CK-12 Physical Science Concepts For Middle School

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CHAPTER 1

Introduction to Physical Science

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CHAPTER 1

Introduction to Physical Science

Introduction

Are you curious about things around you and about other planets? If so, then you're thinking like a scientist. Scientists are curious about things in nature, and they do investigations to better understand them. They often use technology—from microscopes to Mars rovers—to extend their own senses so they can learn even more. In this unit, you'll read about how scientists think and how they investigate and explore the natural world.

1.1 Nature of Science

- Define science.
- State the goal of science.
- Describe how science advances.

Does the word science make you think of high-tech labs and researchers in white coats like the ones in this picture?

This is often an accurate image of science but not always. If you look up science in a dictionary, you would find that it comes from a Latin word that means "having knowledge."

However, this isn't an adequate definition either.

What Is Science?

Science is more about gaining knowledge than it is about simply having knowledge. Science is a way of learning about the natural world that is based on evidence and logic. In other words, science is a process, not just a body of facts. Through the process of science, our knowledge of the world advances.

The Goal of Science

Scientists may focus on very different aspects of the natural world. For example, some scientists focus on the world of tiny objects, such as atoms and molecules. Other scientists devote their attention to huge objects, such as the sun and other stars. But all scientists have at least one thing in common. They want to understand how and why things happen. Achieving this understanding is the goal of science.

Have you ever experienced the thrill of an exciting fireworks show like the one pictured in the Figure 1.1?

Fireworks show how the goal of science leads to discovery.

Fireworks were invented at least 2000 years ago in China, but explaining how and why they work didn't happen until much later. It wasn't until scientists had learned about elements and chemical reactions that they could explain what caused fireworks to create brilliant bursts of light and deep rumbling booms.

Figure 1.1

How Science Advances

Sometimes learning about science is frustrating because scientific knowledge is always changing. But that's also what makes science exciting. Occasionally, science moves forward in giant steps. More commonly, however, science advances in baby steps. Giant steps in science may occur if a scientist introduces a major new idea. For example, in 1666, Isaac Newton introduced the idea that gravity is universal. People had long known that things fall to the ground because they are attracted by Earth. But Newton proposed that everything in the universe exerts a force of attraction on everything else. This idea is known as Newton's law of universal gravitation.

Q: How do you think Newton's law of universal gravitation might have influenced the advancement of science?

A: Newton's law allowed scientists to understand many different phenomena. It explains not only why things always fall down toward the ground or roll downhill. It also explains the motion of many other objects. For example, it explains why planets orbit the sun. The idea of universal gravity even helped scientists discover the planets Neptune and Pluto. The caption and diagram in the Figure 1.2 explain how.

Figure 1.2

In the early 1800s, astronomers noticed a wobble in Uranus' orbit around the sun. They predicted that the wobble was caused by the pull of gravity of another, not-yet-discovered planet.
Scientists searched the skies for the "missing" planet. When they discovered Neptune in 1846, they thought they had found their missing planet. After the astronomers took into account the effects of Neptune's gravity, they saw that Uranus still had an unexplained wobble. They predicted

that there must be another planet beyond Neptune. That planet, now called Pluto, was finally discovered in 1930.

Baby steps in science occur as small bits of evidence gradually accumulate. The accumulating evidence lets scientists refine and expand on earlier ideas. For example, the scientific idea of the atom was introduced in the early 1800s. But scientists came to understand the structure of the atom only as evidence accumulated over the next two centuries. Their understanding of atomic structure continues to expand today.

The advancement of science is sometimes a very bumpy road. New knowledge and ideas aren't always accepted at first, and scientists may be mocked for their ideas. The idea that Earth's continents drift on the planet's surface is a good example. This idea was first proposed by a scientist named Alfred Wegener in the early 1900s. Wegener also proposed that all of the present continents had once formed one supercontinent, which he named Pangaea.

Other scientists not only rejected Wegener's ideas, but ridiculed Wegener for even suggesting them. It wasn't until the 1950s that enough evidence had accumulated for scientists to realize that Wegener had been right. Unfortunately, Wegener did not live long enough to see his ideas accepted.

Figure 1.3

This map shows the supercontinent Pangaea, which was first proposed by Alfred Wegener. Pangaea included all of the separate continents we know today.
Scientists now know that the individual continents drifted apart to their present locations over millions of years.

Q: What types of evidence might support Wegener's ideas?

A: Several types of evidence support Wegener's ideas. For example, similar fossils and rock formations have been found on continents that are now separated by oceans. It is also now known that Earth's crust consists of rigid plates that slide over molten rock below them. This explains how continents can drift. Even the shapes of today's continents show how they once fit together, like pieces of a giant jigsaw puzzle.

Summary

- Science is a way of learning about the natural world that is based on evidence and logic.
- The goal of science is to understand how and why things happen.
- Science advances as new evidence accumulates and allows scientists to replace, refine, or expand on accepted ideas about the natural world.

Vocabulary

- **science:** Way of learning about the natural world that is based on evidence and logic.

Review

1) Define science.
2) What is the goal of science?
3) Use examples to show how science may advance.

1.2 Scientific Induction

Objectives

- Define inductive reasoning.
- Describe how inductive reasoning is used in science.
- Explain why inductive reasoning cannot prove conclusively that an idea is true.

What Is Inductive Reasoning?

Inductive reasoning is the process of drawing general conclusions based on many clues, or pieces of evidence. Many crimes are solved using inductive reasoning. It is also the hallmark of science and the basis of the scientific method.

Q: How might a policeman use inductive reasoning to solve a crime?

A: The policeman might gather clues that provide evidence about the identity of the person who committed the crime. For example, he might find fingerprints or other evidence left behind by the perpetrator. The policeman might eventually find enough clues to be able to conclude the identity of the most likely suspect.

Inductive Reasoning in Science

A simple example will help you understand how inductive reasoning works in science. Suppose you grew up on a planet named Quim, where there is no gravity. In fact, assume you've never even heard of gravity. You travel to Earth (on a student exchange program) and immediately notice things are very different here than on your home planet.

For one thing, when you step out of your spacecraft, you fall directly to the ground. Then, when you let go of your cell phone, it falls to the ground as well. On Quim, nothing ever falls to the ground. For example, if you had let go of your cell phone back home, it would have just stayed in place by your upper appendage.
You notice that everything you let go of falls to the ground. Using inductive reasoning, you conclude that all objects fall to the ground on Earth.

Then, you make the observation pictured (Figure 1.5). You see round objects rising up into the sky, rather than falling toward the ground as you expect.

Figure 1.5

Clearly, your first conclusion - although based on many pieces of evidence - is incorrect.

You need to gather more evidence to come to a conclusion that explains all of your observations.

Q: What conclusion might you draw based on the additional evidence of the balloons rising instead of falling?

A: With this and other evidence, you might conclude that objects heavier than air fall to the ground but objects lighter than air do not.

Limits on Inductive Reasoning

Inductive reasoning can't solve a crime or arrive at the correct scientific conclusion with 100 percent certainty. It's always possible that some piece of evidence remains to be found that would disprove the conclusion. That's why jurors in a trial are told to decide whether the defendant is guilty "without a reasonable doubt" - not without a shred of doubt.

Similarly, a scientific theory is never really proven conclusively to be true. However, it can be supported by so much evidence that it is accepted "without a reasonable doubt."

Summary

- Inductive reasoning is the process of drawing general conclusions based on many pieces of evidence. This type of reasoning is the basis of the scientific method.
- In science, inductive reasoning is used to draw general conclusions from evidence. The conclusions are changed if necessary to explain new evidence as it becomes available.
- Inductive reasoning cannot prove conclusively that an idea is true, but it may lead to conclusions that are very likely to be true.

Vocabulary

- inductive reasoning

Practice

Deductive reasoning is another type of reasoning. You can think of deductive reasoning as inductive reasoning in reverse. With deductive reasoning, you draw specific conclusions based on general statements that are assumed to be true.

Review

1) What is inductive reasoning?
2) Describe how inductive reasoning is used in science.
3) Rayna studied rats in a lab. She observed that all 50 rats in her sample preferred to eat brand A rat food and would eat brand B food only when brand A was not available. Can she correctly conclude that all rats prefer brand A rat food over brand B food? Why or why not?

1.3 Scientific Theory

Objective

- Define scientific theory.
- Give examples of theories in physical science.
- Relate the law of parsimony to scientific theories.

Not "Just a Theory"

The term theory is used differently in science than it is used in everyday language. A scientific theory is a broad explanation that is widely accepted because it is supported by a great deal of evidence. Because it is so well supported, a scientific theory has a very good chance of being a correct explanation for events in nature. Because it is a broad explanation, it can explain many observations and pieces of evidence. In other words, it can help connect and make sense of many phenomena in the natural world.

Examples of Theories in Physical Science

A number of theories in science were first proposed many decades or even centuries ago, but they have withstood the test of time. An example of a physical science theory that has mainly withstood the test of time is Dalton's atomic theory.

John Dalton was a British chemist who lived in the late 1700s and early 1800s. Around 1800, he published his atomic theory, which is one of the most important theories in science.

According to **Dalton's atomic theory**, all substances consist of tiny particles called atoms. Furthermore, all the atoms of a given element are identical, whereas the atoms of different elements are always different.

These parts of Dalton's atomic theory are still accepted today, although some other details of his theory have since been disproven.

Dalton based his theory on many pieces of evidence. For example, he studied many substances called compounds. These are substances that consist of two or more different elements. Dalton determined that a given compound always consists of the same elements in exactly the same proportions, no matter how small the sample of the compound.

This idea is illustrated for the compound water in the Figure 1.6.

Dalton concluded from this evidence that elements must be made up of tiny particles in order to always combine in the same specific proportions in any given compound.

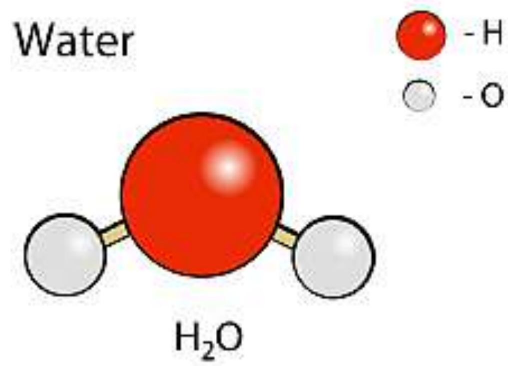


Figure 1.6

Water is a compound that consists of the elements hydrogen (H) and oxygen (O). Like other compounds, the smallest particles of water are called molecules. Each molecule of water (H2O) contains two atoms of hydrogen and one atom of oxygen.

Q: Dalton thought that atoms are the smallest particles of matter. Scientists now know that atoms are composed of even smaller particles. Does this mean that the rest of Dalton's atomic theory should be thrown out?

A: The discovery of particles smaller than atoms doesn't mean that we should scrap the entire theory. Atoms are still known to be the smallest particles of elements that have the properties of the elements. Also, it is atoms—not particles of atoms—that combine in fixed proportions in compounds. Instead of throwing out Dalton's theory, scientists have refined and expanded on it.

