SCIENCE—THE BASICS

Before we get started on our adventure in physical science, we should review some basics. It is quite possible that you have learned some of what you'll read in this module before, but it is necessary that we review before we add new, more in-depth concepts. Thus, even if some of the topics we cover sound familiar, please read this module thoroughly so that you will not get lost in a later module. After all, most students your age know something about atoms, air, the construction of our planet, and weather. Just like every day of your life is familiar and yet different, so, too, is science. We build on the knowledge that comes before us.

natural notes

In this course you are going to learn a lot about the nonliving natural world and the universe it is in. You will study things as familiar as the air around you and others as mysterious as gravity, radioactivity, and quarks. You will learn about the structure of the Earth as well as how weather affects the Earth. These topics and many others like them are all a part of what is called physical science. I promise that as you work to learn the material in this course, you will gain a grand appreciation for the wonder of God's creation!

FIGURE 1.1
Lightning Strikes the Rock Formations in Monument Valley, Utah

I will try to demonstrate as many concepts as possible with experiments. Hopefully, the "hands-on" experience will help you understand the concepts better than any discussion could. In some cases, of course, this will not be possible, so I will use as many illustrations to accompany the words as possible. The Advanced Concepts sections go further into the topics we are discussing. As explained in the Student Notes in the textbook, all students are encouraged to read through these, but only those on the advanced track will be tested on this material.

IN THIS MODULE YOU WILL READ ABOUT THE FOLLOWING MAIN IDEAS:

- What is Science?
- The Scientific Process
- Measuring and Manipulating Data
- Organizing, Analyzing, and Presenting Scientific Data

WHAT IS SCIENCE?

Have you ever flipped over a rock to see if anything was living under it? Or added a new ingredient to the cookies you baked to see if they tasted better? Or mixed two different paint colors (or food coloring) together to see what new color you could make? If you have, then you have exercised your God-given gift of curiosity *and* you've engaged in science! You see, curiosity is the basis of science. When you're curious about something you ask questions and hopefully try to figure out ways to find the answers to your questions—that is science.

You may have thought of science as textbooks full of facts. Or maybe you think science is what chemists, astronauts, marine biologists, and geologists do (Figure 1.2). And you would be right—in a way. Science is a body of knowledge and provides wonderful careers for many people, but science is also so much more. It is a way of investigating and discovering the natural world around us—God's creation. Science is also a system of organizing the knowledge discovered and forming explanations and predictions about different natural phenomena and sharing that knowledge with others. So, science is both a system of knowledge and a process used to find that knowledge, as well as a sharing of that knowledge. Science is exciting because you never know what you might discover!

FIGURE 1.2
Some Aspects of Science

SCIENCE AND TECHNOLOGY

Have you ever thought about how things like telephones, cars, and video games have changed over the years? Over time many things we commonly use continue to change. And much of that is due to science. As scientific knowledge is discovered, it can be applied to help people. This is called technology—using scientific knowledge to solve practical problems and improve people's lives. Take telephones, for example. It may be hard to believe, but some adults will remember a time when there were no cell phones. And older generations may even remember a time when not every home had a phone! Every time you make or receive a phone call on a cell phone, you're making use of technology. Figure 1.3 illustrates how telephones have changed over the years as technology improved.

FIGURE 1.3
Telephone Technology Timeline

Science and technology are embedded in every aspect of life. From growing the food you eat to the jet skis you ride on vacation, from electric blankets that keep you warm to satellites that measure global temperatures, science and technology improve human life at every level. As you can see with the telephone, the more science we understand, the better our technologies become. Often, the better our technologies become, the more science we're able to understand!

WHAT IS PHYSICAL SCIENCE?

Physical science is a branch of the natural sciences, and it deals with the study of nonliving things. In this course we will mostly study chemistry and physics. Chemistry is the study of matter—its composition, structure, properties, and interactions or reactions. Physics is the study of matter and energy and how they interact through forces and motion. Since so much of what you'll study in other science courses depends on an understanding of matter and energy, physical science is a good background course for all further science courses.

There is one thing that is important to keep in mind. Remember that science is both a process and a body of knowledge. The information you will read in this text represents the best, most up-to-date scientific knowledge and models we have of how God created the universe to work. But like all scientific knowledge, it can be rejected or replaced in the future as new information becomes available with better technologies. So as you read, think, and ask questions, be aware that the scientific facts today may change tomorrow. The scientific process, though, is the best process we have to make new scientific discoveries, so you'll want to practice it as you study this year. Just think, you may be the one who makes a discovery in the future that will change what we know about how creation works!

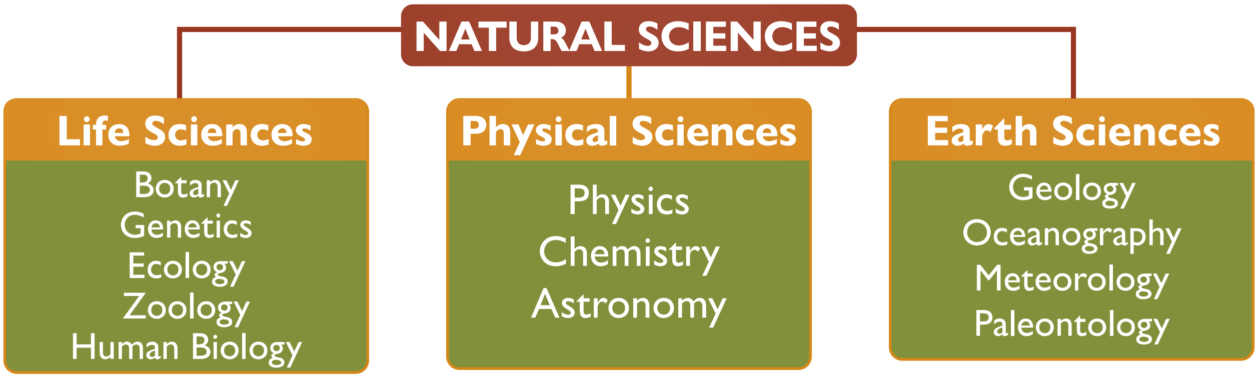


FIGURE 1.4
Generalized Branches of Science

Now, the natural sciences are generally divided into three categories: life science, physical science, and Earth science. Each of these three branches of science can be further subdivided into more specialized topics (Figure 1.4). This is a nice way of dividing science into groups; however, it really isn't as simple as this. You see, there is often a great deal of overlap between these subdivisions. For instance biology, the study of living things, incorporates botany, zoology, ecology, oceanography, chemistry, and even some physics. So the boundaries separating each science is not always very clear.

Before moving forward, complete On Your Own questions 1.1–1.3. Spaces to record your answers are included in the Student Notebook. You can then check your work against the answer key found at the end of this module.

ON YOUR OWN

1.1 What is science?

1.2 How are science and technology related?

1.3 What is physical science?

THE SCIENTIFIC PROCESS

In the last section I mentioned that the scientific process is the best method we have for making new scientific discoveries, so in this section we will review that process. You have probably heard of this process referred to as the scientific method. The scientific method is a systematic process that scientists use to help them solve problems, answer questions, or better understand observed events. Figure 1.5 outlines the steps to the scientific method as described in this section. Keep in mind that scientific methods can vary depending on what is being studied. The steps shown in Figure 1.5 are important and the skills required for each step should be practiced as you work through this course. However, sometimes in everyday science, the steps may be completed in a different order or the specific steps may not be as clear as shown. But one activity always occurs: making observations.

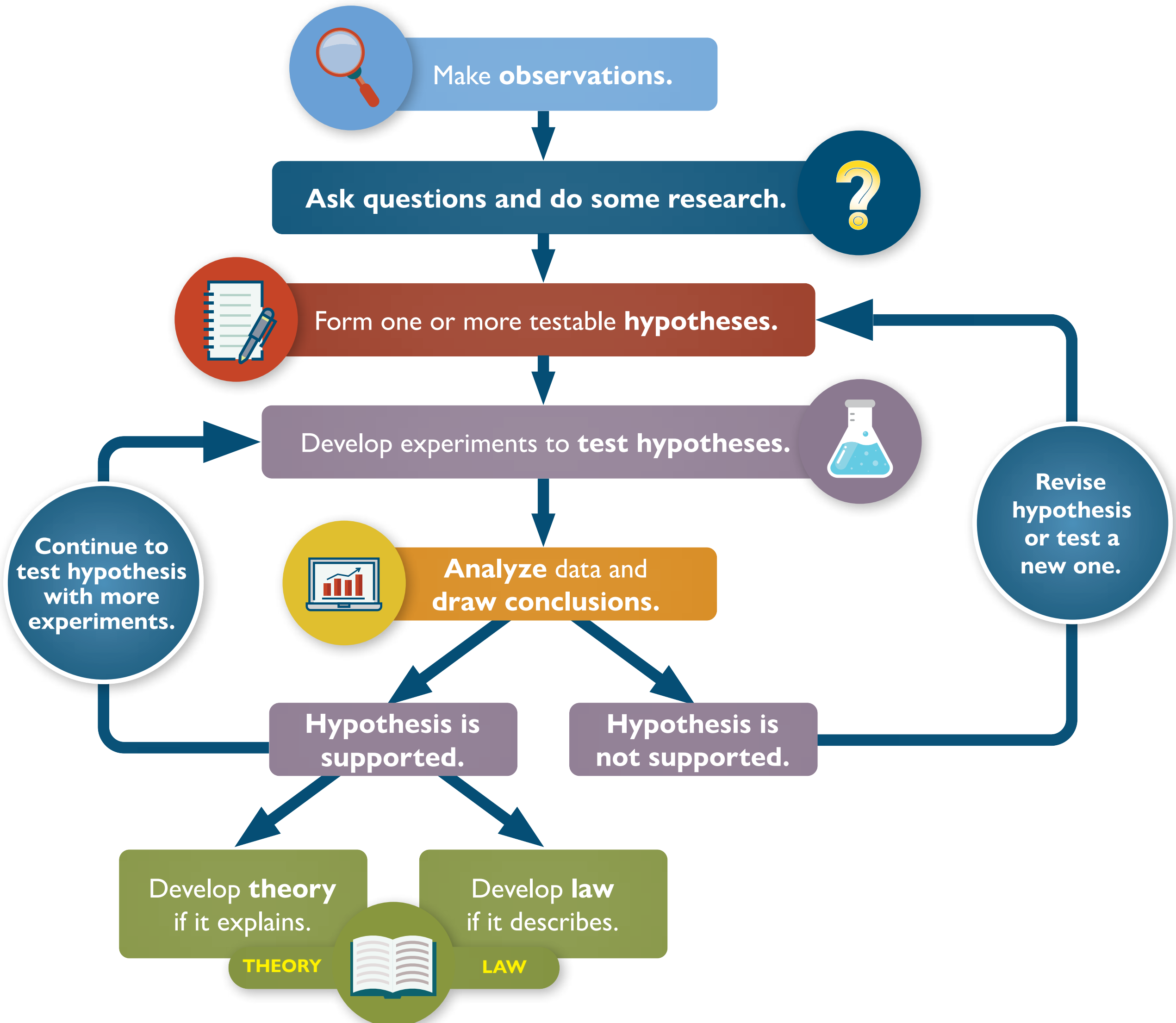


FIGURE 1.5
The Scientific Method

MAKING OBSERVATIONS

Gaining new scientific knowledge through the scientific process is based on observations of the natural world. You make observations when you gather information using your five senses or with the help of instruments.

