percentage.html .

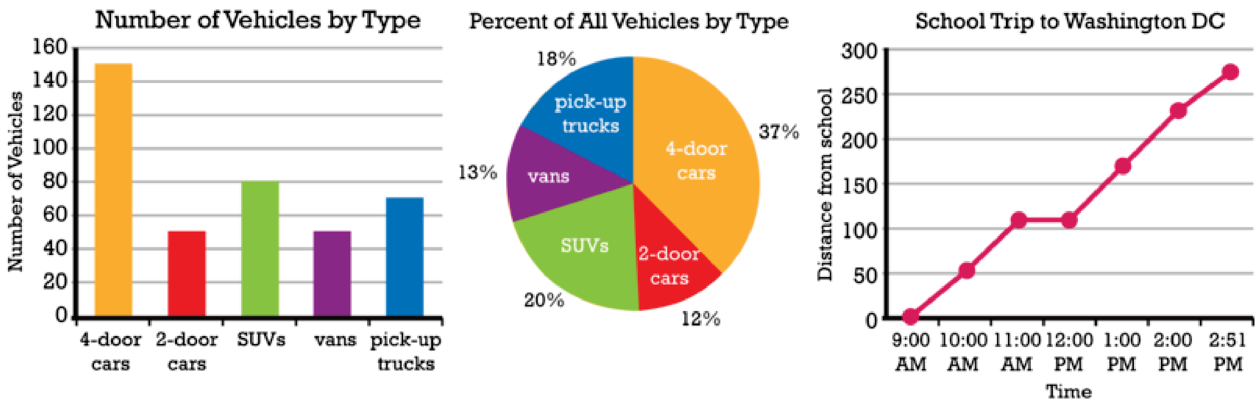


FIGURE 2.9

These are three commonly used types of graphs. When would you want to use a bar graph? What about a line graph?

Using Models

Did you ever read a road map, sketch an object, or play with toy trucks or dolls? No doubt, the answer is yes. What do all these activities have in common? They all involve models. A **model** is a representation of an object, system, or process. For example, a road map is a representation of an actual system of roads on the ground.

Models are very useful in science. They provide a way to investigate things that are too small, large, complex, or distant to investigate directly. **Figure** 2.10 shows an example of a model in chemistry. To be useful, a model must closely represent the real thing in important ways, but it must be simpler and easier to manipulate than the real thing. Do you think the model in **Figure** 2.10 meets these criteria?

Staying Safe in Science

Research in physical science can be exciting, but it also has potential dangers. Whether in the lab or in the field, knowing how to stay safe is important.

Safety Symbols

Lab procedures and equipment may be labeled with safety symbols. These symbols warn of specific hazards, such as flames or broken glass. Learn the symbols so you will recognize the dangers. A list of common safety symbols is shown in **Figure** 2.11. Do you know how to avoid each hazard? You can learn more at this URL: http://www.angelfire.com/va3/chemclass/safety.html .

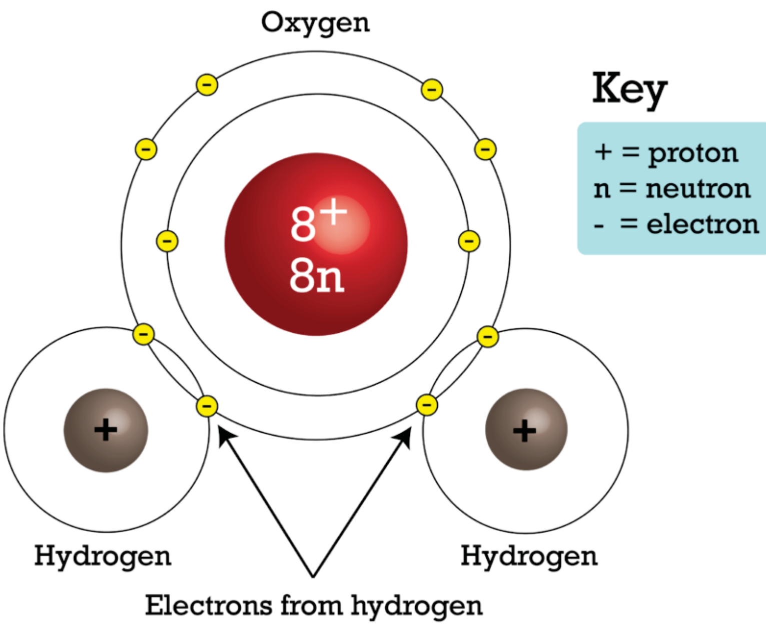


FIGURE 2.10
This model represents a water molecule. It shows that a water molecule consists of an atom of oxygen and two atoms of hydrogen. What else does the model show?