There are many other important physical science theories. Here are three more examples:

- Einstein's theory of gravity
- Kinetic theory of matter
- Wave-particle theory of light

Keep It Simple

The formation of scientific theories is generally guided by the law of parsimony. The word parsimony means "thriftiness."

The law of parsimony states that, when choosing between competing theories, you should select the theory that makes the fewest assumptions. In other words, the simpler theory is more likely to be correct. For example, you probably know that Earth and the other planets of our solar system orbit around the sun. But several centuries ago, it was believed that Earth is at the center of the solar system and the other planets orbit around Earth. While it is possible to explain the movement of planets according to this theory, the explanation is unnecessarily complex.

Q: Why do you think parsimony is an important characteristic of scientific theories?

A: The more assumptions that must be made to form a scientific theory, the more chances there are for the theory to be incorrect. If one assumption is wrong, so is the theory. Conversely, the theory that makes the fewest assumptions, assuming it is well supported by evidence, is most likely to be correct.

Summary

- A scientific theory is a broad explanation that is widely accepted because it is supported by a great deal of evidence.
- Examples of theories in physical science include Dalton's atomic theory, Einstein's theory of gravity, and the kinetic theory of matter.
- The formation of scientific theories is generally guided by the law of parsimony. According to this law, the simplest of competing theories is most likely to be correct.

Vocabulary

- scientific theory: Broad explanation that is widely accepted because it is supported by a great deal of evidence.

Review

1) What is a scientific theory?
2) Compare and contrast how the term theory is used in science and in everyday language.
3) Identify two physical science theories.
4) Relate scientific theories to the law of parsimony.

1.4 Scientific Law

Objectives

- Define scientific law, and give examples of laws in physical science.
- Describe the place of laws in science.

It's the Law

Did you ever drive a bumper car? As you drive around the track, other drivers try to bump into your car and push it out of the way. When another car bumps into yours, both cars may bounce back from the collision. The harder the two cars collide, the farther back they bounce.

It may seem like common sense that bumper cars change their motion when they collide. That's because all objects behave this way - it's the law! A scientific law, called Newton's third law of motion, states that for every action there is an equal and opposite reaction. Thus, when one bumper car acts by ramming another, one or both cars react by pushing apart.

Q: What are some other examples of Newton's third law of motion? What actions are always followed by reactions?

A: Other examples of actions and reactions include hitting a ball with a bat and the ball bouncing back; and pushing a swing and the swing moving away.

Laws in Science

Newton's third law of motion is just one of many scientific laws. A scientific law is a statement describing what always happens under certain conditions.

Other examples of laws in physical science include:

- Newton's first law of motion
- Newton's second law of motion
- Newton's law of universal gravitation
- Law of conservation of mass
- Law of conservation of energy
- Law of conservation of momentum

Laws vs. Theories

Scientific laws state what always happen. This can be very useful. It can let you let you predict what will happen under certain circumstances. For example, Newton's third law tells you that the harder you hit a softball with a bat, the faster and farther the ball will travel away from the bat. However, scientific laws have a basic limitation. They don’t explain why things happen.

“Why” questions are answered by scientific theories, not scientific laws.

Q: You know that the sun always sets in the west. This could be expressed as a scientific law. Think of something else that always happens in nature. How could you express it as a scientific law?

A: Something else that always happens in nature is water flowing downhill rather than uphill. This could be expressed as the law, “When water flows over a hill, it always flows from a higher to a lower elevation.”

Summary

- A scientific law is a statement describing what always happens under certain conditions. Newton’s three laws of motion are examples of laws in physical science.
- A scientific law states what always happens but not why it happens. Scientific theories answer “why” questions.

Vocabulary

- **scientific law**: Statement describing what always happens under certain conditions in nature.

Review

1. Define scientific law.
2. Identify three laws in physical science.
3. Which of these statements could be a scientific law?
    a. Metals such as copper conduct electric current.
    b. Metals can conduct electricity because they have free electrons.
4. How is a scientific law different from a scientific theory?
5. Contrast scientific laws with traffic laws or other laws devised by people.

1.5 History of Science

Objectives

- Summarize the evolution of science.
- Identify major contributions in the history of science.

Evolution of Science

People have probably wondered about the natural world for as long as there have been people. So it's no surprise that science has roots that go back thousands of years. Some of the earliest contributions to science were made by Greek philosophers more than two thousand years ago. It wasn't until many centuries later, however, that the scientific method and experimentation were introduced. The dawn of modern science occurred even more recently. It is generally traced back to the scientific revolution, which took place in Europe starting in the 1500s.

In the Beginning

A Greek philosopher named Thales, who lived around 600 BCE, has been called the "father of science" for his ideas about the natural world. He proposed that natural events such as lightning and earthquakes have natural causes. Up until then, people understood such events to be the acts of gods or other supernatural forces.

Q: Why was Thales' idea about natural causes such an important contribution to science?
A: Natural causes can be investigated and understood, whereas gods or other supernatural causes are "above nature" and not suitable for investigation.

Just a few hundred years after Thales, the Greek philosopher Aristotle made a very important contribution to science. Prior to Aristotle, other philosophers believed that they could find the truth about the natural world by inward reflection—in other words, just by thinking about it. Aristotle, in contrast, thought that truth about the natural world could come only from observations of nature and inductive reasoning. He argued that knowledge of nature must be based on evidence and logic.

This idea is called empiricism, and it is the basis of science today.

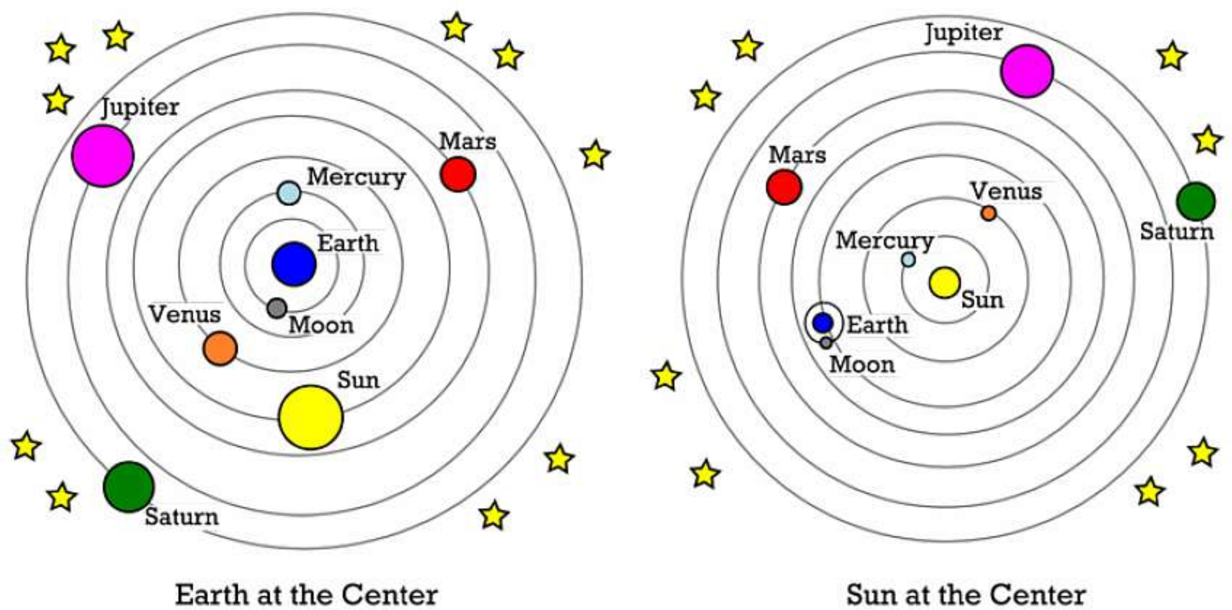
Introducing the Scientific Method

In the first 1000 years CE, Europe went through a period called the Dark Ages. Science and learning in general were all but abandoned. However, in other parts of the world science flourished. During this period, some of the most important contributions to science were made by Persian scholars. For example, during the 700s CE, a Persian scientist named Geber introduced the scientific method and experimentation in chemistry. His ideas and methods were later adopted by European chemists. Today, Geber is known as the “father of chemistry.”

Modern Western Science Emerges

Starting in the mid-1500s, a scientific revolution occurred in Europe. This was the beginning of modern Western science. Many scientific advances were made during a period of just a couple of hundred years.

The revolution in science began when Copernicus made the first convincing arguments that the sun—not Earth—is the center of what we now call the solar system. (You can see both models of the solar system in the Figure 1.8.) This was a drastic shift in thinking about Earth’s place in the cosmos.



Around 1600, the Italian scientist Galileo greatly improved the telescope, which had just been invented, and made many important discoveries in the field of astronomy. Some of Galileo’s observations provided additional evidence for Copernicus’ sun-centered solar system.

Q: Copernicus’ ideas about the solar system were so influential that the scientific revolution is sometimes called the “Copernican revolution.” Why do you think Copernicus’ ideas led to a revolution in science?

A: Copernicus’ ideas about the solar system are considered to be the starting point of modern astronomy. They changed how all future scientists interpreted observations in astronomy. They also led to a flurry of new scientific investigation.

Other contributions to science that occurred during the scientific revolution include:

- Kepler’s laws of planetary motion
- Newton’s law of universal gravitation
- Newton’s three laws of motion

Einstein Rocks Science

Another major shift in science occurred with the work of Albert Einstein. In 1916, Einstein published his general theory of relativity. This theory relates matter and energy. It also explains gravity as a property of space and time (rather than a property of matter as Newton thought).

Einstein’s theory has been supported by all evidence and observations to date, whereas Newton’s law of gravity does not apply to all cases. Einstein’s theory is still the accepted explanation for gravity today.

Q: How might Einstein’s theory have influenced the course of science?

A: Einstein’s theory suggested new areas of investigation. Many predictions based on the theory were later found to be true. For example, black holes in the universe were predicted by Einstein’s theory and later confirmed by scientific evidence.

Summary

- Science has roots that go back thousands of years to Greek philosophers including Thales and Aristotle.
- The scientific method was introduced in the 700s by a Persian scientist named Geber.
- Modern science began with the scientific revolution in Europe the 1500s and 1600s. The scientific revolution was launched by Copernicus’ new ideas about the solar system.
- In the early 1900s, Einstein rocked science with his theory of gravity, which explained the concept in an entirely new way.

Review

1. Why is Thales called the “father of science”?
2. What is empiricism? Who “invented” this important idea?
3. Describe Geber’s role in the history of science.
4. Relate Copernicus’ ideas about the solar system to the scientific revolution.
5. How did Einstein rock science?

1.8 Scope of Physical Science

Objectives

- Define physical science.
- Give examples of ways that people depend on physical science.

What Is Physical Science?