Observation—The gathering of information using senses or with the aid of instruments

Notice in the definition of observation that there are two ways to make observations. These are called qualitative and quantitative observations. A qualitative observation is an observation made using one of the five senses: sight, smell, touch, taste, or hearing. On the other hand, a quantitative observation is an observation of a quantity, such as counting objects or using an instrument like a ruler, scale, beaker, or other device.

You use your senses all the time to make *qualitative* observations. You notice the changing shape of the moon over several weeks. You smell ammonia gas as you clean windows. You feel the heat radiating from a bonfire. You hear thunder shortly after seeing a lightning flash. All of these are qualities or traits, which are qualitative observations.

Sometimes observations can be made specific or more detailed by using instruments. You measure the heat radiating from the bonfire with a thermometer. You use a watch to time how long it takes to hear the thunder after seeing the lightning flash. These observations use instruments to make numerical measurements, so they are quantitative observations. All *quantitative* observations will have a number in them. The number may be a counting number but is most often a measurement that includes a unit. We'll discuss units in much more detail in a later section, but an example would be 40 ounces. Forty is the number associated with your quantitative observation and ounces is the unit that gives your number meaning. The question "40 what?" is answered with "40 ounces"—not pounds, centimeters, or degrees.

YOU DO SCIENCE

Qualitative & Quantitative Observations

Look at the photo in Figure 1.6. Make two qualitative and two quantitative observations about the photo before reading the next paragraph.

Hopefully you were able to make several observations of each kind even though you can only use your sight for this exercise. Some qualitative observations may include:

FIGURE 1.6
African Animals Near a Water Hole
What quantitative and qualitative observations can you make about what is happening in this photo?

- the ground looks dry
- the air looks hazy or hot
- there is more space between the animals and the lion than between the animals and each other
- the animals seem to be watching the lion
- the antelope stay together

Some quantitative observations may include:
- there are four giraffes
- there is only one lion
- there is only one ostrich

Making observations is the basis of science. Experiments begin with observing. After you observe something that you are curious about, you ask questions, which can lead to more observations. As you experiment and make more observations you may find you have more questions that lead to new experiments. Complete Experiment 1.1 (use the lab report form in your Student Notebook) to gain experience in making observations.

EXPERIMENT 1.1
MAKING OBSERVATIONS

PURPOSE:
To explore qualitative and quantitative observations as they relate to the properties of solids.

MATERIALS:
- *Alka Seltzer tablet*
- *A small, solid object (such as a pebble or eraser)*
- *Magnifying glass*
- *Centimeter ruler*
- *Kitchen scale*
- *Beaker of water*
- *Stirring rod or spoon to stir*

PROCEDURE:
1. *Examine the small, solid object using your senses. In the data table in your Student Notebook, make a list of your observations. CAUTION: Never taste anything in a science experiment. Unknown substances may be hazardous.*
2. *Observe the object with a magnifying glass. Record what you see.*
3. *Use the kitchen scale to determine the weight of the object. Add the weight (be sure to include units) to your list of observations.*
4. *Use a centimeter ruler to measure two dimensions (length, width, height, or diameter) of the object. Record these observations and be sure to include units.*
5. *Place the object in the beaker of water and stir. Record any observations.*
6. *Remove the object from the beaker.*
7. *Repeat steps 1 through 5 for the Alka Seltzer tablet. Record all observations in the data table of your Student Notebook.*
8. *Empty the beaker down the drain, rinse the beaker, and return all materials to their proper place.*

CONCLUSION:
Answer the following questions in a paragraph as you sum up what you learned:
1. *How did the appearance of each object differ under the magnifying glass?*
2. *Which data were obtained by qualitative observations?*
3. *Which data were obtained by quantitative observations?*
4. *How did the instruments extend the observations you made with your senses?*
5. *How did the objects change when placed in the beaker of water?*

What did you learn in this experiment? You should have gained some experience in measuring and weighing solids. But you should also have noticed that the properties of some solids can change when they are in water. Hopefully you recorded in your observations seeing bubbles when the Alka Seltzer was dropped into water. I hope you were asking questions, such as "What caused the bubbles?" or "Where did the solid Alka Seltzer tablet go?" Part of the reason we make detailed observations is to spark good questions. Always include any questions that come to mind while you're observing something so that later you can think about these or decide if you want to investigate further. This is an important step in the scientific process. You will learn more about what the bubbles meant and what happened to the Alka Seltzer tablet in a later module, so make sure your observations are written well enough that when asked to review them you will remember what happened!

Finally, I want to mention that when scientists consider experimentation, they conduct background research. This helps them make sense of their observations and develop questions to answer. In fact, the best way to know how to design an experiment or understand your results is to research a bit. Now complete On Your Own question 1.4 before reading on.

ON YOUR OWN

1.4 Label each of the following observations as qualitative or quantitative:

a. It is light blue in color. ____________

b. It makes a loud popping sound. _____

c. It is 8.3 centimeters long. _________

d. It smells sweet. ________________

e. The temperature increases by 6 °C. ________________________

FORMING HYPOTHESES

A hypothesis (hi poth' uh sis) is a tentative explanation for one or more observations or a proposed answer to a question. For a hypothesis to be a good one, it must be able to be tested.

Hypothesis—A possible, testable explanation for one or more observations or a suggested, testable answer to a question

ADVANCED CONCEPTS

Scientists in the late 1600s observed that some substances burned very easily while others did not. They questioned how that could be. In 1697, one German scientist by the name of Georg Ernst Stahl hypothesized that easily combustible materials must contain a special substance he called phlogiston. Materials that did not burn easily were thought to not contain phlogiston. According to Stahl's hypothesis, wood was made up of ash and a lot of phlogiston. As wood burned, the phlogiston was given off into the air and only the ash remained. This seemed to explain why combustible substances such as wood and charcoal lost weight when burned.

Years later, around 1772, Antoine Lavoisier (a 29-year-old French chemist) observed some things about materials burning that caused him to develop an alternate hypothesis. Lavoisier

FIGURE 1.7
Wood Burning
The phlogiston hypothesis states that wood burns because it contains phlogiston that escapes as it burns. The oxygen hypothesis says that wood combined with oxygen will burn.

hypothesized that burning was the result of a combustible material combining with a component of air—oxygen, not phlogiston (Figure 1.7).

For a decade or so, both hypotheses were used. Both hypotheses about how things burned could explain why candles burn down completely. According to the phlogiston hypothesis, candles contain a lot of the substance phlogiston and so will burn until all the phlogiston is burned off. According to the oxygen hypothesis, there is enough oxygen in the air around the candle to allow it to burn down completely. Both hypotheses are good ones because you can predict what might happen based on each hypothesis and then you can test your predictions.

TESTING HYPOTHESES

What led Lavoisier to think of an alternate hypothesis for why things burn? Observations, of course. As a chemist, he was studying metals. According to the phlogiston hypothesis, if an element burned it would lose all its phlogiston and then it should weigh less after it burned than before. So with that prediction in mind, he tested the hypothesis. Lavoisier conducted experiments where he weighed the elements phosphorus, sulfur, and lead and recorded their mass (you'll learn more about what mass means in a following section). He then burned these elements, such as in Figure 1.8, and reweighed them. What he found was that the elements gained mass after burning and that combustion required air. What did that do to the phlogiston hypothesis?

If you said it disproved the hypothesis, you're right. Since the prediction that the elements would weigh less after burning was based on the phlogiston hypothesis and that is not what happened, then the phlogiston hypothesis must be changed or discarded. As it turns out, the phlogiston hypothesis was ultimately discarded. It took about 5 more years of experimenting for Lavoisier (with the help of Joseph Priestley) to propose his new theory of combustion that excluded phlogiston.

In 1774, Joseph Priestley conducted an experiment in which he discovered that one of the components of air was very combustible. (At the time scientists called all gases air because they had not yet identified what a gas was.) Priestley called this "dephlogisticated air" because a candle would burn five or six times longer in this "air" than in "common air." He told Lavoisier about his discovery and this provided the spark Lavoisier needed to flesh out his new hypothesis. Lavoisier named the "dephlogisticated air" *oxygen* in 1779 and cast doubt on the substance phlogiston.

FIGURE 1.8
Burning Magnesium
A scientist burns magnesium at extremely high temperatures.

There are two important things to consider when it comes to creating a hypothesis:

1. Do not include personal pronouns in this more formal mode of writing.
2. Make sure the hypothesis is testable by using an "if-then" statement.

Say you create the hypothesis, "If the air supply to a burning candle is removed, then the candle will not continue to burn." You can test that hypothesis by conducting an experiment. You might predict that if a lid is placed on the jar containing a burning candle, then the flame will go out. You could perform the experiment and observe the outcome as illustrated in Figure 1.9.

FIGURE 1.9
Flame Extinguishes When Air Is Limited

CONDUCTING EXPERIMENTS

To create a good experiment, it is crucial to make sure you are testing only one thing at a time. This is called a controlled experiment. As the scientist, you control what you are testing. And to be methodical, you should only test one thing at a time.

Controlled experiment—An investigation in which the factors that influence the outcome are kept the same except for one—the factor being studied

The factors that influence the outcome of an experiment are called variables (vayr' ee uh bulz).

Variable—A factor that can change in an experiment

All variables in a controlled experiment should be kept the same throughout the experiment except the one variable whose effect you are studying. This variable, which you intentionally change or manipulate, is called the independent variable. The variable that responds to the changing variable is called the dependent variable.

To explain the difference between an independent and dependent variable, let's use a very simple example. Say your hypothesis is, "If an increasing number of weights is added to a floating toy boat, then it will float lower and lower in the water." Your prediction based on this hypothesis is that the boat will float lower in the water as more weights are added to it. This can be tested by gathering some weights of the same size, floating a toy boat in a tub, and marking the water level on the boat's side. Then you can add weights to the boat—one

FIGURE 1.10
Physics Buoyancy Experiment
As a controlled experiment, what variables should be kept the same?

at a time—marking the water level on the boat with each additional weight. That will show how low the boat is floating in the water.

The goal in the experiment is to keep everything in the experiment the same with the exception of how many weights are added to the boat so you can observe how the boat responds to changing weight only. Thus, you must make sure to use weights of the same size. You also need to use the same boat throughout the experiment. You see, besides added weights, those are possible things that can change (other possible variables) in the experiment. The goal here is to control, or keep constant, all the possible variables within the experiment with the exception of the one we want to change (increasing weight), which is our independent variable. That way any response that the boat makes will be a direct response to the independent variable in the experiment.

- To summarize, the independent variable is the variable that we manipulate. So in the boat example, the independent variable was the number of weights added to the boat. We were intentionally changing that.
- The boat's response to that change was our dependent variable. So the level the boat floated in the water was the dependent variable because it floated lower and lower in the water depending on the number of weights it was carrying.