FIGURE 2.11
Why does glassware pose a hazard?

Safety Rules

Following basic safety rules is the best way to stay safe in science. Safe practices help prevent accidents. Several lab safety rules are listed below. Different rules may apply when you work in the field. But in all cases, you should always follow your teacher's instructions.

Lab Safety Rules

- Wear safety gear, including goggles, an apron, and gloves.
- Wear a long-sleeved shirt and shoes that completely cover your feet.
- Tie back your hair if it is long.
- Do not eat or drink in the lab.
- Never work alone.
- Never perform unauthorized experiments.
- Never point the open end of a test tube at yourself or another person.
- Always add acid to water —never water to acid —and add the acid slowly.
- To smell a substance, use your hand to fan vapors toward your nose rather than smell it directly. This is demonstrated in **Figure** 2.12.
- When disposing of liquids in the sink, flush them down the drain with lots of water.
- Wash glassware and counters when you finish your lab work.
- Thoroughly wash your hands with soap and water before leaving the lab.

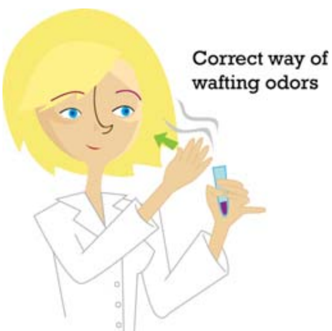


FIGURE 2.12
This is the correct way to smell a chemical in science lab. This helps prevent possible injury from toxic fumes.

Even when you follow the rules, accidents can happen. Immediately alert your teacher if an accident occurs. Report all accidents, even if you don't think they are serious.

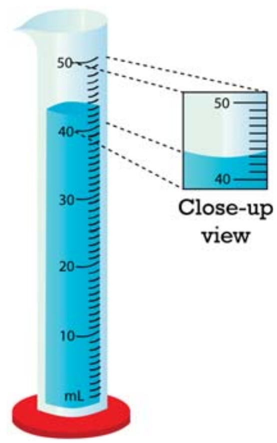
Lesson Summary

- Most scientists use the SI system of units. It includes the Kelvin scale for temperature. Measurements should be both accurate and precise.
- Good record keeping is very important in scientific research.
- Doing science often requires calculations, such as finding derived quantities. Calculations may involve significant figures or scientific notation.
- Descriptive statistics and graphs help organize data so patterns and trends are more apparent. Descriptive statistics include the mean and range. Types of graphs include bar, circle, and line graphs.
- A model is a representation of an object, system, or process. Models help scientists investigate things that are too small, large, complex, or distant to study directly.
- Staying safe while doing scientific research means recognizing safety symbols and following safety rules.

Lesson Review Questions

Recall

1. What are the basic SI units for length, volume, and mass?
2. How much liquid does this graduated cylinder contain?



3. Define the mean and range of a data set. How are they calculated?
4. What is a model? How are models used in science?
5. What hazard does each of these symbols represent?

Apply Concepts

6. Do the following calculations:
   a. Write the number 0.0000087 in scientific notation.
   b. Convert 50°C to °F.
   c. Find the volume of a cube that measures 5 cm on each dimension (length, width, and height).
7. Make a safety poster to convey one of the lab safety rules in this lesson.

Think Critically

8. Compare and contrast accuracy and precision of measurements in science.

Points to Consider

Most of the skills described in this lesson are important in technology as well as science.

- What is technology?
- How do you think technology differs from science?

2.3 Technology

Lesson Objectives

- Define technology.
- Outline the technological design process.
- Explain how science and technology are related.
- Describe how technology and society influence each other.

Lesson Vocabulary

- engineer
- technological design
- technology

Introduction

What do you think of when you hear the word technology? Do devices like computers and solar-powered cars come to mind? Devices such as these are just one meaning of the term "technology." As a field of study, technology is much broader than that.

What Is Technology?

Technology is the application of knowledge to real-world problems. It includes methods and processes as well as devices like computers and cars. An example is the Bessemer process. It is a cheap method of making steel that was invented in the 1850s. It is just one of many technological advances that have occurred in manufacturing. Technology is also responsible for most of the major advances in agriculture, transportation, communications, and medicine. Clearly, technology has had a huge impact on people and society. It is hard to imagine what life would be like without it.

Professionals in technology are generally called **engineers**. Most engineers have a strong background in physical science. There are many different careers in engineering. You can learn about some of them at the URLs below.