Physical science is the study of matter and energy. That covers a lot of territory because 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 also universal. It’s what gives matter the ability to move and change. Electricity, heat, and light are some of the forms that energy can take.

Chemistry and Physics

Physical science, in turn, can be divided into chemistry and physics.

- Chemistry is the study of matter and energy at the scale of atoms and molecules. For example, the synthetic fibers in today’s swimmer’s suit were created in labs by chemists.
- Physics is the study of matter and energy at all scales—from the tiniest particles of matter to the entire universe. Knowledge of several important physics concepts—such as motion and forces—contributed to the design of the swimmer’s suit.

Q: It’s not just athletes that depend on physical science. We all do. What might be some ways that physical science influences our lives?

A: We depend on physical science for just about everything that makes modern life possible. You couldn’t turn on a light, make a phone call, or use a computer without centuries of discoveries in chemistry and physics.

Summary

- Physical science is the study of matter and energy. It includes chemistry and physics.
- We depend on centuries of discoveries in physical science for just about everything we do.

Vocabulary

- physical science: Study of matter and energy.

Review

- Outline the scope of physical science.
- Describe some ways that physical science influences your own life.

1.9 Scope of Chemistry

Objectives

- Define chemistry.
- Give examples of chemistry in everyday life.

What Is Chemistry?

Chemistry is the study of matter and energy and how they interact, mainly at the level of atoms and molecules. Basic concepts in chemistry include chemicals, which are specific types of matter, and chemical reactions. In a chemical reaction, atoms or molecules of certain types of matter combine chemically to form other types of matter. All chemical reactions involve energy.

Q: How do you think chemistry explains why the copper on buildings is green instead of brownish red?

A: The copper has become tarnished. The tarnish—also called patina—is a compound called copper carbonate, which is green. Copper carbonate forms when copper undergoes a chemical reaction with carbon dioxide in moist air. The green patina that forms on copper actually preserves the underlying metal.

Chemistry and You

Chemistry can help you understand the world around you. Everything you touch, taste, or smell is made of chemicals, and chemical reactions underlie many common changes. For example, chemistry explains how food cooks, why laundry detergent cleans your clothes, and why antacid tablets relieve an upset stomach.

Chemistry even explains you! Your body is made of chemicals, and chemical changes constantly take place within it.

Summary

- Chemistry is the study of matter and energy and how they interact, mainly at the level of atoms and molecules. Basic concepts in chemistry include chemicals and chemical reactions.

- Chemistry can help you understand the world around you. Everything you touch, taste, or smell is a chemical, and chemical reactions underlie many common changes.

Vocabulary

- **chemistry:** Study of the structure, properties, and interactions of matter, usually at the scale of atoms and molecules.

Review

1) What is chemistry?
2) Describe three ways that chemistry is important in your life.

1.10 Scope of Physics

Objective

- Identify the scope of physics.
- Describe ways that physics explains the world around you.

The Scope of Physics

Physics is the study of energy, matter, and their interactions. It's a very broad field because it is concerned with matter and energy at all levels—from the most fundamental particles of matter to the entire universe. Some people would even argue that physics is the study of everything! Important concepts in physics include motion, forces such as magnetism and gravity, and forms of energy such as light, sound, and electrical energy.

Q: How do you think physics explains the distorted images formed by a funhouse mirror?

A: Physics explains how energy interacts with matter. In this case, for example, physics explains how visible light reflects from mirrors to form images. Most mirrors, such as bathroom mirrors, have a flat surface. Light reflected from a flat mirror forms an image that looks the same as the object in front of it.
Funhouse mirrors are different. They have a curved surface that reflects light at different angles. This explains why the images they form are distorted.

Physics in the World Around You

Physics can help you understand just about everything in the world around you. That’s because everything around you consists of matter and energy. Below are several examples of matter and energy interacting:

a) All musical instruments make sounds in the same basic way. A source of energy makes matter vibrate, and the energy of the vibrations travels in waves through the air in all directions.
b) An incandescent light bulb contains a filament made of a metal called tungsten. When electrical energy flows through the filament, it becomes so hot that it glows and gives off light energy.
c) All moving matter has energy just because it is moving. When a moving cricket bat strikes the ball, some of its energy is transferred to the cricket ball which will fly off in the direction of movement of the bat.

Q: Based on the examples above, what might be other examples of energy and matter interacting?

A: Anything that vibrates produces waves of energy that travel through matter. For example, when you throw a pebble into a pond, waves of energy travel from the pebble through the water in all directions.
Like an incandescent light bulb, anything that glows consists of matter that produces light energy. For example, fireflies use chemicals to produce light energy.
Like a moving cricket bat or tennis racket, anything that moves has energy because it is moving, including your eyes as they read this sentence.

Summary

- Physics is the study of energy, matter, and their interactions. It is concerned with matter and energy at all levels—from the most fundamental particles of matter to the entire universe.
- Physics can help you understand just about everything in the world around you. That’s because everything around you is matter and has energy.

Vocabulary

- **physics:** Study of energy and how it interacts with matter.

Review

1. Outline the scope of physics.
2. Describe three examples of interacting matter and energy in the world around you.

1.12 Nature of Technology

Objective

- Define technology.
- Outline how technology evolves.

What Is Technology?

Technology is the application of science to solve problems. Because technology finds solutions to practical problems, new technologies may have major impacts on society, science, and industry.

How Technology Evolves

New technologies often evolve slowly as new materials, designs, or processes are invented. Solar-powered cars are a good example. For several decades, researchers have been working on developing practical solar-powered cars. Why? Cars powered by sunlight have at least two important advantages over gas-powered cars. The energy they use is free and available almost everywhere, and they produce no pollution.

The evolution of solar-powered cars:

- In 1954 the first modern solar cell was invented by a team of researchers at Bell Labs in the U.S. It could convert light energy to enough electricity to power devices.
- In 1955, William G. Cobb of General Motors demonstrated his 15-inch-long "Sunmobile," the world's first solar-powered automobile. Its tiny electric motor was powered by 12 solar cells on top of the car.
- In 1983, the first drivable solar car was created by Hans Tholstrup, a Danish inventor who was influenced by the earlier Sunmobile.
- In 2008, the first commercial solar car was introduced. Called the Venturi Astrolab, it has a top speed of 120 km/h. To go this fast while using very little energy, it is built of ultra-light materials.

Q: Why was the invention of the solar cell important to the evolution of solar car technology?

A: The solar car could not exist without the solar cell. This invention provided a way to convert light energy to electricity that could be used to run a device such as a car.

Q: The 1955 "Sunmobile" was just a model car. It was too small for people to drive. Why was it an important achievement in the evolution of solar car technology?

A: The car wasn't practical, but it was a working solar car. It showed people that solar car technology is possible. It spurred others, including Hans Tholstrup, to work on solar cars that people could actually drive.

Summary

- Technology is the application of science to solve practical problems.
- Technology evolves as new materials, designs, and processes are invented.

Vocabulary

- **technology:** Application of knowledge to real-world problems.

Review

1. What is technology?
2. Explain how technology evolves, using examples from the development of solar-powered cars.

1.15 Technology and Science

Objective

- Explain how technology and science are related.
- Give examples of ways that technology and science help each other advance.

How Technology and Science Are Related

The Hubble telescope is a very powerful telescope that orbits Earth like a satellite. Scientists placed the Hubble telescope into space so it could make clear images like this without background lights on Earth competing with the dim light from distant stars. It has led to many scientific discoveries.

The Hubble space telescope shows that technology and science are closely related. Technology uses science to solve problems, and science uses technology to make new discoveries. However, technology and science have different goals.

- The goal of science is to answer questions and increase knowledge.
- The goal of technology is to find solutions to practical problems.

Although they have different goals, science and technology work hand in hand, and each helps the other advance. Scientific knowledge is used to create new technologies such as the space telescope. New technologies often allow scientists to explore nature in new ways.

How Technology Revolutionized Science

The Hubble telescope was put into orbit around Earth in the 1990s, but scientists have been using telescopes to make discoveries for hundreds of years. The first telescope was invented in the early 1600s. The inventor was probably a Dutch lens maker named Hans Lippershey. Lippershey used scientific knowledge of the properties of light and lenses to design his telescope.

Lippershey’s new technology quickly spread all over Europe. Almost immediately, the Italian scientist and inventor Galileo started working to improve Lippershey’s design. In just two years, Galileo had made a more powerful telescope. It could make very distant objects visible to the human eye.

Galileo started using his telescope to explore the night sky. He soon made some remarkable discoveries. He observed hills and valleys on the moon and spots on the sun. He discovered that Jupiter has moons and that the sun rotates on its axis. With his discoveries, Galileo was able to prove that the sun, not Earth, is at the center of the solar system. This discovery played an important role in the history of science. It led to a scientific revolution that gave birth to modern Western science. And it all began with technology!

Other Examples

There are many other examples that show how technology and science work together.

- Another example is the microscope. It may have been invented by Galileo around the same time as the telescope. Like the invention of the telescope, the invention of the microscope also depended on scientific knowledge of light and lenses.
- A seismometer is a device that senses and records ground movements caused by earthquakes. Invention of the seismometer depended on scientific knowledge of waves and motion.
- A spectrometer is a device that measures properties of light given off by matter. This helps scientists to determine the composition of matter. Invention of the spectrometer depended on knowledge of light and of chemical elements.

Q: How do you think the invention of the microscope helped science advance?

A: The microscope let scientists view a world of tiny objects they had never seen before. It led to many important scientific discoveries, including the discovery of cells, which are the basic building blocks of all living things.

Summary

- Science and technology help each other advance.
- Scientific knowledge is used to create new technologies.
- New technologies often allow scientists to explore nature in different ways and make new discoveries.

Review

1. What is the relationship between technology and science?
2. What scientific knowledge was necessary for the invention of the telescope and microscope?
3. Identify a scientific discovery made possible by technology.

1.16 Technology and Society

Objectives

- Summarize how major advances in technology impact human society.
- Describe how the Industrial Revolution affected people's lives.

How Technology Affects Society

Important new technologies such as the wheel have had a big impact on human society. Major advances in technology have influenced every aspect of life, including transportation, food production, manufacturing, communication, medicine, and the arts. That's because technology has the goal of solving human problems, so new technologies usually make life better. They may make work easier, for example, or make people healthier. Sometimes, however, new technologies affect people in negative ways. For example, using a new product or process might cause human health problems or pollute the environment.

Q: Can you think of a modern technology that has both positive and negative effects on people?
A: Modern methods of transportation have both positive and negative effects on people. They help people and goods move quickly all over the world. However, most of them pollute the environment. For example, gasoline-powered cars and trucks add many pollutants to the atmosphere. The pollutants harm people's health and contribute to global climate change.

Industrial Revolution

Few technologies have impacted society as greatly as the powerful steam engine developed by Scottish inventor James Watt in 1775 (see Figure 1.18). Watt's steam engine was soon being used to power all kinds of machines. It started a revolution in industry. For the first time in history, people did not have to rely on human or animal muscle, wind, or water for power. With the steam engine to power machines, new factories sprang up all over Britain.