Before we move on, you should be aware that there are different types of experiments. Look back at Experiment 1.1 and notice that there was no hypothesis. That is because some experiments are simply observational experiments, where the goal is to investigate something by simply making observations. Studying things under the microscope or performing dissections are good examples of this type of experiment. This type of experiment often provides the observations that will spark questions that lead to the type of experiment where you make hypotheses and predictions, develop ways to test them, and then make more observations. Review what you've read so far in this section by completing On Your Own questions 1.5–1.7.

ON YOUR OWN

1.5 For a hypothesis to be considered useful, it should be

a. in mathematical terms.
b. a creative guess made without observations.
c. capable of being tested.
d. general and broad in scope.

1.6 What are variables?

1.7 What is the difference between independent and dependent variables?

ANALYZING DATA

Any time you collect and record observations you're gathering data. Because science is methodical, your data should be organized, and data tables will help you do that. You can also visually show the data using graphs and charts (Figure 1.11). We will go over measuring data and creating data tables, graphs, and charts in more detail in the next two sections.

FIGURE 1.11
Graphs and Charts
Graphs and charts help scientists visualize and analyze data.

Analyzing your data is important. A big part of what goes on in science involves thinking about the data that have been collected. The key thing for you to remember is to try to look at your data results with a critical eye. Ask yourself if you followed all the instructions or if you forgot something. Did you make any mistakes? Did you record units with all your data measurements and record thorough qualitative observations? Do you have enough data to see any patterns or do you need to collect more data? Did you calculate an average for the different trials of your experiment (if needed)?

DRAWING CONCLUSIONS

The reason scientists think about and analyze data for patterns is so they can try to draw conclusions about their hypothesis. Conclusions summarize whether your results support or contradict your original hypothesis. Your conclusion summary could take a few sentences, but most often it will require a paragraph or more.

If your experiment results support that your hypothesis is true, you should summarize how you could tell that by comparing the relationship between the independent and dependent variables. In other words, explain in words how the responding variable changed when you manipulated the independent variable. If your experiment results do not support the hypothesis, then you know your hypothesis is false. What happens if you find your hypothesis is false? It doesn't mean that your experiment was a failure! It is important, however, to never change the results to fit the original hypothesis. Simply explain why things did not go as expected. If you think you need additional experimentation or parts of the experiment should be altered, you should include a description of what you think should happen next in your conclusion summary.

Scientists often find that results do not support their hypothesis. In fact, science works by making mistakes *and* learning from them. Many times scientists use their unexpected results as the first step in revising their original hypothesis or proposing a new one. They must then design a new experiment to test the revised or new hypothesis, and the process of science continues.

SCIENTIFIC THEORIES AND LAWS

Before we begin this section, I want to ask you an important question. What is the difference between asking *how or why something in nature works* and *what you can predict from studying something in nature*? This is the basic difference between a scientific theory and a scientific law. Let me explain what I mean by that. You've probably heard the word *theory* used in detective stories before. The everyday, ordinary meaning of a theory is like a hypothesis—a tentative explanation of observations that may or may not be correct. But the word *theory* in science means something different. To a scientist, a scientific theory is one or a set of hypotheses that explains some aspect of the natural world. Scientific theories have been well tested by many experiments and have a *large* amount of supporting data.

Scientific theory—A well-tested explanation of a phenomenon in the natural world

For example, you will learn about the theory of the atom in a later module. The atomic theory is a scientific theory that explains the nature of matter, which is composed of atoms. Through many experiments in the field of chemistry, a large amount of evidence was collected that supported the theory that the smallest "units" of matter were atoms. Once something has become a theory, it is well accepted by scientists because it agrees with many observations and experiments.

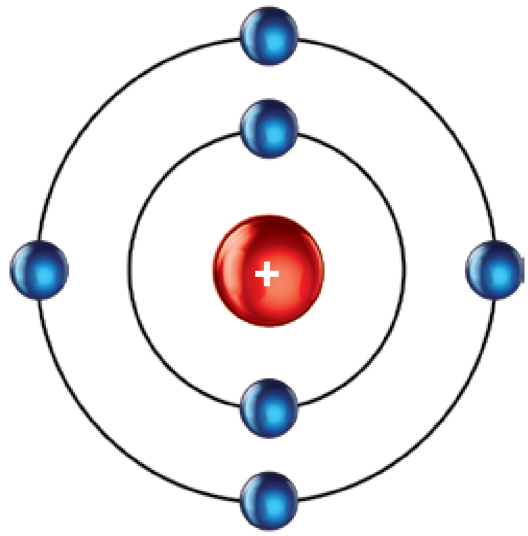


FIGURE 1.12
Carbon Atom
This 1913 model of a carbon atom is based on the atomic theory.

Even so, a scientific theory is not permanent. If evidence is ever gathered that contradicts a theory, the theory is changed to explain the new evidence. For example, the atomic theory has changed greatly in the last hundred years as scientists have discovered more about how atoms behave. If enough evidence is gathered that contradicts a theory, the theory may be completely discarded.

Unlike a scientific theory which explains, a scientific law accurately describes some phenomenon or relationship in the natural world without explaining what causes it or why it exists.

Scientific law—A well-tested description of one phenomenon in the natural world that often includes mathematical terms

Just like a theory, a law is supported by many, many experiments and observations. And also like a theory, a law is well accepted by scientists. Remember, the difference is that theories explain while laws describe.

SCIENCE DOES NOT PROVE

You may have heard a statement that starts out something like, "This is scientific proof that…" Finish the sentence however you'd like, but know that the statement will always be false. Why? Because science is not about proving things. Science is about collecting evidence. Even if all the evidence ever collected supports the atomic theory, there's always the chance that some evidence collected in the future (maybe when we have better technology) will contradict what we think we know. Science is *continually* changing based on new information—nothing in science is ever final.

All the scientific knowledge, theories, and laws we have today are just the currently accepted, best explanations and descriptions we have so far. Science is a process and so any hypothesis, theory, or law—no matter how widely accepted today—can be overturned tomorrow if the evidence warrants it. In other words, scientific hypotheses, laws, and theories are only valid if they can explain all the available data. Science accepts or rejects ideas based on the evidence. Science does not prove or disprove ideas. This is what makes science so much fun! You might be the next scientist to shed light on something we don't yet know.

ADVANCED CONCEPTS

You will learn about Newton's laws of motion in a later module. Newton made many observations and performed many experiments to understand how forces affect the motion of objects. Newton's third law states, "Every action has an equal and opposite reaction." This is a statement that describes what we observe to be true, and it has been verified over and over. But scientists have not yet been able to explain, with hard evidence, how Newton's third law happens or why it works that way. A law can provide predictions of an observed pattern in nature without necessarily explaining the pattern.

Like scientific theories, scientific laws must be consistent with observations and provide accurate predictions. If a law is determined to not be true under all conditions, it must be changed or discarded.

FIGURE 1.13
Chamber for Subatomic Particle Experimentation
Experiments on positrons collect evidence to support their existence but cannot prove their existence.

There is one last thing I want to point out about scientific theories and laws (and hypotheses, for that matter). Some people think that if scientists find enough evidence that supports a hypothesis, the hypothesis is then raised to a theory. Then if the theory is found to be true through more testing, it is raised to a law. That is not how it works! One cannot grow into another. Scientific hypotheses, theories, and laws all have data to support them (or they would be changed), but they differ in scope. Hypotheses are possible explanations about a single or limited idea. Scientific theories explain phenomena in our world in a more in-depth way and are well tested and supported by scientists. And scientific laws describe (but don't explain) phenomena in our world and often include mathematical terms.

WHEN DIRECT OBSERVATION ISN'T POSSIBLE IN THE SCIENTIFIC METHOD

It's not always possible to directly observe some things studied in science. For example, scientists cannot directly observe atoms and molecules, black holes, or the bottom of the deepest part of the ocean. Yet, scientists want to know more about these things, so they gather information in other ways.

Inferences

Besides the conclusions made at the end of an experiment to summarize their results, scientists often make another type of conclusion. An inference (in' fer uns) is a logical conclusion drawn from observations and information that is available.

Inference—A logical conclusion drawn from observations, previous knowledge, and available information

Scientists usually make many inferences when trying to put together an overall picture of what is taking place. Scientists also make inferences when they investigate things that they cannot directly observe. For example, paleontologists (scientists who study fossils) have never observed living dinosaurs, but they gather evidence about them in other ways. Paleontologists have been able to study fossilized dinosaur droppings to gather evidence about what the dinosaur ate while it was alive. They hadn't observed the dinosaur eating but used the evidence they gathered from the fossilized droppings to make an inference.

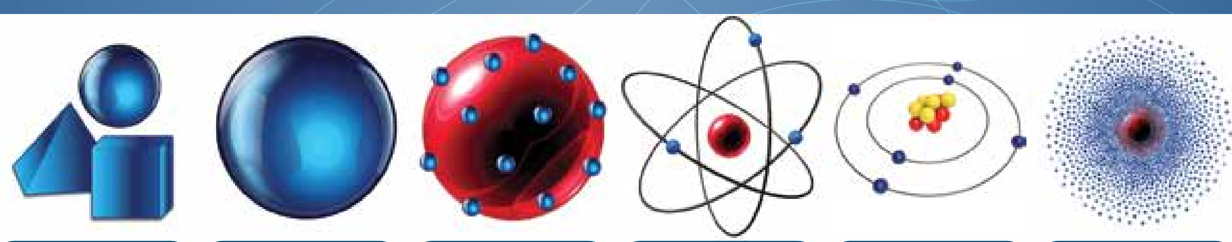
It's important not to mix up observations and inferences. Look at Figure 1.14. In this photo we can observe a meadow, some clouds, and a very vivid rainbow. These are all qualitative observations we can make because we can see them in the photograph. If we take those observations and combine them with knowledge we already have, we can make some inferences. We can infer that it must have been (or perhaps still is) raining. We can also infer that the sun must be shining. Although we can't observe the rain or the sun in the photo, we know that rainbows occur when the sun hits water particles in the air. So in order to see that vivid rainbow, we infer that the sun must be shining on water droplets left in the air after a rain shower.

FIGURE 1.14
Observations and Inferences
What observations and inferences can you make about this picture?

ADVANCED CONCEPTS

Another way that scientists try to make it easier to understand things that are unfamiliar or to visualize things they cannot see is to use models. A scientific model is a useful simplification that is used to make difficult things easier to understand. Models can also be used to illustrate things that might be hard to directly observe. Look back at Figure 1.12. That drawing is a Bohr model of the carbon atom. Niels Bohr used the data he collected (as well as data collected from scientists before him) to infer how an atom looks. He then constructed the Bohr model of the atom based on his inferences. Notice how it looks different from the Bohr model shown in Figure 1.15. Bohr used Rutherford's model but added the new information that the nucleus is composed of subatomic units. A model's job is to help you mentally picture objects too large or small to see, or to identify what is going on in a process you can't observe.

Scientific models need to change if they don't accurately represent all the evidence available. So when new data is collected that is not explained by the current model, the model is changed to reflect the new information. For example, you can see how models of the atom changed quite a bit from 1803 until our current model designed in 1926.