- http://www.sciencebuddies.org/science-fair-projects/science_careers.shtml?gclid=CMbjl5HB4qgCFcW8Kgod7HdmGQ
- http://www.careertoolkits.com/engineering/

Technological Design

The development of new technology is called **technological design**. It is similar to scientific investigation. Both processes use evidence and logic to solve problems.

Technological Design Process

Figure 2.13 shows the steps of the technological design process. Consider the problem of developing a solar-powered car. Many questions would have to be researched in the design process. For example, what is the best shape for gathering the sun's rays? How will the energy from the sun be stored? Will a back-up energy source be needed? After researching the answers, possible designs are developed. This takes imagination as well as reason. Then a model is made of the best design, and the model is tested. This allows any problems with the design to be worked out before a final design is selected.

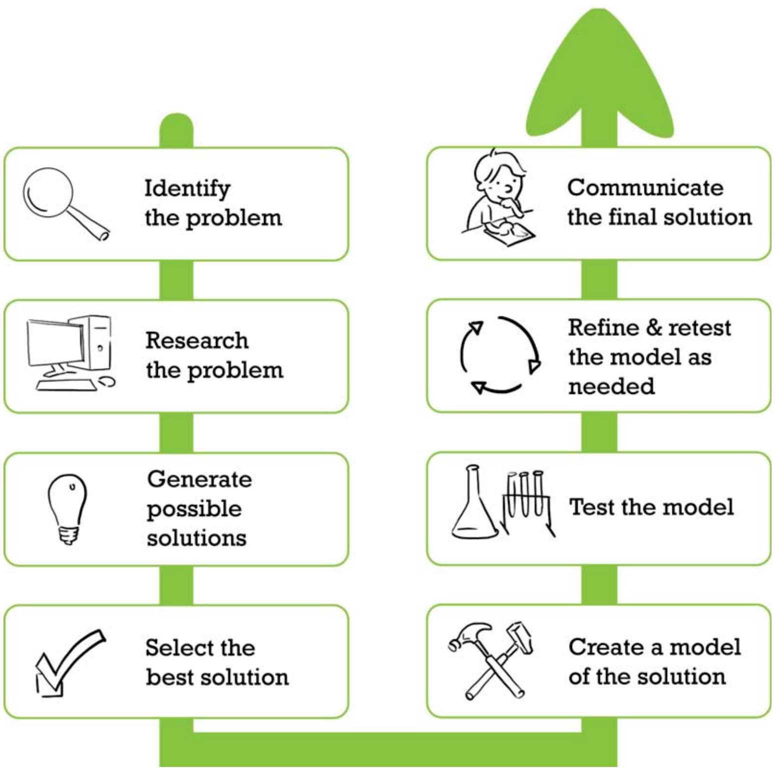


FIGURE 2.13
This flowchart represents the process of technological design. How does the technological design process resemble a scientific investigation?

Constraints on Technological Design

Technological design always has constraints. Constraints are limits on the design. Common constraints include:

- laws of nature, such as the law of gravity.
- properties of the materials used.
- cost of producing a technology.

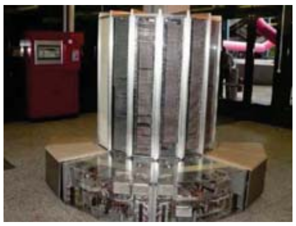
Ethical concerns are also constraints on many technological designs. Like scientists, engineers must follow ethical rules. For example, the technologies they design must be as safe as possible for people and the environment.

Engineers must weigh the benefits and risks of new technologies, and the benefits should outweigh the risks.

Advances in Technology

Technology advances as new materials and processes are invented. Computers are a good example. **Table** 2.5 and the videos below show some of the milestones in their evolution. The evolution of modern computers began in the 1930s. Computers are still evolving today. How have computers changed during your lifetime?

- http://www.youtube.com/watch?v=ETVAlcMXitk (4:11)



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- http://www.youtube.com/watch?v=gas2Xi0rW6A (5:36)

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TABLE 2.5: Evolution of Computers

Computer (Year)	Description
ENIAC (1946)  *US Army Photo*	Like other early computers, the huge ENIAC computer used vacuum tubes for electrical signals. This made it very large and expensive. It could do just one task at a time. It had to be rewired to change programs. That's what the women in this photo are doing.
ERMA (1955)	The ERMA computer represented a new computer technology. It used transistors instead of vacuum tubes. This allowed computers to be smaller, cheaper, and more energy efficient.