Figure 1.18

This is a museum model similar to the steam engine invented by James Watt..

The Industrial Revolution began in Britain the late 1700s. It eventually spread throughout Western Europe, North America, Japan, and many other countries.

It marked a major turning point in human history. Almost every aspect of daily life was influenced by it in some way. Average income and population both began to grow faster than ever before. People flocked to the new factories for jobs, and densely populated towns and cities grew up around the factories. The new towns and cities were crowded, and soot from the factories polluted the air. This made living conditions very poor. Working conditions in the factories were also bad, with long hours and the pace set by machines.

Even young children worked in the factories, damaging their health and giving them little opportunity for education or play.

Q: In addition to factory machines, the steam engine was used to power farm machinery, trains, and ships. What effects might this have had on people's lives?

A: Farm machinery replaced human labor and allowed fewer people to produce more food. This is why many rural people migrated to the new towns and cities to look for work in factories.

Steam-powered trains and ships made it easier for people to migrate. Food and factory goods could also be transported on steam-powered trains and ships, making them available to far more people.

Summary

- Major advances in technology have influenced every aspect of human society, usually in good ways but sometimes in bad ways as well.
- Almost every aspect of people's lives was influenced by the Industrial Revolution that followed James Watt's invention of a powerful steam engine in 1775.

Review

1. In general, how do major advances in technology usually affect society?
2. What was the Industrial Revolution?
3. What are some ways the Industrial Revolution changed people's lives?

1.18 Scientific Process

Objectives

- State the role of investigations in science.
- Outline the steps of the scientific method.

Investigations in Science

Investigations are at the heart of science. They are how scientists add to scientific knowledge and gain a better understanding of the world. Scientific investigations produce evidence that helps answer questions. Even if the evidence cannot provide answers, it may still be useful. It may lead to new questions 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 questions. However, most scientists follow the general steps outlined in the Figure 1.21.

This approach is sometimes called the scientific method. Keep in mind that the scientific method is a general approach and not a strict sequence of steps. For example, scientists may follow the steps in a different order. Or they may skip or repeat some of the steps.

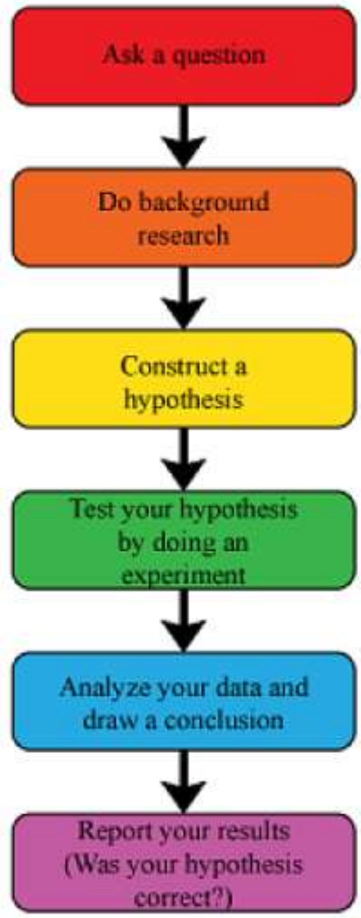


Figure 1.21
The general steps followed in the scientific method.

Using the Scientific Method: a Simple Example

A simple example will help you understand how the scientific method works. While Cody eats a bowl of cereal, he reads the ingredients list on the cereal box. He notices that the cereal contains iron. Cody is studying magnets in school and knows that magnets attract objects that contain iron. He wonders whether there is enough iron in a flake of the cereal for it to be attracted by a strong magnet. He thinks that the iron content is probably too low for this to happen, even if he uses a strong magnet.

Q: If Cody were doing a scientific investigation, what would be his question and hypothesis?

A: Cody's question would be, "Is there enough iron in a flake of cereal for it to be attracted by a strong magnet?"

His hypothesis would be, "The iron content of a flake of cereal is too low for it to be attracted by a strong magnet."

Cody decides to do an experiment to test his hypothesis. He gets a strong magnet from his mom's toolbox and places a dry flake of cereal on the table. Then he slowly moves the magnet closer to the flake. To his surprise, when the magnet gets very close to the flake, the flake moves the rest of the way to the magnet.

Q: Based on this evidence, what should Cody conclude?

A: Cody should conclude that his hypothesis is incorrect. There is enough iron in a flake of cereal for it to be attracted by a strong magnet.

Q: If Cody were a scientist doing an actual scientific investigation, what should he do next?
A: He should report his results to other scientists.

Summary

- Investigations are at the heart of science. They produce evidence that helps scientists answer questions and better understand the world.
- Most scientists follow the same general approach to investigation, which is called the scientific method. It includes the following steps: ask a question, do background research, construct a hypothesis, test the hypothesis by doing an experiment, analyze the data and draw a conclusion, and report the results.

Review

1. What is the role of investigation in science?
2. List the steps of the scientific method.
3. Assume that Cody used a weak magnet and the flake of cereal was not attracted to it. What conclusion might he have drawn then?

1.19 Observation

Objectives

- Define observation.
- Identify the role of observation in scientific investigation.

What Are Observations?

An observation is any information that is gathered with the senses. Our senses include vision, hearing, touch, smell, and taste. We see with our eyes, hear with our ears, touch with our hands, smell with our nose, and taste with our tongue. We can also extend our senses and our ability to make observations by using instruments such as microscopes, telescopes, and thermometers.

Q: How do these instruments extend human senses and our ability to make observations?

A: Microscopes and telescopes extend the sense of vision. They allow us to observe objects that are too small (microscopes) or too distant (telescopes) for the unaided eye to see. Thermometers extend the sense of touch. Using our sense of touch, we can only feel how warm or cold something is relative to our own temperature or the temperature of something else. Thermometers allow us to measure precisely how warm or cold something is.

Using Observations to Gather Evidence

Besides raising questions for investigation, observations play another role in scientific investigations. They help scientists gather evidence. For example, to investigate whether a chemical change has occurred, a scientist might observe whether certain telltale signs are present. In some chemical changes, for example, a substance turns from one color to another.

Figure 1.23

You can see an example of this in the Figure 1.23. Some of these pennies are shiny and copper colored. That’s how pennies look when they are new.

The older pennies are dull and brown. Copper at the surface of these pennies has combined with air to become a different substance with different properties.

The change in color shows that a chemical change has occurred.

In other chemical changes, an odor is produced or gas bubbles are released. All of these changes can be observed with the senses.

Q: Some chemical changes release heat. How could this change be observed?

A: The sense of touch—or a thermometer—could be used to observe an increase in temperature.

Summary

- An observation is any information that is gathered with the senses.
- Observations raise questions that lead to scientific investigations. Observations also help scientists gather evidence in investigations.

Vocabulary

- **observation:** Any information that is gathered with the senses.

Review

1. What is an observation?
2. What senses can we use to make observations?
3. Why are observations important to scientific investigations?

1.20 Hypothesis

Objective

- State two criteria of a scientific hypothesis.
- Explain why a hypothesis cannot be proven true.

Scientific investigations discover evidence that helps science advance, and the purpose of scientific investigations generally is to test hypotheses. Finding evidence to support or disprove hypotheses is how science advances.

What Is a Scientific Hypothesis?

The word hypothesis can be defined as an "educated guess." For example, it might be an educated guess about why a natural event occurs. But not all hypotheses—even those about the natural world—are scientific hypotheses. What makes a statement a scientific hypothesis rather than just an educated guess? A scientific hypothesis must meet two criteria:

- A scientific hypothesis must be testable.
- A scientific hypothesis must be falsifiable.

A Scientific Hypothesis Must Be Testable

For a hypothesis to be testable means that it is possible to make observations that agree or disagree with it. If a hypothesis cannot be tested by making observations, it is not scientific. Consider this statement:

"There are invisible creatures all around us that we can never observe in any way."

This statement may or may not be true, but it is not a scientific hypothesis. That's because it can't be tested. Given the nature of the hypothesis, there are no observations a scientist could make to test whether or not it is false.

A Scientific Hypothesis Must Be Falsifiable

A hypothesis may be testable, but even that isn't enough for it to be a scientific hypothesis. In addition, it must be possible to show that the hypothesis is false if it really is false. Consider this statement:

“There are other planets in the universe where life exists.”

This statement is testable. If it is true, it is at least theoretically possible to find evidence showing that it's true. For example, a spacecraft could be sent from Earth to explore the universe and report back if it discovers an inhabited planet. If such a planet were found, it would prove the statement is true.

However, the statement isn't a scientific hypothesis. Why? If it is false, it's not possible to show that it's false. The spacecraft may never find an inhabited planet, but that doesn't necessarily mean there isn't one. Given the vastness of the universe, we would never be able to check every planet for life!

Both Testable and Falsifiable

Let's consider one last example:

"Any two objects dropped at the same time from the same height will reach the ground at the same time (assuming the absence of air resistance)."

Is this statement testable? Yes. You could drop two objects at the same time from the same height and observe when they reach the ground. Of course, you would have to drop the objects in the absence of air to prevent air resistance, but at least such a test is theoretically possible.

Is the statement falsifiable if it really is false? Again, the answer is yes. You can easily test many combinations of two objects and if any two objects do not reach the ground at the same time, then the hypothesis is false. If a hypothesis really is false, it should be relatively easy to disprove it.

Can You Prove a Hypothesis Is True?

If the hypothesis above about falling objects really were false, it is likely that this would be discovered sooner or later after enough objects had been dropped. It takes just one exception to disprove a hypothesis. But what if the hypothesis really is true? Can this be demonstrated as well? No; it would require testing all possible combinations of objects to show that they always reach the ground at the same time. This is impossible. New objects are being made all the time that would have to be tested. It's always possible an exception would be found in the future to disprove the hypothesis. Although you can't prove conclusively that a hypothesis is true, the more evidence you gather in support of it, the more likely it is to be true.

Summary

- In science, a hypothesis is an educated guess that can be tested with observations and falsified if it really is false.
- You cannot prove conclusively that most hypotheses are true because it's generally impossible to examine all possible cases for exceptions that would disprove them.

Vocabulary

- **hypothesis:** Potential answer to a question that can be tested by gathering information.

Review

1. Identify the role of the hypothesis in science.
2. State two criteria of a scientific hypothesis.
3. Which of these two statements meets the criteria of a scientific hypothesis?
    a. Acids turn red litmus paper blue.
    b. All life in the universe exists on Earth.
4. Why is it usually impossible to prove that a hypothesis is true?

1.21 Scientific Experiments

Objectives

- Define experiment.
- Contrast manipulated and responding variables in an experiment.
- Explain why other variables in an experiment must be controlled.

What Is an Experiment?

An experiment is a controlled scientific study of specific variables. A variable is a factor that can take on different values. For example, the speed of an object down a ramp might be one variable, and the steepness of the ramp might be another.

Experimental Variables

There must be at least two variables in any experiment: a manipulated variable and a responding variable.