Democritus (400–300 BC)	John Dalton (1803)	J.J. Thomson (1897)	Rutherford (1909)	Niels Bohr (1913)	Schrödinger (1926)
Atoms are solid, invisible, indestructible, and unchangeable. Atoms of different things (water, rocks, etc.) differ in size and shape.	Atoms are solid, invisible spheres. They cannot be destroyed nor created.	Atoms are spheres of positive charge with a few negatively charged electrons throughout like raisins in plum pudding.	Atoms are made of a small, dense, positively charged nucleus with negatively charged electrons orbiting the central nucleus.	Like Rutherford model, but electrons move in fixed, circular orbits (energy levels) around the nucleus. All atoms have same set orbits.	Electrons orbit within a space (cloud) around the nucleus. The cloud is dense where the probability of finding an electron is high.

400–300 BC............. 1800 1805 .... 1895 1900 1905 1910 1915 1920 1925 1930

FIGURE 1.15
Atomic Models Timeline

Review what you learned in this section by completing On Your Own questions 1.8–1.9.

ON YOUR OWN

1.8 Match the term with the definition.

a. hypothesis	A well-tested description of one phenomenon in the natural world that often includes mathematical terms
b. scientific theory	A possible, testable explanation for an observation
c. scientific law	A well-tested explanation of a phenomenon in the natural world

1.9 Why do we say science cannot prove anything?

creation connection

One. One what? One day, 1 week, 1 month, 1 year, 1 second, 1 minute, or 1 hour? Maybe it's 1°F with a 1% chance of snow. Hmm, numbers by themselves aren't very useful, right? Take a moment to look around. You will see that numbers and their units surround you. Explore your kitchen, rifle through some tools in your garage, or read the labels on some vitamins, and you'll quickly notice that numbers and their units allow you to measure, calculate, understand, and make use of your natural world. As we study physical science together this year, you'll learn that science deals with vast numbers that span our universe and infinitesimally small numbers that describe distances within a single atom. And you'll see that scientists have come up with units that help us make sense of these concepts of extremely large or small. But as you master manipulations of numbers and units, it is important that you realize that humans may have assigned names to them, but we did not create them—God did. You see, we do not live in a world of chaos. God created everything we see and even the things we cannot see, and that includes mathematics. Mathematics is a language that describes creation and helps us learn what God already knows. And that seems like a great reason for us to understand the mathematics behind the science.

MEASURING AND MANIPULATING DATA

As you saw in the last section, when you make an observation that you describe with numbers, you are making a quantitative observation. Quantitative observations involve taking measurements. Measurements always have two parts—a number followed by a unit.

Let's suppose I'm making curtains for a friend's windows. I ask the person to measure his windows and give me their dimensions so I can make the curtains the right size. My friend tells me that his windows are 50 × 60, so that's how big I make the curtains. When I go over to his house, it turns out that my curtains are more than twice as big as his windows! My friend tells me that he's certain he measured the windows right, and I tell my friend that I'm certain I measured the curtains correctly. How can this be? The answer is quite simple. My friend measured the windows with a metric ruler. His measurements were in *centimeters* (cm). I, on the other hand, used a yardstick and measured my curtains in *inches*. Our problem was not caused by one of us measuring incorrectly. Instead, our problem was the result of measuring with different units.

When we are making measurements, the units we use are just as important as the numbers that we get. If my friend had told me that his windows were 50 cm × 60 cm, there would have been no problem. I would have known exactly how big to make the curtains. Since he failed to do this (and I failed to ask for clarification), the numbers that he gave me (50 × 60) were essentially useless.

think about this

It's important to note that a failure to indicate the units involved in measurements can lead to serious problems. For example, on July 23, 1983, the pilot of an Air Canada Boeing 767 passenger airplane had to make an emergency landing because his plane ran out of fuel. In the investigation that followed, it was determined that the fuel gauges on the aircraft were not functional, so the ground crew had measured the fuel level manually. However, the fuel gauges were metric, so those were the units with which the pilot worked. The ground crew, however, ended up using English units to report the amount of fuel. The number they reported was the correct number, but since the units were wrong, the airplane ran out of fuel. Thankfully, the pilot was able to make the emergency landing with no casualties.

FIGURE 1.16
A Boeing 767

In the end, then, scientists never simply report numbers; they always include units with those numbers so that everyone knows exactly what those numbers mean. That will be the rule in this course. If you answer a question or a problem and do not list units with the numbers, your answer will be considered incomplete. In science, numbers mean nothing unless there are units attached to them. Since scientists use units in all their measurements, it is convenient to define a standard set of units that will be used by everyone. This system of standard units is called the metric system. The modern metric system, known as the International System of Units, or SI (from the French *Système International d'Unitès*), contains the units that scientists all over the world have agreed to use—units ranging from very large to very small.

Unfortunately, there are many other unit systems in use today besides the metric system. In fact, the metric system is probably not the system with which you are most familiar. You are probably most familiar with the English system. We will discuss the English system as you learn about the metric system for comparison, but in this course you will be using SI units.

THE METRIC SYSTEM

The metric system is a system of measuring. There are a total of seven standard SI units, but we will learn about only three right now: the *meter* for length, the *kilogram* for mass (the amount of matter something has), and the *second* for time. Believe it or not, with just these three simple measurements we can measure just about everything in creation!

TABLE 1.1
Physical Quantities and Their Standard SI and English Units

Physical Quantity	Standard SI Unit	SI Unit Symbol	Corresponding English Unit	English Unit Symbol
length	meter	m	foot	ft
mass	kilogram	kg	slug	sl
time	second	s	second	s

The English unit for mass is (believe it or not) called the *slug*. Although we will not use the slug often in this course, you should be able to recognize it. Notice how the SI unit for mass is the *kilo*gram. You may have thought the SI unit should be the gram (g). Well, a kilogram is equal to 1,000 grams, so you're not far off. The reason the SI unit of mass is the kilogram is really a matter of convenience. One gram is very small (the mass of a U.S. dollar bill is about 1 g), so measuring the mass of most things would result in very large numbers if the unit were grams. In using the metric system, you will use grams with other prefixes as well.

This is one of the advantages to the metric system—there are many metric number prefixes that allow us to talk about really big or really small things. Table 1.2 summarizes the most commonly used prefixes and their numerical meanings. The prefixes in blue type are the ones we will use over and over again. You will be expected to have those three prefixes and their meanings memorized.

TABLE 1.2
Common Prefixes Used with Metric (SI) Units

Name	Number	Prefix	Symbol
trillion	1,000,000,000,000	tera	T
billion	1,000,000,000	giga	G
million	1,000,000	mega	M
thousand	**1,000**	**kilo**	**k**
hundred	100	hecto	h
ten	10	deka	da
one	**1**		
tenth	0.1	deci	d
hundredth	**0.01**	**centi**	**c**
thousandth	**0.001**	**milli**	**m**
millionth	0.000 001	micro	μ
billionth	0.000 000 001	nano	n
trillionth	0.000 000 000 001	pico	p

Because this can be a confusing point, I want to mention it again: the SI unit (standard unit) for mass is the kilogram. However, when doing conversions between mass units we always reference the gram, as it is the most convenient conversion between the powers of ten. This is also the same for liter when converting between volume units, meter for units of length, and seconds for time. So, if you wanted to measure the length of something small, the only unit you could use in the English system would be the inch. However, if you used SI units, you would have all sorts of options for which unit to use. If you wanted to measure the length of someone's foot, you could use the decimeter. Since the decimeter is one tenth of a meter, it measures things that are only slightly smaller than a meter. On the other hand, if you wanted to measure the length of a sewing needle, you could use the centimeter because a sewing needle is significantly smaller than a meter. If you wanted to measure the length of an insect's antenna, you might use the millimeter since it is one thousandth of a meter, which is a really small unit.

So you see, the metric system is more logical and versatile than the English system. That is, in part, why scientists use it as their main system of units. The other reason scientists use the metric system is that most countries in the world use it. Except for the United States, Myanmar, and Liberia, every other country in the world uses the metric system as its standard system of units. Since scientists in the United States frequently work with scientists from other countries around the world, it is necessary that American scientists use and understand the metric system.

There are many different things we need to measure when studying creation. Now that you're familiar with the metric system, we'll briefly discuss mass, length, volume, time, and temperature since they are most often measured in science.

Mass

First, we must determine how much matter exists in the object we want to study. We know that there is a lot more matter in a car than there is in a feather since a car weighs significantly more than a feather. To study an object precisely, however, we need to know *exactly* how much matter is in the object. To accomplish this, we measure the object's mass. Mass is the amount of matter something has. As I mentioned earlier, the SI unit for mass is the kilogram, but when doing conversions between mass units we will reference the gram (abbreviated g). The kilogram is also part of other common units you will learn about in chemistry and physics, such as the newton and the joule.

FIGURE 1.17
Mass Balance
The mass of the cylinders is in grams, so the unit for the mass of salt will be in grams.

Suppose you find that a certain amount of salt will balance two 5-g mass cylinders (Figure 1.17). The question, "How much salt is there?" can now be answered: 10 grams. It's easy to see that the 10 grams of salt has 10 times the matter that is in an object with a mass of 1 gram. To give you an idea of the size of a gram, the average mass of a United States dollar bill is about 1 gram. Based on this fact, we can say that a gram is a rather small unit. Most of the objects we will measure will have masses of 10 to 10,000 grams. For example, when full, a 12-ounce can of soda has a mass of about 400 grams (Figure 1.18). We will talk more about mass in a later module.

FIGURE 1.18
Relative Mass
A U.S. dollar bill has a mass of about 1 g, and a full can of soda has about 400 times more mass.

Length

The standard SI unit for length is the meter. If you stretch out your left arm as far as it will go, the distance from your right shoulder to the tip of the fingers on your left hand is about 1 meter. The abbreviated form, or symbol, for meter is *m*.

FIGURE 1.19
Running
An average runner can complete 1 km (about 0.62 miles) in under 5 minutes.

Large distances are measured in kilometers (km). The prefix *kilo-* means one thousand (Table 1.2). One kilometer is equal to 1,000 meters (Figure 1.19).

Smaller lengths can be measured in centimeters (cm). The prefix *centi-* means one hundredth, so a centimeter is 1/100 of a meter. Even smaller lengths can be measured in millimeters (mm). The prefix *milli-* means one thousandth, so a millimeter is 1/1,000 of a meter, and there are 10 mm in 1 cm (Figure 1.20).

I hope you're beginning to see that all the prefixes indicate a change of 10 times. This is another big advantage to using the metric system of units. With a little practice you will easily be able to convert from one metric unit to another.

FIGURE 1.20
Centimeters and Millimeters
How many millimeters wide is your fingernail or thick is a penny?

think about this

MASS vs. WEIGHT. There is a big difference between mass and weight. Sometimes we use the terms mass and weight interchangeably, but in science it is important to know the difference! Mass is a measurement of the amount of matter something contains. We measure mass by using a balance and comparing the unknown mass to the mass of a known amount of matter. Weight, on the other hand, is a measurement of the pull of gravity on an object. We measure weight with a scale. You will learn more about the difference between mass and weight in a later module.

