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 non-living natural world around you 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 how weather affects the Earth. These topics and many others like them are all a part of what we call physical science. We 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

We will try to illustrate 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 we will use as many illustrations to accompany the words as possible.

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 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

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 your parents will remember a time when there were no cell phones. And your grandparents 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

If you studied *Exploring Creation with General Science, 3rd Edition* last year, you got a taste for all the different branches of science. Natural science is generally divided into three categories, life science, physical science, and Earth and space science. Each of these 3 branches of science can be further subdivided into more specialized topics (Figure 1.4).

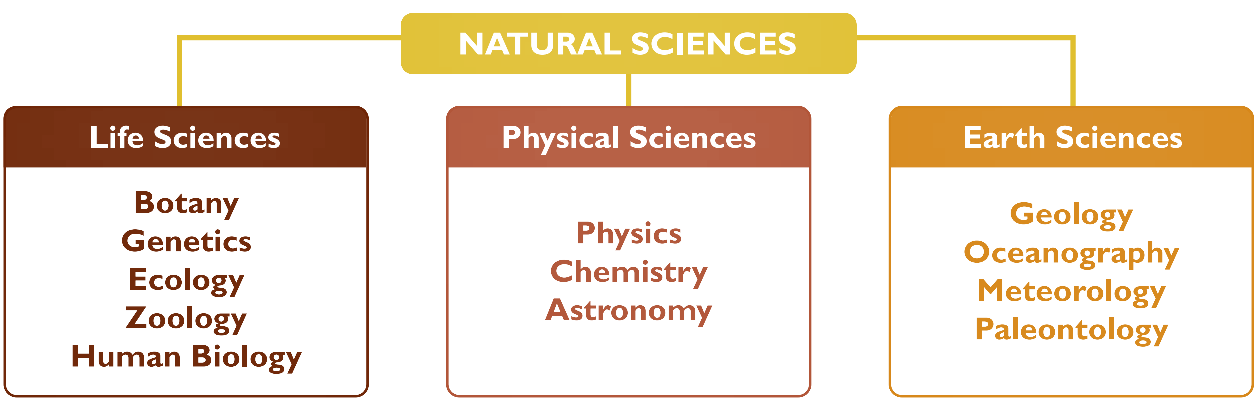


FIGURE 1.4
Generalized Branches of Science

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 often not always very clear.

So what is physical science? Physical science deals with the study of non-living things. In this course we will be discussing two of the three main areas: 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. We'll then use the information we learn in our study of physical science to briefly study the Earth (Earth science). 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, ask questions, and 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 that will change what we know about how Creation works in the future! Before reading about the scientific process, complete On Your Own questions 1.1–1.3.

ON YOUR OWN

1.1 What is science?

1.2 How are science and technology related?

1.3 What is physical science and why is it an important course?

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.

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.