- A manipulated variable is a variable that is changed by the researcher.
  A manipulated variable is also called an *independent variable*.
- A responding variable is a variable that the researcher predicts will change if the manipulated variable changes.
  A responding variable is also called a *dependent variable*.

Q: If you were to do an experiment to find out what influences the speed of an object down a ramp, what would be the responding variable? How could you measure it?

A: The responding variable would be the speed of the object. You could measure it indirectly with a stopwatch. You could clock the time it takes the object to travel from the top to the bottom of the ramp. The less time it takes, the faster the average speed down the ramp.

Q: What variables might affect the speed of an object down a ramp?

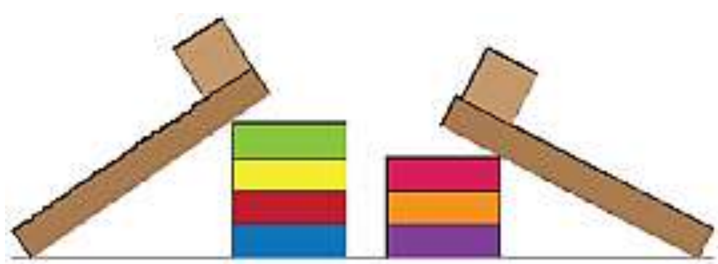
A: Variables might include factors relating to the ramp or to the object. An example of a variable relating to the ramp is its steepness. An example of a variable relating to the object is the way it moves—it might roll or slide down the ramp. Either of these variables could be manipulated by the researcher, so you could choose one of them for your manipulated variable.

Experimental Controls

Assume you are sliding wooden blocks down a ramp in your experiment. You choose steepness of the ramp for your manipulated variable. You want to measure how changes in steepness affect the time it takes a block to reach the bottom of the ramp.

You decide to test two blocks on two ramps, one steeper than the other, and see which block reaches the bottom first. You use a shiny piece of varnished wood for one ramp and a rough board for the other ramp. You raise the rough board higher so it has a steeper slope (see sketch below). You let go of both blocks at the same time and observe that the block on the ramp with the gentler slope reaches the bottom sooner.

You're surprised, because you expected the block on the steeper ramp to go faster and get to the bottom first.



Q: What explains your result?

A: The block on the steeper ramp would have reached the bottom sooner if all else was equal. The problem is that all else was not equal. The ramps varied not only in steepness but also in smoothness. The block on the smoother ramp went faster than the block on the rougher ramp, even though the rougher ramp was steeper.

This example illustrates another important aspect of experiments: experimental controls. A control is a variable that must be held constant so it won't influence the outcome of an experiment. In the case of your ramp experiment, smoothness of the ramps should have been controlled by making each ramp out of the same material.

Q: What other variables do you think might influence the outcome of your ramp experiment? How could these other variables be controlled?

A: Other variables might include variables relating to the block. For example, a smoother block would be expected to go down a ramp faster than a rougher block. You could control variables relating to the block by using two identical blocks.

Summary

- 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 any experiment: a manipulated variable and a responding variable.
- A control is a variable that must be held constant so it won't influence the outcome of an experiment.

Vocabulary

- **control:** Variable in an experiment that is held constant so it will not influence the outcome.
- **experiment:** Controlled scientific study of a limited number of variables.
- **manipulated variable:** Factor that is changed, or manipulated, by a researcher in a scientific experiment; also called independent variable.
- **responding variable:** Factor in an experiment that is expected to change, or respond, when the manipulated variable changes; also called dependent variable.

Review

1. What is an experiment?
2. Distinguish between the manipulated variable and the responding variable in an experiment.
3. Why is it important for other variables in an experiment to be controlled?

1.25 International System of Units

Objectives

- Describe the International System of Units (SI).
- Convert units between International and English systems.

SI Units

It is important to use a standard system of measurement in science and technology. The measurement system used by most scientists and engineers is the International System of Units, or SI. There are a total of seven basic SI units, including units for length (meter) and mass (kilogram). SI units are easy to use because they are 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 units to indicate the powers of ten, as shown in the Table 1.4.

TABLE 1.4: Prefixes of SI Units

Prefix	Multiply Basic Unit x	Basic Unit of Length = Meter (m)
kilo- (k)	1000	kilometer (km) = 1000 m
deci- (d)	0.1	decimeter (dm) = 0.1 m
centi- (c)	0.01	centimeter (cm) = 0.01 m
milli- (m)	0.001	millimeter (mm) = 0.001 m
micro- (μ)	0.000001	micrometer (μm) = 0.000001 m
nano- (n)	0.000000001	nanometer (nm) = 0.000000001 m

Q: What is the name of the unit that is one-hundredth (0.01) of a meter?
A: The name of this unit is the centimeter.

Q: What fraction of a meter is a decimeter?
A: A decimeter is one-tenth (0.1) of a meter.

Unit Conversions

In the Table 1.5, two basic SI units are compared with their English system equivalents. You can use the information in the table to convert SI units to English units or vice versa. For example, from the table you know that 1 meter equals 39.37 inches.

How many inches are there in 3 meters?

3 m = 3(39.37 in) = 118.11 in

TABLE 1.5: Unit Conversions		
Measure	SI Unit Unit	English Unit Equivalent
Length	Meter (m)	1 m = 39.37 in
Mass	Kilogram (kg)	1 kg = 2.20 lb

Q: Rod needs to buy a meter of wire for a science experiment, but the wire is sold only by the yard. If he buys a yard of wire, will he have enough? (Hint: There are 36 inches in a yard.)

A: Rod needs 39.37 inches (a meter) of wire, but a yard is only 36 inches, so if he buys a yard of wire he won't have enough.

Summary

- The measurement system used by most scientists and engineers is the International System of Units, or SI.
  There are seven basic SI units, including units for length and mass.
- If you know the English equivalents of SI units, you can convert SI units to English units or vice versa.

Vocabulary

- **SI:** International System of Units, which is used by most scientists.

Review

1. What does SI stand for?
2. Why is it important for scientists and engineers to adopt a common system of measurement units?
3. How many grams equal 1 kilogram?
4. What fraction of a meter is a millimeter?
5. How many pounds equal 5 kilograms?

1.26 Scientific Measuring Devices

Objectives

- State how to read a metric ruler.
- Describe how to measure mass with a triple beam balance.
- Outline how to measure the volume of a liquid with a graduated cylinder.

The device pictured at right is called a pH meter. It is a scientific measuring device that measures the acidity of a liquid. Being able to use scientific measuring devices such as this is an important science skill. That's because doing science typically involves making many measurements.

For example, if you do lab exercises in science, you might measure an object's length or mass, or you might find the volume of a liquid.

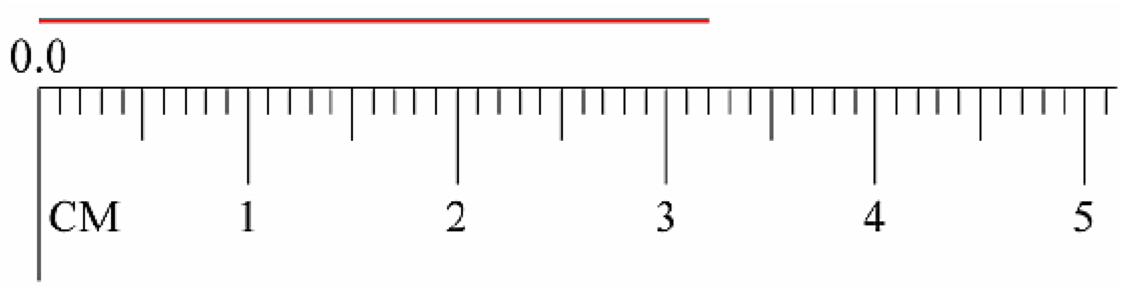
Scientists use sensitive measuring devices to make measurements such as these. The measurements are usually made using SI units of measurement.

Measuring Length with a Metric Ruler

You've probably been using a ruler to measure length since you were in elementary school. But you may have made most of the measurements in English units of length, such as inches and feet.

In science, length is most often measured in SI units, such as millimeters and centimeters. Many rulers have both types of units, one on each edge.

The ruler pictured below has only SI units. It is shown here bigger than it really is so it's easier to see the small lines, which measure millimeters. The large lines and numbers stand for centimeters. Count the number of small lines from the left end of the ruler (0.0). You should count 10 lines because there are 10 millimeters in a centimeter.

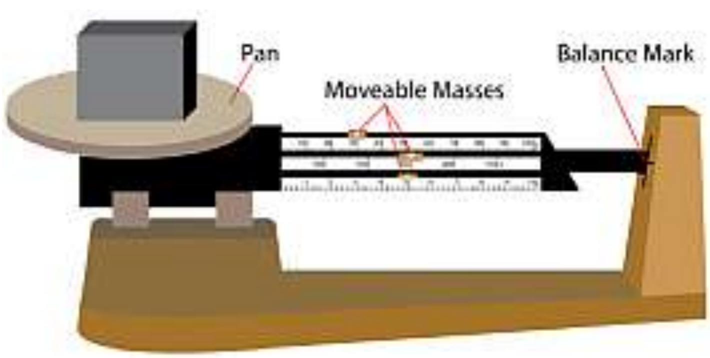


Q: What is the length in millimeters of the red line above the metric ruler?
A: The length of the line is 32 mm.

Q: What is the length of the line in centimeters?
A: The length of the line is 3.2 cm.

Measuring Mass with a Balance

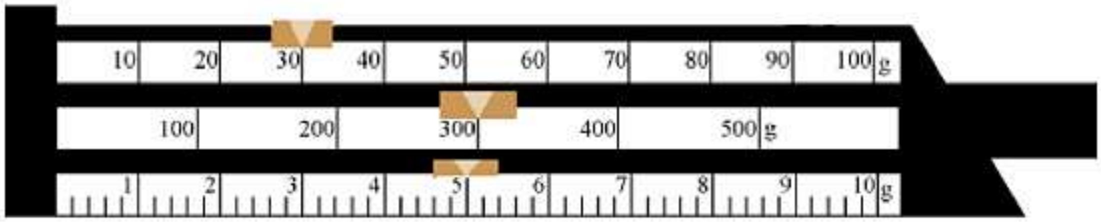
Mass is the amount of matter in an object. Scientists often measure mass with a balance. A type of balance called a triple beam balance is pictured below.



To use this type of balance, follow these steps:

1. Place the object to be measured on the pan at the left side of the balance.
2. Slide the movable masses to the right until the right end of the arm is level with the balance mark. Start by moving the larger masses and then fine tune the measurement by moving the smaller masses as needed.
3. Read the three scales to determine the values of the masses that were moved to the right. Their combined mass is equal to the mass of the object.

The figure below is an enlarged version of the scales of the triple beam balance. It allows you to read the scales. The middle scale, which measures the largest movable mass, reads 300 grams. This is followed by the top scale, which reads 30 grams. The bottom scale reads 5.1 grams.