Volume

We also need to be able to measure how much space an object occupies. This measurement is commonly called volume. Since the volume of a cube is a length × length × length, volume is measured in cubic meters (abbreviated m^3). A cube that is 1 meter on each side has a volume of 1 m × 1 m × 1 m, or 1 m^3. For smaller solids, cubic centimeters (cm^3) may be used.

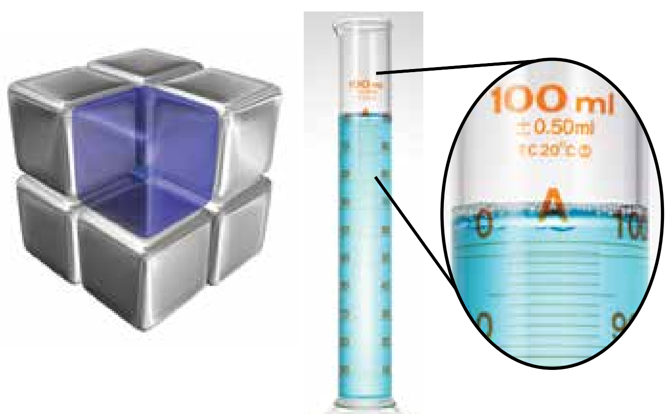


FIGURE 1.21
Cubic Meters and Milliliters
Solids are often measured in cubic meters, cubic centimeters, or cubic millimeters. Liquids are often measured in liters or milliliters.

Volume is also measured in the metric system with the unit liter. The main unit for measuring volume in the English system is the gallon. To give you an idea of the size of a liter, it takes just under 4 liters to make a gallon. The abbreviation for liter is L. Any time you use a graduated cylinder or beaker in a science experiment, you will be measuring volume in milliliters (Figure 1.21). The abbreviation for milliliters is mL. An interesting fact is that the volume of 1 cm^3 is equal to the volume of 1 mL. You will find that a handy conversion factor in your science classes. We'll look at converting units in more detail in the next section.

Let's stop for a minute and consider that the English units for measuring solid volumes are cubic inches, cubic yards, or cubic miles. The English units for measuring liquid volumes are cups, pints, quarts, and gallons. I hope you're beginning to see that the metric system is easier to use because all you need to remember is what the prefix means.

think about this

FUN VOLUME FACTS:

- A six-sided die (from a set of dice) has a volume of about 1 cm^3.
- A teaspoon of liquid has a volume of about 5 mL (5 cm^3).
- An average-sized refrigerator has a volume of a little over 1 m^3.
- Lake Erie, one of the Great Lakes, has a volume of about 480 km^3.

Time

The SI unit for time is the second (s), a very familiar unit to you. For very short time intervals, time is measured in milliseconds (ms). A millisecond is 1/1,000 of a second. Other everyday units for measuring time include the minute (abbreviated min) and the hour (abbreviated h). You have probably used a stopwatch to measure time at some point. Stopwatches (Figure 1.22) are the most commonly used instruments for measuring time because they are quite accurate, inexpensive, and easy to use. These days all smartphones come with a stopwatch app, so making time measurements has never been easier.

FIGURE 1.22
Stopwatch
Stopwatches are the most common instrument of time measurement.

Temperature

In science, temperature is a measurement of how much energy a substance has. In chemistry and physics courses, you will do quite a few experiments requiring you to measure the transfer of heat energy with a thermometer.

The unit for temperature measurements that is used in most scientific research is degrees Celsius (°C). The Celsius scale (initially called the centigrade scale) was developed in 1742 by the Swedish astronomer Anders Celsius. Celsius developed this scale using the melting point of ice and the boiling point of water as reference points. Using the Celsius scale, ice melts (or water freezes) at 0 °C and water boils at 100 °C.

You may be more familiar with temperature measurements in Fahrenheit (°F) since this is what is used in the United States. However, the scientific community (and most other countries of the world) has adopted the Celsius scale for temperature measurement because it is more compatible with the other base ten units of the metric system of measurements (Figure 1.23).

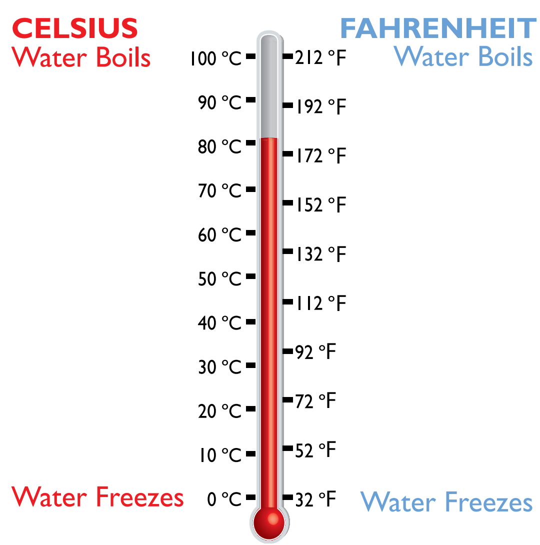


FIGURE 1.23
Thermometer Scale
The Celsius scale is used more commonly in science than the Fahrenheit scale. Can you see why?

CONVERTING UNITS

Table 1.3 shows the common units, symbols, and prefixes that we will be using this year. Now that you understand what prefix units are and how they are used in the metric system, you must become familiar with converting between units within the metric system. In other words, if you measure the length of an object in centimeters, you should also be able to convert your answer to any other distance unit. For example, if I measure the length of a pencil in centimeters, I should be able to convert that length to millimeters, decimeters, meters, etc. Accomplishing this task is relatively simple if you remember a trick you can use when multiplying fractions. Study Example 1.1.

TABLE 1.3
Common Metric Units, Prefixes, and Symbols

Used for	Name	Symbol/Abbreviation
Prefix meaning: 1,000 Prefix meaning: 1/100 Prefix meaning: 1/1,000	kilo- centi- milli-	k- c- m-
mass	*kilogram gram milligram	kg g mg
length	*meter kilometer centimeter millimeter	m km cm mm
time	*second millisecond minute hour	s ms min h
volume	cubic meter cubic centimeter liter milliliter	m^3 cm^3 L mL
temperature	degrees Celsius	°C

*SI units

EXAMPLE 1.1

Suppose I asked you to complete the following problem:

$$\frac{7}{64} \times \frac{64}{13} =$$

There are two ways to figure out the answer.

Option One: Multiply the numerators together and then multiply the denominators together. Simplify the fraction.

$$\frac{7}{64} \times \frac{64}{13} = \frac{448}{832} = \frac{7}{13}$$

Option Two: Cancel out common factors in the numerator and the denominator. Thus, the 64 in the numerator cancels with the 64 in the denominator and gives you a value of 1. Now the only factors left are the 7 × 1 in the numerators and the 13 × 1 in the denominators.

$$\frac{7}{\cancel{64}} \times \frac{\cancel{64}}{13} = \frac{7}{13}$$

Notice how you could arrive at the answer much more quickly using the second approach. In this way the problem takes one less step.

We will use the same idea in converting between units. Suppose I measure the length of a pencil to be 15.1 centimeters, but the person who wants to know the length of the pencil would like me to tell him the measurement in meters. How would I convert between centimeters and meters? Study the steps below in Example 1.2.

EXAMPLE 1.2

Convert 15.1 centimeters to meters.

1. First you need to know the relationship between centimeters and meters. According to Table 1.2, *centi-* means 0.01. So 1 cm is the same thing as 0.01 m. This is called a conversion factor and should be written in mathematical form:

   $$1 \text{ cm} = 0.01 \text{ m}$$

2. Now that we know the relationship between cm and m (the conversion factor), we can convert from one to the other. Always start a problem by writing down what you know (or are given in the problem):

   $$15.1 \text{ cm}$$

3. Remember that any number can be expressed as a fraction by putting the number over the number 1 (any number divided by 1 is the same number). Rewrite the measurement as a fraction:

   $$\frac{15.1 \text{ cm}}{1}$$

4. Now you can take that measurement and convert it into meters by multiplying it with the conversion factor from step 1. Set up your conversion factor as a fraction so the desired unit is in the numerator and the given unit is in the denominator.

   $$\frac{15.1 \cancel{\text{cm}}}{1} \times \frac{0.01 \text{ m}}{1 \cancel{\text{cm}}} = \mathbf{0.151 \text{ m}}$$

   Given Unit — Conversion Factor — Wanted Unit

This tells us that 15.1 centimeters is the same as 0.151 meters. There are two reasons this conversion method, called the factor-label method, works.

1. Since 0.01 m is the same as 1 cm, multiplying our measurement by (0.01 m)/(1cm) is the same as multiplying by 1. Since nothing changes when we multiply by 1, we haven't altered the value of our measurement at all. All conversion factors are equal to 1.
2. By putting the 1 cm in the denominator of the conversion factor (0.01 m)/(1 cm), we allow the centimeters unit to cancel. Once the centimeter units are canceled, the only unit left is meters, so we know that our measurement is now in meters.

This is how we will do all our unit conversions. In your high school chemistry and physics classes you will learn about significant figures and how to round your answers properly, but for now learning how to use conversion factors in the factor-label method will give you a good start for future science classes. You will see many examples of the factor-label method throughout this course, so you will have plenty of practice. But since the factor-label method is so important in our studies of physical science, let's see how it works in another example now.

EXAMPLE 1.3

A student measures the mass of a rock to be 14,351 grams. What is the rock's mass in kilograms?

1. First you need to find the conversion factor, which is the relationship between kilograms and grams. According to Table 1.2, the prefix *kilo-* means 1,000. So 1 kg is equal to 1,000 g. (Always put the 1 in front of the prefix unit, and then the base unit gets the number that corresponds to the definition of the prefix.) Write as:

$$1 \text{ kg} = 1{,}000 \text{ g}$$

2. Now that we know the conversion factor for kg and g, we can convert from one to the other. Always start a problem by writing down what you know (or are given in the problem) and then writing it in fraction form:

$$\frac{14{,}351 \text{ g}}{1}$$

3. Take the given measurement and convert it into kilograms by multiplying it with the conversion factor from step 1. Pay attention to which way the conversion factor should be written as a fraction so that you can cancel the units properly (in this case place 1,000 g in the denominator):

$$\frac{14{,}351 \cancel{\text{g}}}{1} \times \frac{1 \text{ kg}}{1{,}000 \cancel{\text{g}}} = \mathbf{14.351 \text{ kg}}$$

Given Unit | Conversion Factor | Wanted Unit

Thus, 14,351 g = **14.351 kg**.

You can use the factor-label method and conversion factors to convert between systems of units as well as within the metric system of units. Thus, if a measurement is taken in the English system, the factor-label method can be used to convert that measurement to the metric system, or vice versa. Remember, a conversion factor is the relationship between two units and will always equal 1. So you can always convert from one unit (no matter what system of measurement) to another with the factor-label method. Any time you will be asked to convert between systems in this course, you will be given the conversion factor you need. Review what you've learned by completing On Your Own problems 1.10–1.13.