TABLE 2.5: (continued)

Computer (Year)	Description
PDP-8 (1968) 	By the late 1960s, tiny transistors on silicon chips were invented. They increased the speed and efficiency of computers. They also allowed computers to be much smaller. The PDP-8 computer pictured here was the first "mini" computer.
Macintosh 128K (1984) 	The next major advance in computers was the development of microprocessors. A microprocessor consisted of thousands of integrated circuits placed on a tiny silicon chip. This allowed computers to be more powerful and even smaller. The computer pictured here is the first Macintosh personal computer.
MacBook Air (2010) 	The computers of the 21st century are tiny compared with the lumbering giants of the mid-1900s. Their problem-solving abilities are also immense compared with early computers. The diversity of software programs available today allows users to undertake an immense variety of tasks —and no rewiring is needed!

Technology and Science

Technology is sometimes referred to as applied science, but it has a different goal than science. The goal of science is to increase knowledge. The goal of technology is to use knowledge for practical purposes.

Although they have different goals, technology and science work hand in hand. Each helps the other advance. Scientific knowledge is needed to create new technologies. New technologies are used to further science. The microscope is a good example. Scientific knowledge of light allowed 17^{th} century lens makers to make the first microscopes. This new technology let scientists view a world of tiny objects they had never before seen. **Figure** 2.14 describes other examples.

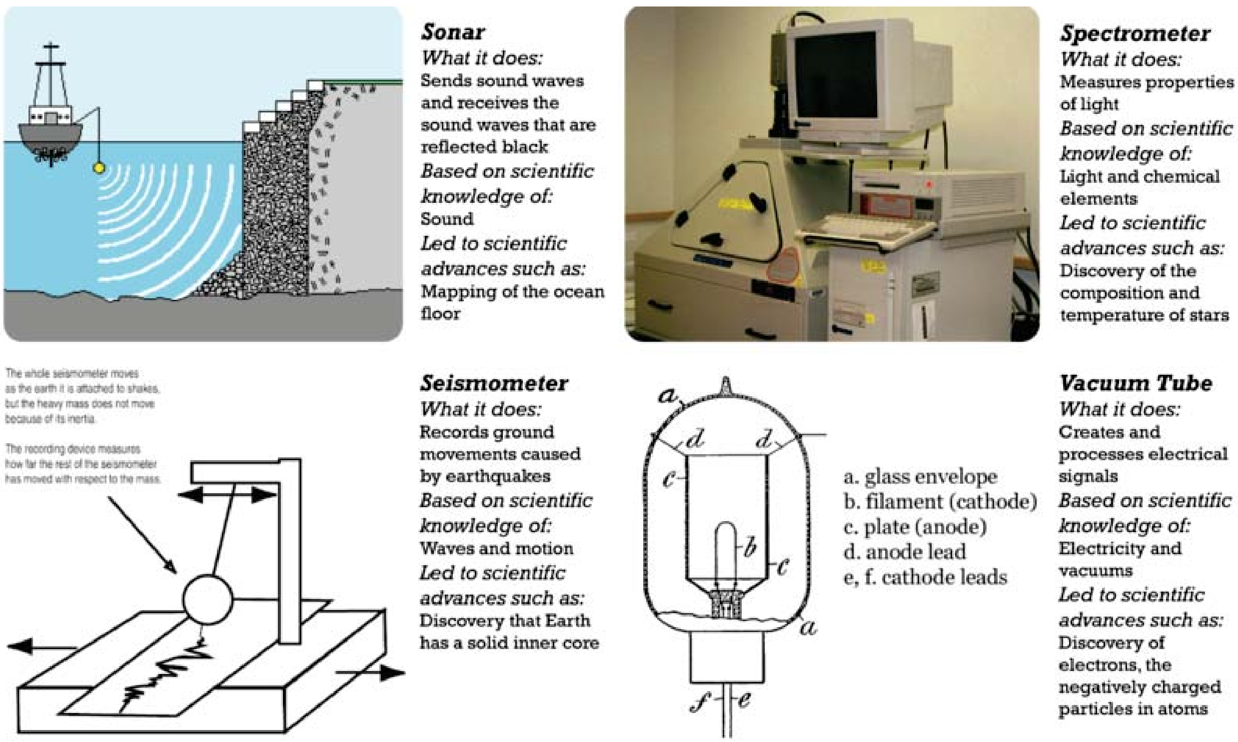

FIGURE 2.14
Each of the technologies pictured here is based on scientific knowledge. Each also led to important scientific advances.

Technology and Society

The goal of technology is to solve people's problems. Therefore, the problems of society generally set the direction that technology takes. Technology, in turn, affects society. It may make people's lives easier or healthier. Two examples are described in **Figure** 2.15.