Therefore, the mass of the object in the pan is:

300 grams + 30 grams + 5.1 grams = 335.1 grams.

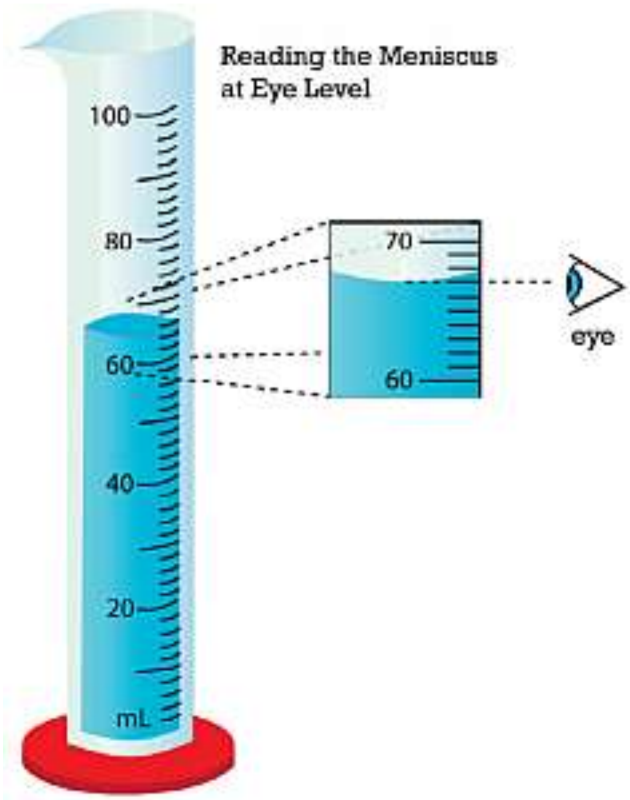
Q: What is the maximum mass this triple beam balance can measure?
A: The maximum mass it can measure is 610 grams (500 grams + 100 grams + 10 grams).

Q: What is the smallest mass this triple beam balance can measure?
A: The smallest mass it can measure is one-tenth (0.1) of a gram.

To measure very small masses, scientists use electronic balances which also makes it easier to make accurate measurements because mass is shown as a digital readout.

Q: How would you measure the mass of a white powder on a plastic weighing tray.
A: First measure the mass of the tray alone, then measure the mass of the tray and powder together. The difference between the two masses is the mass of the powder alone.

Measuring Volume with a Graduated Cylinder



At home, you might measure the volume of a liquid with a measuring cup. In science, the volume of a liquid might be measured with a graduated cylinder, like the one shown.

The cylinder in the picture has a scale in milliliters (mL), with a maximum volume of 100 mL. Follow these steps when using a graduated cylinder to measure the volume of a liquid:

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

Q: What is the volume of the liquid in the graduated cylinder pictured above?
A: The volume of the liquid is 67 mL.

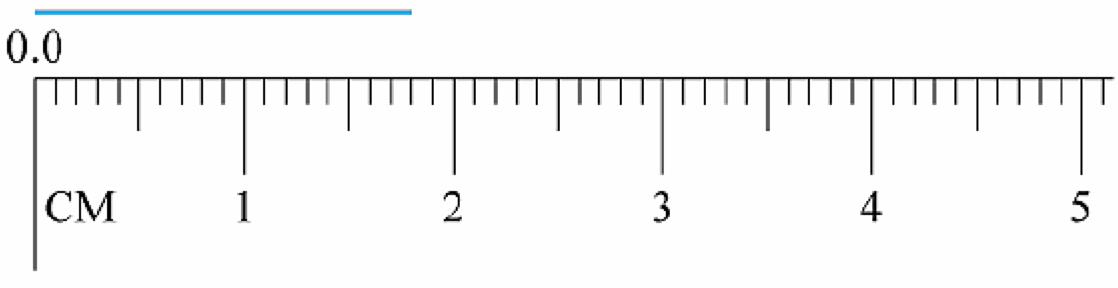
Q: What would the measurement be if you read the highest point of the curved surface of the liquid by mistake?
A: The measurement would be 68 mL.

Summary

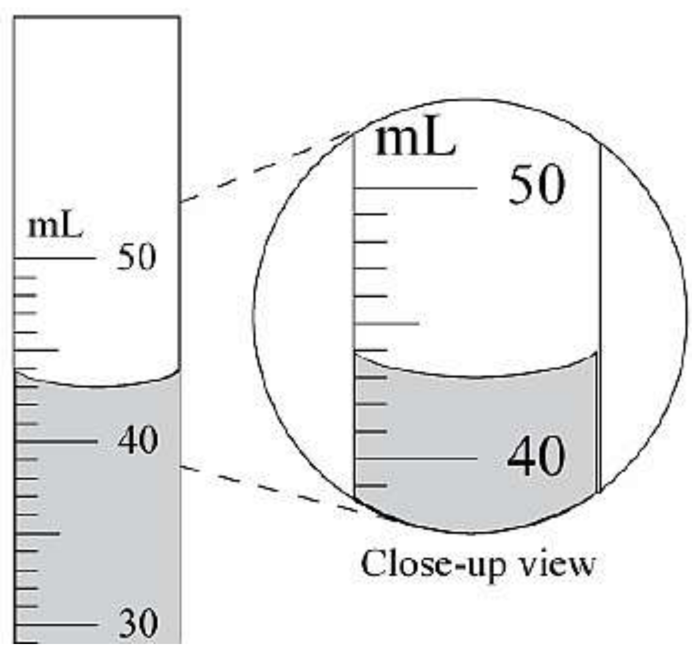
- In science, length may be measured with a metric ruler using SI units such as millimeters and centimeters.
- Scientists measure mass with a balance, such as a triple beam balance or electronic balance.
- In science, the volume of a liquid might be measured with a graduated cylinder.

Review

1. Using the enlarged metric ruler segment shown below, what is the length of the blue line in centimeters?



2. How much liquid does this graduated cylinder contain?



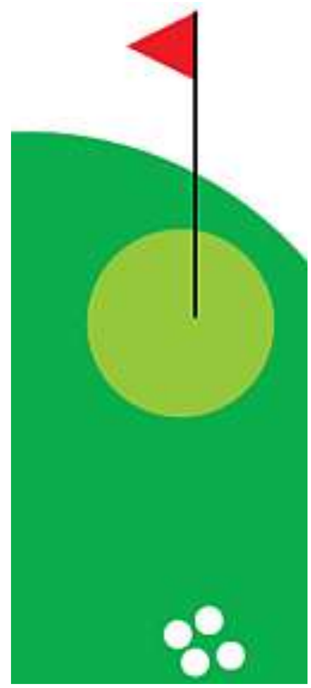
1.27 Accuracy and Precision

Objectives

- Define accuracy of measurements.
- Define precision of measurements.

Accuracy

The accuracy of a measurement is how close the measurement is to the true value. If you were to hit four different golf balls toward an over-sized hole, all of them might land in the hole. These shots would all be accurate because they all landed in the hole. This is illustrated in the sketch below left.



Precision

As you can see from the sketch above left, the four golf balls did not land as close to one another as they could have. Each one landed in a different part of the hole. Therefore, these shots are not very precise. The precision of measurements is how close they are to each other. If you make the same measurement twice, the answers are precise if they are the same or at least very close to one another.

The golf balls in the sketch above right landed quite close together in a cluster, so they would be considered precise. However, they are all far from the hole, so they are not accurate.

Q: If you were to hit four golf balls toward a hole and your shots were both accurate and precise, where would the balls land?
A: All four golf balls would land in the hole (accurate) and also very close to one another (precise).

Summary

- Accuracy means making measurements that are close to the true value.
- Precision means making measurements that are close in value to each other but not necessarily close to the true value.

Vocabulary

- **accuracy:** Closeness of a measurement to the true value.
- **precision:** Exactness of a measurement.

Review

1. Complete this statement: A measurement is accurate when it is __________.
2. What makes two measurements precise?
3. Kami measured the volume of a liquid three times and got these results: 66.71 mL, 66.70 mL, 66.69 mL. The actual volume of the liquid is 69.70 mL. Are Kami's measurements precise? Are they accurate? Explain your answers.

1.28 Calculating Derived Quantities

Objectives

- Define derived quantity.
- Explain how to calculate area, volume, and density.
- Identify units of area, volume, and density.

What Are Derived Quantities?

Derived quantities are quantities that are calculated from two or more measurements. Derived quantities cannot be measured directly. They can only be computed. Many derived quantities are calculated in physical science.

Three examples are **area**, **volume**, and **density**.

Calculating Area

The area of a surface is how much space it covers. It's easy to calculate the area of a surface if it has a regular shape, such as the blue rectangle in the sketch below. You simply substitute measurements of the surface into the correct formula.

To find the area of a rectangular surface, use this formula:

Area (rectangular surface) =

length x width (l x w)

Rectangular Surface

Width (w) = 5 cm

Length (l) = 9 cm

Q: What is the area of the blue rectangle?
A: Substitute the values for the rectangle's length and width into the formula for area:

Area = 9 cm x 5 cm = 45 cm^2

Q: Can you use this formula to find the area of a square surface?
A: Yes, you can. A square has four sides that are all the same length, so you would substitute the same value for both length and width in the formula for the area of a rectangle.

Calculating Volume

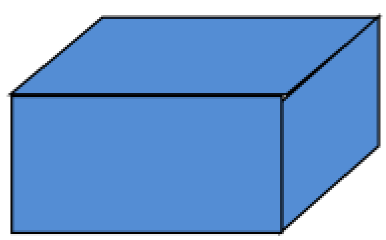
The volume of a solid object is how much space it takes up. It's easy to calculate the volume of a solid if it has a simple, regular shape, such as the rectangular solid pictured in the sketch below.

To find the volume of a rectangular solid, use this formula:

Volume (rectangular solid) =

length x width x height (l *x* w *x* h)

Rectangular Solid



Height (h) = 5 cm

Width (w) = 3 cm

Length (l) = 9 cm

Q: What is the volume of the blue rectangular solid?
A: Substitute the values for the rectangular solid's length, width, and height into the formula for volume:

Volume = 10 cm x 3 cm x 5 cm = 150 cm^3

Calculating Density

Density is a quantity that expresses how much matter is packed into a given space. The amount of matter is its mass, and the space it takes up is its volume.

To calculate the density of an object, then, you would use this formula:

$$\text{Density} = \frac{mass}{volume}$$

Q: The volume of the blue rectangular solid above is 150 cm^3. If it has a mass of 300 g, what is its density?
A: The density of the rectangular solid is:

$$\text{Density} = \frac{300\ g}{150\ cm^2} = 2\ \text{g/cm3}$$

Q: Suppose you have two boxes that are the same size but one box is full of feathers and the other box is full of books. Which box has greater density?
A: Both boxes have the same volume because they are the same size. However, the books have greater mass than the feathers. Therefore, the box of books has greater density.