ON YOUR OWN

1.10 Give the name and symbols for the following standard SI units (Hint: Look back at Table 1.1):

a. time   b. mass   c. length

1.11 Convert 8.3 meters to centimeters.

1.12 A student measures the mass of a large tomato as 136 grams. What is that measurement in kilograms?

1.13 If a glass contains 0.121 liters of milk, what is the volume of milk in milliliters (0.001 L = 1 mL)? What is the volume of milk in gallons (gal) (1 gal = 3.78 L)?

think about this

Conversion factors aren't just mathematical facts you find in science. There are examples everywhere you look in life. Money is traded widely on global financial markets and conversion rates, often called foreign exchange rates, represent the ratio between two currencies. Stock markets, interest rates, and even economic activity worldwide depend on the rate of exchange. Farmers use a variety of conversion factors. They convert crops on the ground into estimated bushels of product, which then convert to truckloads and eventually to storage bin size. Businesses use conversion rates to estimate how many website visitors will turn into actual customers. Can you think of other conversion factors? Perhaps you will find some in your kitchen the next time you are baking.

ORGANIZING, ANALYZING, AND PRESENTING SCIENTIFIC DATA

Now that you're familiar with taking scientific measurements and converting between them, we need to spend some time discussing how to record your data. Data must be collected and then organized and presented so that it can be analyzed. Remember that the goal of experimentation is to draw conclusions about your hypothesis by analyzing your data and looking for relationships between the independent and dependent variables. We'll start with data tables.

DATA TABLES

If you plan your data tables before you conduct your experiment, recording your data becomes easy and orderly. A good data table will have the following elements:

- A short, concise title that explains what the information in the table contains
- Column labels that explain what data is in each column
- Row labels that explain what data is in each row

An orderly data table will help you find any patterns in your data. Look at Figure 1.24 as an example. This is a data table of a toy boat experiment similar to the one shown in Figure 1.10.

Notice how the data table has a title that explains the data contained in the table. You can also clearly identify what data is contained in each column by the titles. In this table, row titles are not necessary. Look over the titles and the data listed. Can you tell which variable was kept constant? The mass of the boat was held constant. In the experiment, the same boat was used for each additional mass so the water level change would only be due to the masses added.

Can you see a pattern in the table? As the added mass increases, the depth of the boat increases too. Seeing the data presented in an organized data table helps you to see patterns that you might miss otherwise.

TABLE 1.4
Testing Depth of Boat with Increasing Masses

Total Mass (g) Added	Mass of Boat (g)	Water Level on Boat (measured from bottom of boat to water line) (cm)
10.0	20.0	1.0
20.0	20.0	2.0
30.0	20.0	3.0
40.0	20.0	4.0
50.0	20.0	5.0

FIGURE 1.24
Data Table of a Toy Boat Experiment
Good data tables have titles, list all the trials conducted, and clearly show what data (including units) were collected.

ANALYZING DATA WITH GRAPHS

Another way that scientists look for patterns in data is to plot the data on a graph. In fact, plotting data on graphs helps scientists see the patterns in a visual way, which helps them to analyze their data and make conclusions. There are several types of graphs that can be used depending on how you want to visualize your data. There are bar graphs, circle graphs, and line graphs, to name a few. Let's look at these types of graphs and when to use them.

Bar Graphs

Bar graphs are one of the most common types of graphs. Bar graphs are used when you want to compare the differences between two or more groups or to show changes over time. For example, you can use a bar graph to show the temperature data collected over a given time period in two or more different cities, as shown in Figure 1.25.

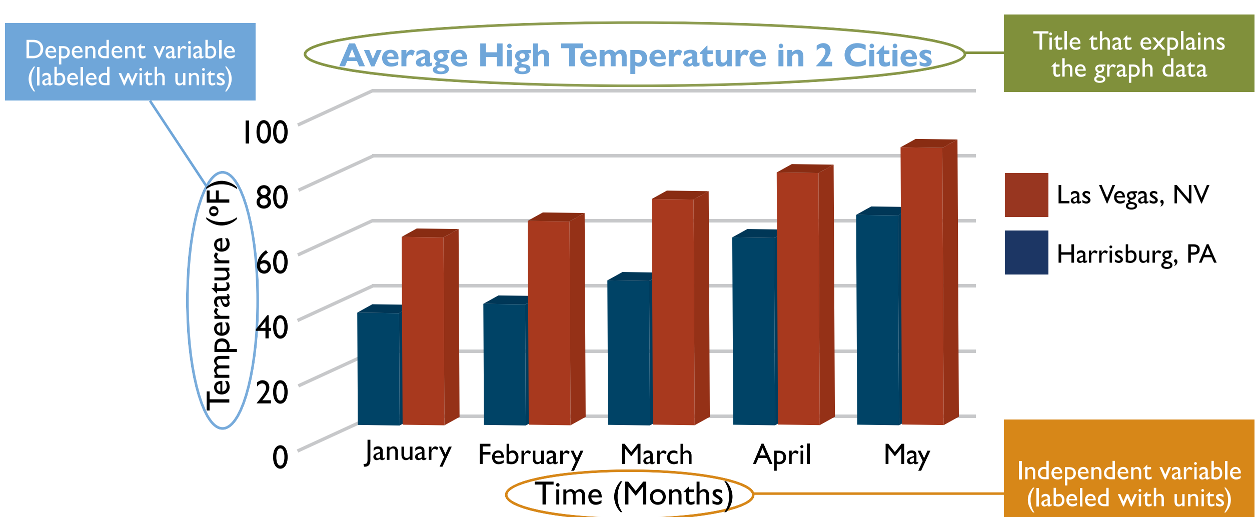


FIGURE 1.25
Bar Graph Comparing High Temperatures for Harrisburg, PA, and Las Vegas, NV
Bar graphs compare two or more groups over time.

When you look at the bar graph in Figure 1.25, notice how easy it is to see which city has the higher temperatures. Bar graphs make visualizing the differences in data easy if the differences are large enough. Also notice that the bar graph has a title. The graph also shows the independent variable (in this case, time) on the horizontal axis of the graph, while the dependent variable (temperature) is shown on the vertical axis of the graph.

Circle Graphs

Circle graphs (also called pie charts) are useful for showing how a part of something relates to the whole. In other words, they are good graphs to use when your data can be expressed as percentages of the total. For example, if you are trying to determine the composition of an unknown mixture of gases, you might show your results using a pie chart, such as the one shown in Figure 1.26.

In Figure 1.26, notice that the gases that make up the air we breathe are shown as a percentage. You can easily see that dry air is made up of more nitrogen than anything else. Isn't it interesting to realize that when you take a breath, only 20.95% of what you're breathing is oxygen?

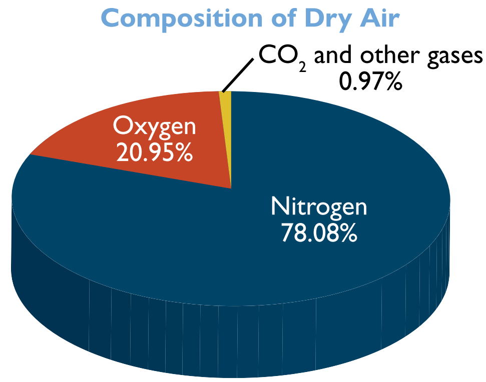


FIGURE 1.26
Pie Chart of the Composition of Dry Air
Circle graphs show how different parts of something relate to the whole.

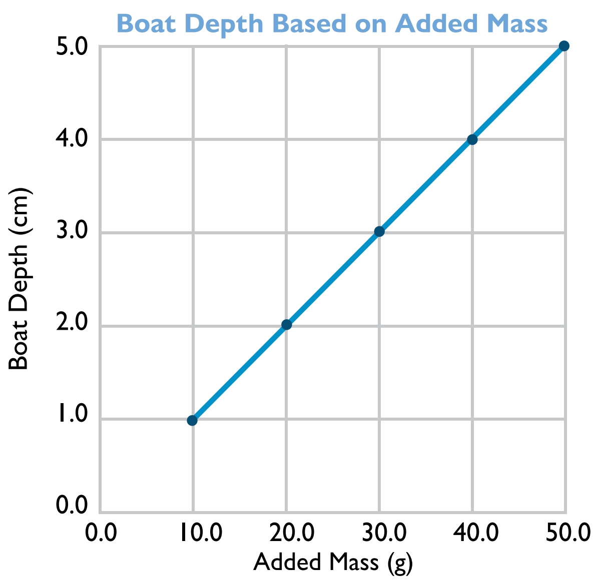


FIGURE 1.27
Line Graph of Boat Depth Based on Added Mass
Line graphs can show even the smallest patterns or trends, so they are the most commonly used graphs in science.

Line Graphs

If you conduct an experiment in which you hypothesize that when you change the independent variable the dependent variable will also change, then a line graph is the best graph to show your data. Line graphs are the most commonly used graphs in science experiments because they can show even the smallest patterns or trends.

It is important to create the line graph correctly, though, so that the data can be properly analyzed. You should only use line graphs if your independent variable is quantitative data (data with numbers), just like the data shown in Figure 1.27.

The key to correctly creating line graphs is to always graph the independent variable—the variable the experimenter controls—on the *x*-axis and the dependent variable—the variable that responds when the independent variable is changed—on the *y*-axis. Remember that line graphs have an *x*-axis (horizontal axis) and a *y*-axis (vertical axis), and the points on the graph are the data points. With the data from Table 1.4

located in Figure 1.24, then, we would make our x-axis be the total mass of the weights added because that was the variable the investigator manipulated. The y-axis would then be the water level on the boat measured from the bottom because that is the responding variable. Remember to choose a scale that will show all the data without being too large or too small. And finally, plot the individual points of data.

Notice that the data makes a straight line that rises to the right. This tells us that as the mass of the added weights increases, the depth of the boat in the water increases. This is called a direct relationship, and relationships between variables in experiments are what scientists look for. Try the pendulum experiment in Experiment 1.2 to get more practice with line graphs. As you complete that experiment, you will be creating data tables and making graphs to analyze your data. You will find more help for this in your Student Notebook too.

EXPERIMENT 1.2

Practice Collecting and Analyzing Data

PURPOSE:

To explore collecting and analyzing data using tables and graphs while investigating pendulums.

MATERIALS:

- *String*
- *Masking tape*
- *Stopwatch or 30-second timer (If you have access to a timer you can set the timer for 30 seconds and do this experiment without a helper. Otherwise you will need a helper to track the stopwatch and tell you when 30 seconds have gone by while you count swings.)*
- *Pencil*
- *Paperclip*
- *5 washers*
- *Half a piece of cardstock paper (cut paper in half lengthwise) or cardboard*
- *Protractor*
- *Metric ruler*

QUESTION:

How does changing the mass of a pendulum affect the number of swings in 30 seconds?
How does changing the length of a pendulum affect the number of swings in 30 seconds?

HYPOTHESIS:

Write your prediction of how the number of swings of a pendulum will change as mass is changed. Write your prediction of how the number of swings of a pendulum will change as length is changed.

PROCEDURE—PART 1, MASS:

1. *Write the independent (mass) and dependent (number of swings) variables in the data section of your Student Notebook.*

2. You must keep all the variables constant except the one you're testing. So to keep the height from which you release the pendulum the same each time, follow these instructions: With the protractor, draw a dotted line down the center of your paper or cardboard. Then position the protractor so the center line of the protractor (90°) is on the dotted line, as shown in Figure 1.28. Draw a solid line about 20° from the dotted line, as shown. Set aside the protractor.
3. Tape the card to the edge of a table so that it hangs down and you can see the lines you just drew.
4. With the ruler, measure out 32 cm of string. Tie one end of the string to the end of the pencil.