You can read about other examples at these URLs:

- http://mezocore.wordpress.com/
- http://www.makingthemodernworld.org.uk/everyday_life/

Lesson Summary

- Technology is the application of knowledge to real-world problems. Engineers are professionals in technology.
- Technological design is the development of new technology. The design process is based on evidence and logic.
- Technology and science have different goals, but each helps the other advance.
- The problems of society generally set the direction of technology. New technologies, in turn, may make

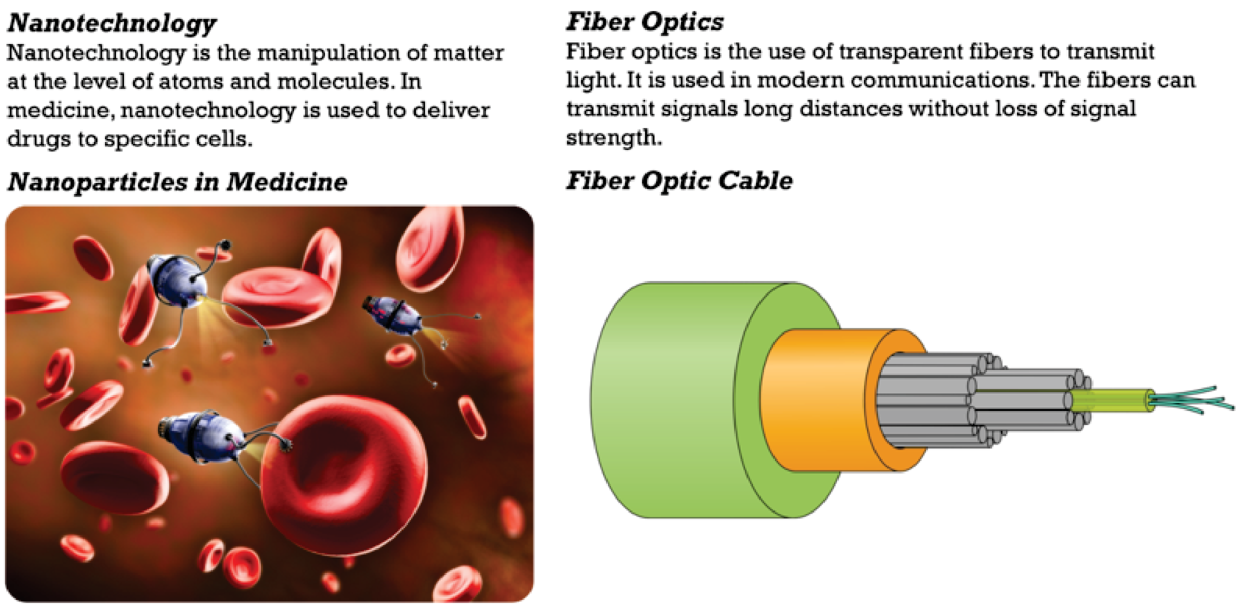

FIGURE 2.15
Technologies that help people may be as simple as forks and knives. Or they may be as complex as the two examples described here. How does technology help you?

people's lives easier or healthier.

Lesson Review Questions

Recall

1. Define technology.
2. What do engineers do?
3. List the steps of the technological design process.

Apply Concepts

4. A team of engineers is designing a new type of car. What are likely to be some of the constraints on the design?

Think Critically

5. Compare and contrast science and technology.
6. Relate technology and society.

Points to Consider

Nanotechnology manipulates atoms and molecules of matter.

- What is matter? What are its characteristics?
- Do you think all matter consists of atoms and molecules?

For **Table** 2.5, from top to bottom,

- ENIAC: Courtesy of US Army. http://commons.wikimedia.org/wiki/File:Two_women_operating_ENIAC.gif . Public Domain.
- PDP-8: User:Alkivar/Wikipedia. http://commons.wikimedia.org/wiki/File:PDP-8.jpg . Public Domain.
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2.4 References

1. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0
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14. Sonar: Courtesy of US Geological Survey; Spectrometer: Courtesy of National Institute for Occupational Safety and Health (NIOSH); Seismometer: Courtesy of US Geological Survey; Vacuum tube: IMeowbot, based on illustration by John Ambrose Fleming. Sonar: http://marine.usgs.gov/fact-sheets/michigan/michigan.html; Spectrometer: http://commons.wikimedia.org/wiki/File:Microscopic_spectrometer.jpg; Seismometer: http://earthquake.usgs.gov/learn/kids/coloring/; Vacuum tube: http://commons.wikimedia.org/wiki/File:Diode-tube.png . Public Domain
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