Units of Derived Quantities

A given derived quantity, such as area, is always expressed in the same type of units. For example, area is always expressed in squared units, such as cm^2 or m^2. If you calculate area and your answer isn't in squared units, then you have made an error.

Q: What units are used to express volume?
A: Volume is expressed in cubed units, such as cm^3 or m^3.

Q: A certain derived quantity is expressed in the units kg/m^3. Which derived quantity is it?
A: The derived quantity is density, which is mass (kg) divided by volume (m^3).

Summary

- Derived quantities are quantities that are calculated from two or more measurements. They include area, volume, and density.
- The area of a rectangular surface is calculated as its length multiplied by its width.
- The volume of a rectangular solid is calculated as the product of its length, width, and height.
- The density of an object is calculated as its mass divided by its volume.
- A given derived quantity is always expressed in the same type of units.
  For example, area is always expressed in squared units, such as cm^2.

Practice

1. Identify six fundamental units in physical science.
2. What is speed? How is it calculated? What are its SI units? (Hint: The symbol Δ represents a difference, or change, in a unit. For example, Δt represents a change in time.)
3. Which derived quantity equals force divided by area?

Review

1. What is a derived quantity? Give an example.
2. What are the dimensions of a square that has an area of 4 cm^2?
3. Explain how you would calculate the volume of a cube.
4. Which derived quantity is used to calculate density?
5. Which derived quantity might be measured in mm^3?

1.29 Significant Figures

- Define significant figures.
- State rules for counting significant figures.
- Explain how to determine significant figures in calculations.
- Identify rules for rounding numbers.

Introduction

Jerod has a homework problem that involves finding the area of a rectangle. He knows that the area of a rectangle equals its length times its width. The rectangle in question has a length of 6.9 m and a width of 6.8 m, so he multiplies the two numbers on his calculator. The answer he gets is 46.92 m^2, which he records on his homework. To his surprise, his teacher marks this answer wrong. The reason? The answer has too many significant figures.

What Are Significant Figures?

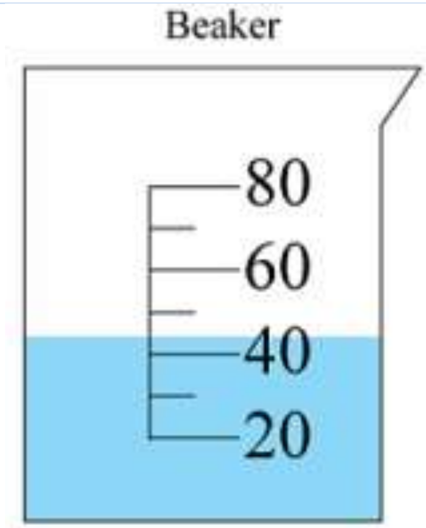
In any measurement, the number of significant figures is the number of digits thought to be correct by the person doing the measuring. It includes all digits that can be read directly from the measuring device plus one estimated digit.

Look at the sketch of a beaker shown. How much blue liquid does the beaker contain?

The top of the liquid falls between the mark for 40 mL and 50 mL, but it's closer to 50 mL.

A reasonable estimate is 47 mL.

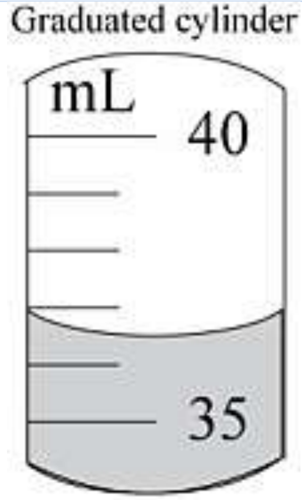
In this measurement, the first digit (4) is known for certain and the second digit (7) is an estimate, so the measurement has two significant figures.



Now look at the graduated cylinder sketched below. How much blue liquid does it contain?

First, it’s important to note that you should read the amount of liquid at the bottom of its curved surface.

This falls about half way between the mark for 36 mL and the mark for 37 mL, so a reasonable estimate would be 36.5 mL.



Q: How many significant figures does this measurement have?
A: There are three significant figures in this measurement. You know that the first two digits (3 and 6) are accurate. The third digit (5) is an estimate.

Rules for Counting Significant Figures

The examples above show that it’s easy to count the number of significant figures when you are making a measurement. But what if someone else has made the measurement? How do you know which digits are known for certain and which are estimated? How can you tell how many significant figures there are in the measurement?

There are several rules for counting significant figures:

- Leading zeros are never significant. For example, in the number 006.1, only the 6 and 1 are significant.
- Zeros within a number between non-zero digits are always significant. For example, in the number 106.1, the zero is significant, so this number has four significant figures.
- Zeros that show only where the decimal point falls are not significant. For example, the number 470,000 has just two significant figures (4 and 7). The zeros just show that
  - the 4 represents hundreds of thousands and
  - the 7 represents tens of thousands.

  Therefore, these zeros are not significant.
- Trailing zeros that aren’t needed to show where the decimal point falls are significant. For example, 4.00 has three significant figures.

Q: How many significant figures are there in each of these numbers:

20,080, 2.080, and 2000?

A: Both 20,080 and 2.080 contain four significant figures, but 2000 has just one significant figure.

Determining Significant Figures in Calculations

When measurements are used in a calculation, the answer cannot have more significant figures than the measurement with the fewest significant figures. This explains why the homework answer above is wrong. It has more significant figures than the measurement with the fewest significant figures.

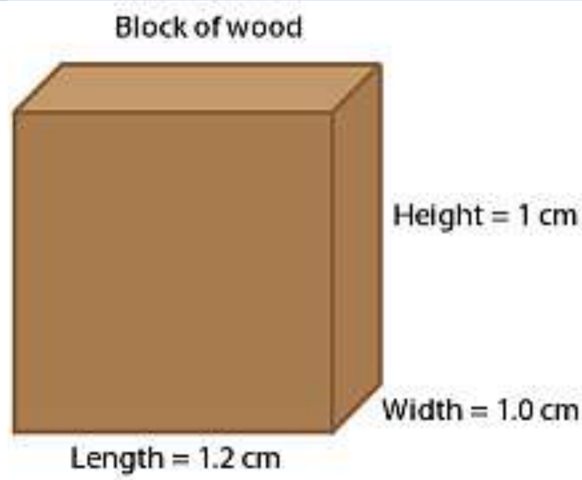
As another example, assume that you want to calculate the volume of the block of wood shown below.

The volume of the block is represented by the formula:

Volume = length x width x height

Therefore, you would do the following calculation:

Volume = 1.2 cm x 1.0 cm x 1 cm = 1.2 cm^3



Q: Does this answer have the correct number of significant figures?
A: No, it has too many significant figures. The correct answer is 1 cm^3. That's because the height of the block has just one significant figure.

Therefore, the answer can have only one significant figure.

Rules for Rounding

To get the correct answer in the volume calculation above, rounding was necessary. Rounding is done when one or more ending digits are dropped to get the correct number of significant figures.

In this example, the answer was rounded down to a lower number (from 1.2 to 1).

Sometimes the answer is rounded up to a higher number. How do you know which way to round?
Simple rules state when to round up and when to round down.

Follow these simple rules:

- If the digit to be rounded (dropped) is less than 5, then round down. For example, when rounding 2.344 to three significant figures, round down to 2.34.
- If the digit to be rounded is greater than 5, then round up. For example, when rounding 2.346 to three significant figures, round up to 2.35.
- If the digit to be rounded is 5, round up if the digit before 5 is odd, and round down if digit before 5 is even.
  For example, when rounding 2.345 to three significant figures, round down to 2.34. This rule may seem arbitrary, but in a series of many calculations, any rounding errors should cancel each other out.

Summary

- In any measurement, the number of significant figures is the number of digits thought to be correct by the person doing the measuring. It includes all digits that can be read directly from the measuring device plus one estimated digit.
- To determine the number of significant figures in a measurement that someone else has made, follow the rules for counting significant figures.
- When measurements are used in a calculation, the answer cannot have more significant figures than the measurement with the fewest significant figures.
- Rounding is done when one or more ending digits are dropped to get the correct number of significant figures.

Vocabulary

- **significant figures:** Correct number of digits in an answer that is based on the least precise measurement used in the calculation.

Review

1. How do you determine the number of significant figures when you make a measurement?
2. Measure the width of a sheet of standard-sized (8.5 in x 11.0 in) loose-leaf notebook paper. Make the measurement in centimeters and express the answer with the correct number of significant figures.
3. How many significant figures do each of these measurements have?
    a. 0.04
    b. 500
    c. 1.50
4. In this calculation, how many significant figures should there be in the answer?

    1.0234 + 1.1 + 0.0056
5. Round each of these numbers to three significant figures:
    a. 1258
    b. 3274
    c. 6845

1.30 Scientific Notation

- State the purpose of scientific notation.
- Explain how to convert numbers to and from scientific notation.

Introduction

Most of the stars of the night sky are hundreds of light years from Earth. A light year is the distance that light can travel in a year, or about 6 trillion (6,000,000,000,000) miles.

As this example shows, quantities in science may be very large. Many other quantities in science are very small. Both very large and very small numbers have many zeroes, so they are hard to read and write without making mistakes.

That's where scientific notation comes in.

What Is Scientific Notation?

Scientific notation is a way of writing very large or very small numbers that uses exponents. Numbers are written in this format: $a\ x\ 10^{b}$
The letter a stands for a decimal number, and the letter b stands for an exponent, or power, of 10.
For example, the number 300 is written in scientific notation as $3.0\ x\ 10^{2}$. The number 0.03 is written as $3.0\ x\ 10^{-2}$.

Using Scientific Notation

It's easier to convert numbers to and from scientific notation than you might think.

Example 1: Large Numbers

Convert a large number such as	6720	Into a small number by moving the decimal point left until you reach the last non-zero digit		Count how many places you moved the decimal point. It is 3 in this example.

We know that $6720 = 6.720 \times 1000 = 6.72 \times 10^{3}$, so for scientific notation ($a\ x\ 10^{b}$), the number a is 6.72 and the number b is positive and equals the number of places that the decimal point was moved to arrive at the number a.

Example 2: Small Numbers

Convert a small number such as	0.048	Into a larger number by moving the decimal point right until you reach the last non-zero digit		Count how many places you moved the decimal point. It is 2 in this example.

We know that $0.048 = 4.80 \div 100 = 4.8 \times 10^{-2}$, so for scientific notation ($a \times 10^{b}$), the number a is 4.8 and the number b is negative and equals the number of places that the decimal point was moved to arrive at the number a.

General Conversion Rules

Follow the steps in the sequence listed here to convert a number to scientific notation.

- Step 1. Move the decimal point left or right until you reach the last nonzero digit. This new decimal number is a in $a \times 10^{b}$.
- Step 2. Count how many places you moved the decimal point in Step 1. This number is b in $a \times 10^{b}$.
- Step 3. Did you move the decimal point left? If so, b is positive. Did you move the decimal point right? If so, b is negative.