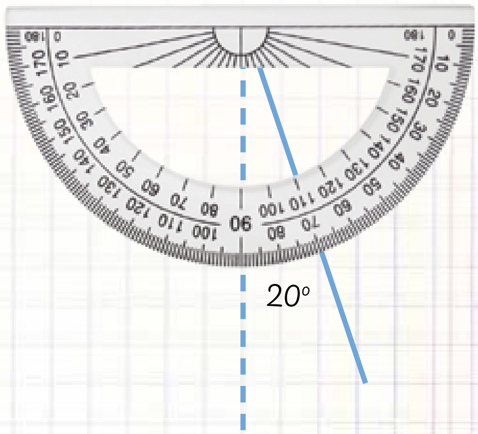


FIGURE 1.28

5. Tape the pencil to the top of the table so that it lines up with the dotted line on your paper and hangs out over the edge enough that the pendulum can easily swing.
6. Next, take the paperclip and bend it so it has a loop at the top and a hook shape at the bottom. It should look like a Christmas ornament hanger (see Figure 1.29).
7. Tie the other end of the string hanging from the pencil to the loop on your paperclip. You now have a pendulum. Check to make sure that the string of your pendulum lines up with the dotted line on your card. If it doesn't, adjust the pencil or the card to make it line up. The string shouldn't touch the card so that it can freely swing, but you should be able to see that the string lines up with your dotted line when looking at it from directly in front of it.

FIGURE 1.29

8. Now you will test the effect of mass on the number of swings. Add one washer to the paperclip. Pull the paperclip back from the rest position (B in Figure 1.30) so that the string lines up with the solid line you drew on the card (position C in Figure 1.30).
9. When your helper says "go," release the paperclip from position (C), and count how many times the washer-pendulum swings back and forth in 30 seconds. One swing is counted from the release position (C) to the other side (A) and back to the release position (C). Create a data table and record the number of swings.
10. Repeat step 9 two more times and record your data.
11. Add two more washers to the paperclip for a total of three. Repeat step 9 three times and record your data in the data table.
12. Add two more washers to the paperclip for a total of five. Repeat step 9 three times and record your data.

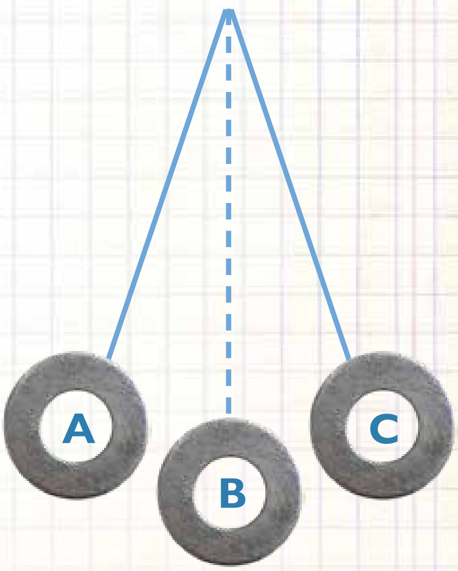


FIGURE 1.30

PROCEDURE—PART 2, LENGTH:

13. Write what the independent and dependent variables are in the data section of your Student Notebook.

14. *Remove 3 washers from the paperclip. You should have 2 washers on the paperclip for the rest of this experiment.*
15. *Measure the length of your pendulum. Measure from the top of the paperclip to where the pendulum is attached to the pencil. It should be about 30 cm. Record this measurement in the data table.*
16. *Repeat step 9 three more times and record your data.*
17. *Shorten your pendulum to about 20 cm by winding the string around the pencil until you reach the correct height. Record this measurement in the data table.*
18. *Repeat step 9 three more times and record your data.*
19. *Shorten your pendulum to about 10 cm by winding the string around the pencil until you reach the correct height. Record this measurement in the data table.*
20. *Repeat step 9 three more times and record your data.*
21. *Clean up and put everything away.*

RESULTS:

1. *Find the average number of swings for each mass in Part 1 of the experiment by adding the number of swings you recorded in each trial and dividing by 3. Record your data.*
2. *Graph the data from Part 1. Remember to put your independent variable (the variable you changed—in this case the mass) on the x-axis and the dependent variable (the responding variable—in this case the average number of swings) on the y-axis. Also remember to choose a scale that shows all the data well, label your axes including units, and give your graph a title.*
3. *Repeat steps 1 and 2 of this Results section for Part 2 of the experiment.*

CONCLUSION:

How has organizing your data in tables and graphs helped you to analyze the data? What patterns or trends do you see? Do they correspond to what you read in the text? Write a short paragraph responding to these questions.

So what did you see in Experiment 1.2? Hopefully you were able to analyze your data using graphs to make a few conclusions. You should have seen that mass does not affect the number of swings of a pendulum. Your first graph should resemble a straight horizontal line like the first graph in the following Advanced Concepts section. The straight line tells us that there is no relationship between the independent (mass) and dependent (number of swings) variables. Again, this means no matter the mass on the pendulum, it will not affect the number of swings for the pendulum. Did this result surprise you? Does this result support your hypothesis, or do you now need to modify your hypothesis to make sense with your data?

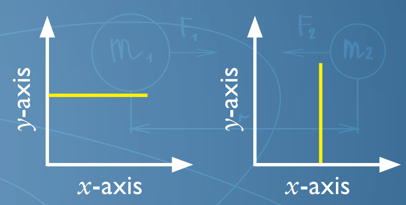
In Part 2, there should have been a different result. Your graph should look like a slightly curved line, similar to the fourth graph in the third row (the indirect relationship row) in the following Advanced Concepts section. In analyzing your data from Part 2, the graph indicates that there is an indirect relationship between the length of a pendulum (independent variable) and the number of swings (dependent variable). In other words, as the length of a pendulum increases, the number of swings decreases. When you take your first physics course, you will get to determine the mathematical equation that describes this relationship, but seeing the results on a graph is the first step. Again, does this result support your hypothesis, or do you now need to modify your hypothesis to make sense with your data?

There is nothing wrong with having to modify a hypothesis. Scientists must do this all the time because they are human. As humans, sometimes we can only provide an educated guess as to what we think will happen. After that we discover what God has already set as the parameters. If we guess correctly, our hypothesis is supported. If not, we must have assumed incorrectly, but that is OK. We now know the results are different than our best educated guess, so we change our hypothesis. It is not really all that different from a family member offering you a piece of cake but asking you to try it with your eyes closed. Imagine a sister offering her brother a piece of cake, but he has to guess the type of cake. Let's say he guesses that it is chocolate since he knows that his sister loves chocolate cake. However, when he does a blind taste-test he discovers the cake is strawberry. The experimental result (strawberry cake) is different from his educated guess—his hypothesis that his sister's cake was chocolate!

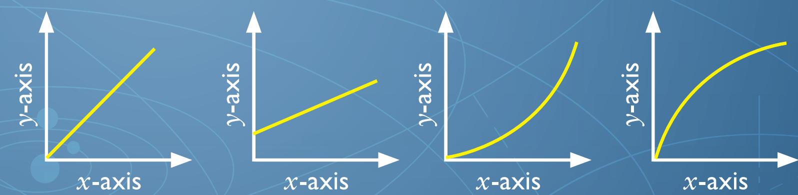
ADVANCED CONCEPTS

In science we look for relationships between the independent and dependent variables. Remember, the *x*-axis is the independent variable that the experimenter controls, and the *y*-axis is the dependent variable that responds when the independent variable is changed. Graphing is a good way to visualize those relationships. There are three main relationships we look for: no relationship, a direct relationship, and an inverse (or indirect) relationship.

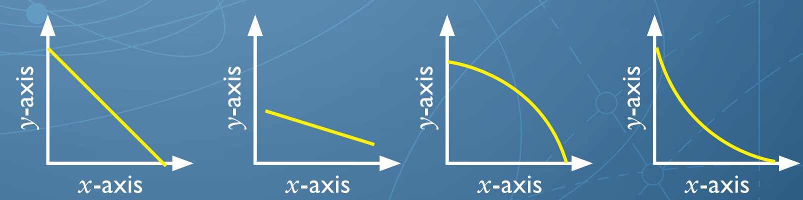
No relationship occurs when you change the independent variable but the dependent variable does not change in response. Alternatively, the dependent variable may change even when the independent variable does not. Both situations tell us that the dependent variable does not depend on the independent variable.



A direct relationship occurs when you increase the independent variable and the dependent variable also increases in response.



An inverse (also called indirect) relationship occurs when you increase the independent variable and the dependent variable decreases.



Additionally, did you know that on a good graph, you can actually predict information? For example, look at your first graph of pendulum mass and how that affected the number of swings.

What would you predict the number of swings would be if there were 2 washers? To determine that you can simply look at the line you drew between 1 washer and 3 washers. Where that line falls tells you what the number of swings would be if you used 2 washers.

Now what if I asked you to predict what the number of swings would be if there were 6 washers? You don't have a line that goes over 6 washers because we stopped at 5. But you can draw a dashed line that extends out to 6 washers to predict what the number of swings would be. This is called extrapolation, and it is another way we can use graphs to analyze and predict data.

SUMMING UP

Physical science helps us engage in and appreciate the beautifully ordered world around us. As you discover scientific laws, learn the scientific method while conducting experiments, and investigate chemistry and physics principles, you will better understand the elegant way our world works and appreciate God's creation. We'll be practicing the skills you learned in this module throughout this course as together we explore the extraordinary physical world God has given us.

As we move through the rest of the modules, please keep in mind that this course is intended to present the content at an introductory level. This solid foundation will prepare you for the specialized chemistry and physics courses you'll take in high school, which will go into more detail than we will cover in this curriculum. Certain topics and their details are simply beyond the scope of this course, but I hope the information here will pique your curiosity and create a desire to learn more about God's awesome design.

SUMMARY OF KEY EQUATIONS IN MODULE 1

Description	Equation
Converting units	$\frac{\text{given unit}}{1}$ x conversion factor (arranged so unwanted units cancel) = wanted unit

ANSWERS TO THE "ON YOUR OWN" QUESTIONS

The blue text is the answer and the black text is further explanation.

1.1 Science is a system of knowledge and the process used to find that knowledge.

1.2 Technology is when science is used (applied) to help people. Often as technologies advance, new advancements in science can occur.

1.3 Physical science deals with the study of nonliving things. It is important because many future science courses depend on a good understanding of matter and energy, which are two of the main topics of physical science. It also helps us understand and appreciate God's order in creation.

1.4
- a. It is light blue in color. Qualitative
- b. It makes a loud popping sound. Qualitative
- c. It is 8.3 centimeters long. Quantitative
- d. It smells sweet. Qualitative
- e. The temperature increases by 6 ^{o}C. Quantitative

1.5 c. A useful hypothesis must be capable of being tested.

1.6 Variables are all the factors that might change in an experiment. When conducting controlled experiments, it is important to keep all variables the same except the one variable you are testing.

1.7 An independent variable is the one variable that the experimenter changes or manipulates. The dependent variable responds to the changes of the independent variable.

1.8

a. hypothesis	c.	A well-tested description of one phenomenon in the natural world that often includes mathematical terms
b. scientific theory	a.	A possible, testable explanation for an observation
c. scientific law	b.	A well-tested explanation of a phenomenon in the natural world

1.9 Science is about collecting evidence, not proving things. If evidence that is contrary to a current hypothesis, scientific theory, or scientific law exists, there cannot be 100% certainty or proof. In science, any hypothesis, theory, or law will be changed or discarded if evidence that disproves it is gathered.

1.10 a. second, s

b. kilogram, kg

c. meter, m

1.11 To do any conversion, we follow the steps given in the text:

Step 1. What is the relationship between the given unit and the desired unit? That is your conversion factor.

Step 2. What is the measurement you are given? Write it as a fraction by placing it over 1.

Step 3. Set up your conversion factor as a fraction so that the desired unit is in the numerator and the given unit is in the denominator. Then multiply the two fractions (the given measurement times the conversion factor) and cancel out the given units.

So in the On Your Own problem, we are asked to convert 8.3 meters to centimeters.

1. What is the relationship between the given unit and the desired unit? You can get this relationship by looking at Table 1.2.

$$1 \text{ cm} = 0.01 \text{ m}$$

(You can also use the relationship of 1 m = 100 cm. That relationship means the same thing and will work. In fact, it might be helpful to try this problem twice, using both forms of the conversion factor to see what I mean!)

2. What is the measurement you are given? Write it as a fraction by placing it over 1.

You are given the measurement of 8.3 meters, so you write

$$\frac{8.3 \text{ m}}{1}$$

3. Set up your conversion factor as a fraction so the desired unit is in the numerator and the given unit is in the denominator. Then multiply the two fractions.

$$\underbrace{\frac{8.3 \cancel{\text{m}}}{1}}_{\text{Given Unit}} \times \underbrace{\frac{1 \text{ cm}}{0.01 \cancel{\text{m}}}}_{\text{Conversion Factor}} = \underbrace{830 \text{ cm}}_{\text{Wanted Unit}}$$

Thus, 8.3 m = 830 cm.

Ask yourself if this answer makes sense. It does because centimeters are smaller than meters. It would take more centimeters than meters, and 830 is more than 8.3.

1.12 1. What is the relationship between the given unit and the desired unit? According to Table 1.2, the prefix *kilo*- means 1,000. So 1 kg is equal to 1,000 g.

$$1 \text{ kg} = 1{,}000 \text{ g}$$

2. What is the measurement you are given? Write it as a fraction by placing it over 1. You are given the measurement of 136 grams, so you write

$$\frac{136 \text{ g}}{1}$$

3. Set up your conversion factor as a fraction so the desired unit is in the numerator and the given unit is in the denominator. Then multiply the two fractions.

$$\underset{\text{Given Unit}}{\frac{136 \not{\text{g}}}{1}} \times \underset{\text{Conversion Factor}}{\frac{1 \text{ kg}}{1{,}000 \not{\text{g}}}} = \underset{\text{Wanted Unit}}{0.136 \text{ kg}}$$

Thus, 136 g = 0.136 kg.

Kilograms are larger than grams. So our number getting smaller makes sense.

1.13 0.121 L = ____ mL

1. First, find the conversion factor. According to Table 1.2, the prefix *milli*- means 0.001. So, we write the relationship, keeping the 1 with mL (since it is the prefix unit) and putting the definition of *milli*- with the base unit:

$$1 \text{ mL} = 0.001 \text{ L}$$

2. Now you can start the problem. Always start a problem by writing down what you know (or are given in the problem) and write it in fraction form (place over 1):

$$\frac{0.121 \text{ L}}{1}$$

3. Since we want to end up with mL, we must place L of our conversion factor on the bottom so it cancels out. The problem looks like:

$$\frac{0.121 \not{\text{L}}}{1} \times \frac{1 \text{ mL}}{0.001 \not{\text{L}}} = 121 \text{ mL}$$

Thus, 0.121 L = 121 mL.

Milliliters are smaller than liters. So our number getting larger makes sense.

0.121 L = ____ gal

1. The conversion factor you are given is:

$$1 \text{ gal} = 3.78 \text{ L}$$

2. Now you can start the problem. Always start a problem by writing down what you know (or are given in the problem) and write it in fraction form (place over 1):

$$\frac{0.121 \text{ L}}{1}$$

3. Since we want to end up with gal, we must place L of our conversion factor in the denominator so it cancels out. The problem looks like:

$$\frac{0.121\cancel{\text{L}}}{1} \times \frac{1 \text{ gal}}{3.78\ \cancel{\text{L}}} = 0.032 \text{ gal}$$

Given Unit	Conversion Factor	Wanted Unit

Thus, 0.121 L = 0.032 gal.

STUDY GUIDE FOR MODULE 1

This guide will help you better understand the key information addressed in the module. It should be used as a guide to help you study and is a great way to review more challenging information and to see how much you remember. To complete this Study Guide, first go through the questions and answer them as best you can. If you aren't sure of an answer, you can make an educated guess. Then, go back through the module to find the answers to any questions you didn't know. Once you have completed the Study Guide, check your answers using the Course Guide & Answer Key. Now you have a great source from which to study for the module test!

1. Match the term to the correct definition.

a. Observation	A factor that can change in an experiment
b. Hypothesis	A well-tested explanation of a phenomenon in the natural world
c. Controlled experiment	A possible, testable explanation for one or more observations or a suggested, testable answer to a question
d. Variable	The gathering of information using senses or with the aid of instruments
e. Scientific theory	An investigation in which the factors that influence the outcome are kept the same except for one—the factor being studied
f. Scientific law	A logical conclusion drawn from observations, previous knowledge, and available information
g. Inference	A well-tested description of one phenomenon in the natural world that often includes mathematical terms

2. Which *two* of the following are examples of an action using technology?
   a. Calling on a cell phone
   b. Observing rain fall
   c. Describing the best type of wood for a construction project
   d. Using a power drill to insert a screw

3. Which *two* of the following fall within the branch of physical science?
   a. Counting the number of legs of an insect
   b. Observing a beam of light from a flashlight
   c. Measuring the time it takes for a ball to drop from a specific height
   d. Recording the month of a year a plant produces flowers

4. You are testing how much weight a toy boat can hold while it remains afloat in a tub of water. You add weights to the boat, one at a time. Each weight weighs 5 grams. You discover that the boat floated a little lower with each weight, and that it can hold 6 weights (30 grams total) but sinks when it has 7 weights (35 grams total). Give an example of a quantitative and a qualitative observation in this experiment.

Answer questions 5 and 6 based on the following paragraph:

A student wants to know if a generic candle burns more quickly compared to a brand-name candle. He decides he will conduct an experiment where he burns two 12-inch, tapered candles: one that is a brand-name candle and the other that is a generic candle. Because he wants to determine which candle burns more quickly, he thinks to himself, *If I time how long it takes for each candle to burn until it measures 6 inches in height, the brand-name candle will burn slower.* He conducts the experiment and records the time it takes for each candle to burn down to 6 inches in height.

5. Which of the following is a good hypothesis for the student's experiment?
   a. Brand-name candles are better to buy.
   b. I think that generic candles burn faster than brand-name candles.
   c. If the candles are timed while they are allowed to burn until they measure 6 inches in height, then the brand-name candle will take a longer time to burn.
   d. If a candle burns down to 6 inches in height, then I think I will get my money's worth.

6. Of the two variables (candle brand and time to burn), which one is the independent variable?

7. Can science actually prove anything? Explain your answer.

8. Match the following prefixes to their numerical meaning:

a. *centi-*	0.001 (or 1/1,000)
b. *milli-*	1,000
c. *kilo-*	0.01 (or 1/100)

9. Match the following measurement types to the appropriate metric units:

a. mass	cubic meter
b. length	gram
c. solid volume	meter

10. You need to convert the measurement 6 meters to centimeters. The conversion relationship between meters and centimeters is 0.01 meter = 1 centimeter. To convert, you first set up your given measurement as a fraction of $\frac{6\ \text{m}}{1}$.

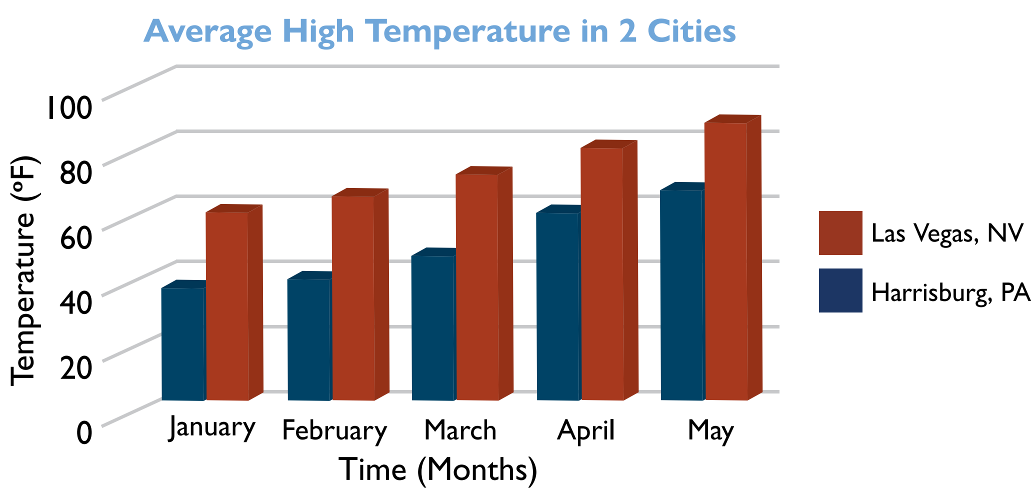
    Which is the correct way to set up the conversion factor?

    a. $\frac{0.01\ \text{m}}{1\ \text{cm}}$ b. $\frac{1\ \text{cm}}{0.01\ \text{m}}$

11. Convert 675 centimeters to meters.

12. If a person has a mass of 80 kg, what is his or her mass in grams?

13. Based on the bar graph below, which of the two locations have overall higher temperatures from January through May? What is the average high temperature in Harrisburg, PA, in May?



14. A 300 L water storage tank is being filled. Table 1.5 shows the volume of water in the tank at different times. Create a line graph showing how the volume of water changes as time passes. Time is the independent variable. Make sure you include a title, labeled axes, and units.

TABLE 1.5

Time (min)	Volume of Water (L)
0	0
5	50
10	100
15	150
20	200
25	250
30	300

ADVANCED CONCEPTS

15. When scientific data is collected that is not explained by the current model, what happens to that model?

16. The owners of a theme park wanted to know when people were entering their park throughout the day. They kept track of how many people entered the park in hourly increments, beginning when the park opened at 9 a.m. and ending with its closing at 8 p.m. On a graph, which variable (time or number of people) is the independent variable and which is the dependent variable? Which variable would go on the x-axis of a graph?

17. When considering relationships between variables, when you increase the independent variable and the dependent variable also increases, the result is a/an (direct/indirect) relationship.

18. Convert 67 centimeters to inches (1 in = 2.54 cm).