Follow the steps in the reverse order to convert a number from scientific notation.

Q: Apply the steps above to write 450,000 in scientific notation.
A: The unwritten decimal point in this number follows the last zero. Move the decimal point from this position to the left and stop just before the last digit, giving you 4.5 for a. The decimal point was moved five places to the left, so b is 5.

In scientific notation the number is 4.5×10^{5}.

Q: Apply the steps in reverse order to write the number that is expressed as 7.2×10^{4} in scientific notation.
A: Add zeroes to 7.2 as you move the decimal point four places to the right. This gives you the number 72,000.

Summary

- Scientific notation is a way of writing very large or very small numbers that uses exponents. Numbers are written in the format $a \times 10^{b}$.
- Changing numbers to or from scientific notation is easy to do by following three simple steps.

Vocabulary

- scientific notation: Way of writing very large or very small numbers that uses exponents in the format a x 10^b.

Review

1. What is scientific notation? Why are numbers written in scientific notation?
2. Write 0.0045 in scientific notation.
3. What number is written as 6.0 x 10^6 in scientific notation?

1.31 Descriptive Statistics

- State why descriptive statistics are useful.
- Identify the mean, median, and mode of a sample.
- Describe the range of a sample.

The girls in this picture vary in height. The shortest girl has a height of 52 cm, and the tallest girl has a height of 64 cm. The other two girls fall in between these two extremes.

How could you describe the heights of all four girls with a single number? How could express how they vary in height with another number?

Using Statistics to Describe a Sample

The girls in the picture above make up a small sample—there are only four of them. In scientific investigations, samples may include hundreds or even thousands of people or other objects of study. Especially when samples are very large, it's important to be able to summarize their overall characteristics with a few numbers.

That's where descriptive statistics come in.

Descriptive Statistics are measures that show the central tendency, or center, of a sample or the variation in a sample.

Describing the Center

The central tendency of a sample can be represented by the **mean, median**, or **mode**.

- The **mean** is the average value. It is calculated by adding the individual measurements and dividing the sum by the total number of measurements.
- The **median** is the middle value. To find the median, rank all the measurements from smallest to largest and then find the measurement that is in the middle.
- The **mode** is the most common value. It is the value that occurs most often.

Q: A sample of five children have the following heights: 60 cm, 58 cm, 54 cm, 62 cm, and 58 cm. What are the mean, median, and mode of this sample?
A: The mean is (60 cm + 58 cm + 54 cm + 62 cm + 58 cm) ÷ 5 = 58 cm. The median and mode are both 58 cm as well. The mean, median, and mode are not always the same, as they are for this sample. In fact, sometimes these three statistics are very different from one another for the same sample.

Describing the Range

Many samples have a lot of variation in measurements. Variation can be described with a statistic called the range.
The **range** is the total spread of values in a sample. It is calculated by subtracting the smallest value from the largest value.

Q: What is the range of heights in the sample of children in the previous question?
A: The range is 62 cm – 54 cm = 8 cm.

Summary

- Descriptive statistics are measures that summarize the characteristics of a sample.
- The central tendency, or center, of a sample can be represented by the mean, median, or mode.
- The variation in a sample can be represented by the range, or the total spread of values.

Vocabulary

- **mean:** Average value of a set of measurements; calculated by summing the measurements and dividing the total by the number of measurements.
- **range:** Total spread of values in a set of measurements; calculated by subtracting the smallest value from the largest value.

Review

1. What are descriptive statistics, and why are they useful?
2. Find the mean, median, and mode of this set of values: 12 g, 9 g, 13 g, 12 g, 20 g, 17 g, 15 g.
3. What is the range of the set of values in question 2?

1.33 Scientific Modeling

- Identify properties of useful models in science.
- Describe examples of simple models in physical science.

Did you ever read a road map or made a sketch of a house or other object and played with toy cars or dolls. What do all these activities have in common?
They all involve models.

What Is a Model?

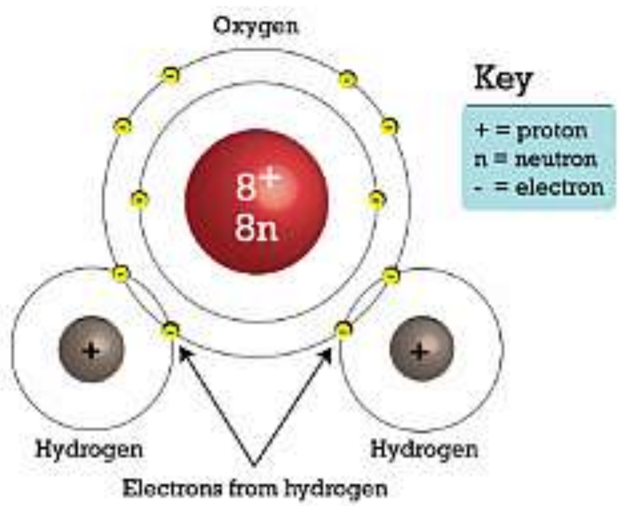
A model is a representation of an object, system, or process. For example, a road map is a representation of an actual system of roads on the ground. Models are very useful in science. They provide a way to investigate things that are too small, large, complex, or distant to investigate directly. To be useful, a model must closely represent the real thing in important ways, but it must be simpler and easier to understand than the real thing.

Q: What might be examples of things that would be modeled in physical science because they are difficult to investigate directly?
A: Examples include extremely small things such as atoms, very distant objects such as stars, and complex systems such as the electric grid that carries electricity throughout the country.

Q: What are ways that these things might be modeled?
A: Types of models include two-dimensional diagrams, three-dimensional structures, mathematical formulas, and computer simulations. Examples of simple two-dimensional models in physical science are described below.

Simple Models in Physical Science

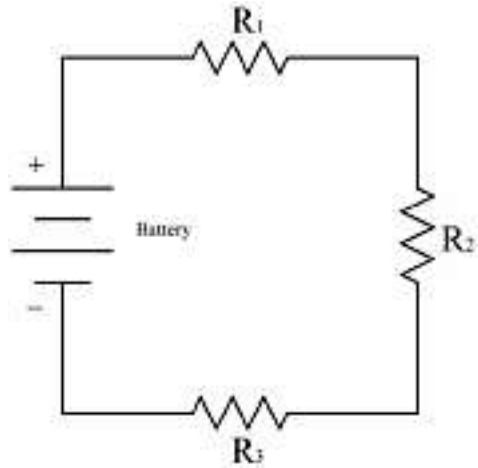
The diagram below is a simple two-dimensional model of a water molecule. This is the smallest particle of water that still has the properties of water. The model shows that each molecule of water consists of one atom of oxygen and two atoms of hydrogen.



Q: What else can you learn about water molecules from this model?
A: The model shows the number of atomic particles—protons, neutrons, and electrons—in each type of atom. It also shows that each hydrogen atom in a water molecule shares its electron with the oxygen atom.

Q: Do you think this water molecule model satisfies the criteria of a useful model? In other words, does it represent a real water molecule in important ways while being simpler and easier to understand than a real water molecule?
A: The model shows the basic structure of a water molecule and how the atoms in the molecule share electrons. These features of the water molecule explain important properties of water. The model is also simpler and easier to understand than a real water molecule. In a real molecule, electrons spin around the nuclei at the center of the atoms in a cloud, rather than in neat, circular orbits, as shown in the model. The atoms of a real water molecule also contain even smaller particles than protons, neutrons, and electrons. For many purposes, however, it’s not necessary to represent these more complex features of a real water molecule.

The diagram below shows another example of a simple model in physical science. This diagram is a model of an electric circuit. It represents the main parts of the circuit with simple symbols. Horizontal lines with + and – signs represent a battery. The parts labeled R1, R2, and R3 are devices that use electricity provided by the battery. For example, these parts might be a series of three light bulbs.



Q: In the electric circuit diagram, what do the black lines connecting the battery and electric devices represent?
A: The black lines represent electric wires. The wires are necessary to carry electric current from the battery to the electric devices and back to the battery again.

Q: How is a circuit diagram simpler and easier to understand than an actual electric circuit?
A: A circuit diagram shows only the parts of the circuit that carry electric current, and it uses simple symbols to represent them.

Summary

- A model is a representation of an object, system, or process that is simpler and easier to understand than the real thing.
- Examples of simple models in physical science include two-dimensional models of molecules and electric circuits.

Vocabulary

- **model:** Representation of an object, system, or process.

Review

1. What is a model?
2. Why are models useful in science?
3. Identify characteristics of a good model.
4. Describe a simple model in physical science.

1.34 Safety in Science

- Identify the meaning of lab safety symbols.
- List rules for staying safe in the lab.
- State what to do in case of accidents in the lab or field.

Research in physical science can be exciting, but it also has potential dangers. For example, a field scientist may be collecting water samples from treatment ponds. There are many microorganisms in the water that could make him sick. The water and shore can also be strewn with dangerous objects such as sharp can lids and broken glass bottles that could cause serious injury.

Whether in the field or in the lab, knowing how to stay safe in science 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. Then learn how to avoid them.

Many common safety symbols are shown below.

Q: Do you know how you can avoid these hazards?
A: Wearing protective gear is one way to avoid many hazards in science. For example, to avoid being burned by hot objects, use hot mitts to protect your hands. To avoid eye hazards, such as harsh liquids splashed into the eyes, wear safety goggles.

Safety Rules

Following basic safety rules is another important 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 long sleeves and shoes that completely cover your feet.
- If your hair is long, tie it back or cover it with a hair net.
- Protect your eyes, skin, and clothing by wearing safety goggles, an apron, and gloves.
- Use hot mitts to handle hot objects.
- Never work in the lab alone.
- Never engage in horseplay in the lab.
- Never eat or drink in the lab.
- Never do experiments without your teacher's approval.
- Always add acid to water, never the other way around, and add the acid slowly to avoid splashing.
- Take care to avoid knocking over Bunsen burners, and keep them away from flammable materials such as paper.
- Use your hand to fan vapors toward your nose rather than smelling substances directly.
- Never point the open end of a test tube toward anyone—including yourself!
- Clean up any spills immediately.
- Dispose of lab wastes according to your teacher's instructions.
- Wash glassware and counters when you finish your work.
- Wash your hands with soap and water before leaving the lab.

In Case of Accident

Even when you follow the rules, accidents can happen. Immediately alert your teacher if an accident occurs. Report all accidents, whether or not you think they are serious.

Summary

- Lab safety symbols warn of specific hazards, such as flames or broken glass. Knowing the symbols allows you to recognize and avoid the dangers.
- Following basic safety rules, such as wearing safety gear, helps prevent accidents in the lab and in the field.
- All accidents should be reported immediately.

Practice

Examine this sketch of students working in a lab, and then answer the question below.

1. These students are breaking at least six lab safety rules. What are they doing that is unsafe?

Review

1. What hazard do think this safety symbol represents?

2. Identify three safety rules that help prevent accidents in the lab.
3. Create a safety poster to convey one of the three rules you listed in your answer to 2.