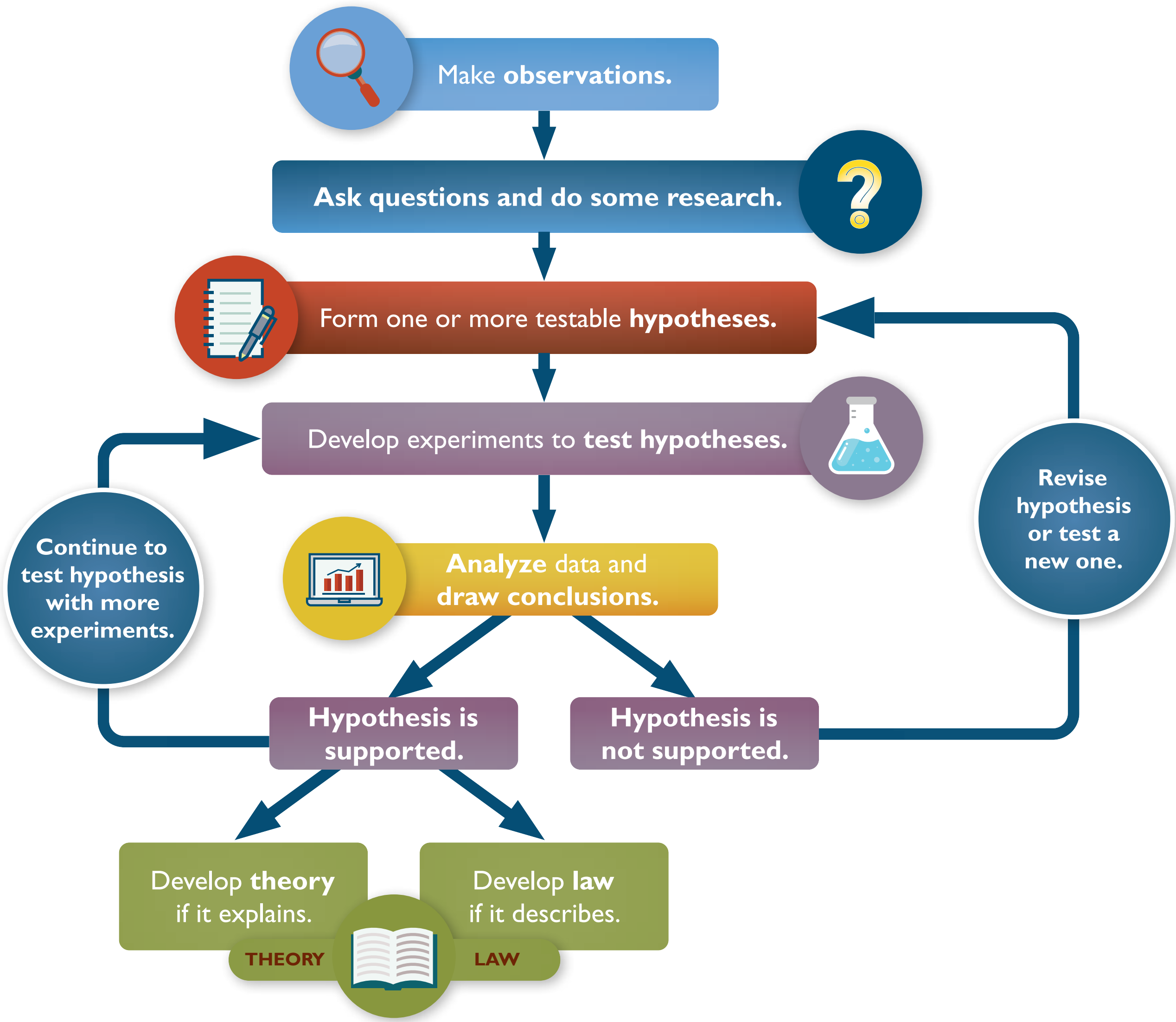


FIGURE 1.5
The Scientific Method

Observation—Gathering 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.

Qualitative observation—Observations made using one of the five senses: sight, smell, touch, taste, or hearing

Quantitative observations—Observations made with instruments such as rulers, balances, graduated cylinders, beakers, thermometers, etc.

When you observe the natural world with any of your senses, that is called making qualitative observations. You use your senses all the time to make 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 qualitative observations.

Sometimes qualitative 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. You use a telescope with a ruler to see the moon better and measure the changes over the weeks. 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.

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

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

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:

- 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 4 giraffes,
- there is only 1 lion,
- there is only 1 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. So you can see making observations is important for making advancements in science. 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 balance
- 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 balance 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). 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 your 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!

One thing I should mention before we move on, is that scientists are always conducting background research. Research helps them make sense of their observations and helps them develop questions to answer. The best way to know how to design an experiment or understand your results is to research a bit. Now complete On Your Own 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 degrees C. ________________

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

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

For example, scientists in the late 1600's 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 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 hypothesized that burning was the result of a combustible material combining with a component of air—oxygen, not phlogiston.

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 a metal 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 metals phosphorus, sulfur, and lead and recorded their weights. He then burned the metals and reweighed them. What he found was that the metals gained weight 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 metals 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.

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

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 5 or 6 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.

So how would you test the oxygen hypothesis? First what would you predict would happen to a burning candle when placed under a jar that cuts of the air supply? For the oxygen hypothesis to be supported, you should predict that if a jar is placed over a burning candle then the flame will go out when the oxygen inside the jar is used up. To test your prediction based on the oxygen hypothesis, you would conduct an experiment in which you place a jar over a burning candle (this seals out the air) and record observations. This experiment is shown in Figure 1.9.

FIGURE 1.9
Flame Extinguishes Under Glass
When a jar is placed over a burning candle, the flame is extinguished. What hypothesis explains this observation?

Experiments

Experiments, like the ones shown in Figures 1.8 and 1.9, are how scientists methodically test their hypotheses and the predictions based on their hypotheses. There are a few very important things to remember when developing experiments. First it is crucial to make sure you are testing only one thing at a time. This is called a **controlled experiment.**

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).

Variables—A factor that changes 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** or the **manipulated variable.** The variable that responds to the changing variable is called the **dependent variable** or the **responding variable.**

For example, suppose your hypothesis is that the number of swings per second of a pendulum is determined by the mass of the pendulum. Based on this hypothesis your

FIGURE 1.10
Physics Pendulum Experiment
As a controlled experiment, what variables (other than mass) should be kept the same?

prediction would be that the number of swings per second will change as you change the mass of the ball at the end of the pendulum string.

You can easily set up an experiment to test the prediction based on your hypothesis. Look at Figure 1.10. The pink, green, and tan pendulum balls are all of different masses. You can see that the pink and green are attached to pendulum strings. If both balls are pulled back and released from the same height, the number of swings in a given time interval of each pendulum can be counted. The number of swings and the mass of each pendulum is recorded.

Think about the other variables that could affect the number of swings in a certain time interval in this experiment. If you thought of the length of the string, the position of the pendulum ball before release, and the shape of the pendulum ball, then you are thinking like a scientist. For this to be a controlled experiment, all the factors except the mass of the ball must not change during the experiment. We are intentionally changing the mass of the ball, so mass is the independent variable (the manipulated variable). The number of swings per second would be our dependent variable (the one responding to the variable we changed).

You could change the experiment to test a different independent variable—length for example. If you tested the length of a pendulum to determine if that affects the number of swings per second, then you would need to keep the mass constant (as well as the other variables) and only change the length of the pendulum string. How would you test whether the initial position of the pendulum ball influenced the number of swings per second? Well you would need to keep both the mass and the length constant and only change the starting height from which you release the pendulum ball.

It is often difficult to be sure that all variables are really being controlled. For this reason, and to be sure that the results found are only because of the independent variable, good science requires that an experiment be repeatable. What that means is that someone else must be able to conduct the experiment the exact same way and get the exact same results. This is why it is so important to record exactly what materials you use in an experiment and detail the steps you follow in the procedure. Many scientists will include sketches in their notes to show how they set up an experiment like this one. Any time you repeat an experiment and your results contradict a hypothesis that has survived many previous experiments, look for variables that may not have been controlled properly.

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 object is to investigate something and simply make observations. Studying things under the microscope or dissections are good examples of this type of experiment. However, 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? How are they important in controlled experiments?

1.7 What is the difference between independent and dependent variables?

Analyzing Data

Any time you collect and record observations you're gathering **data.** To use data to make conclusions 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 scientist 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 did you forget 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 hypotheses. 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 to 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

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 (more often) a set of hypotheses that explain some aspect of the natural world. Theories have been well-tested by many experiments and have a *large* amount of supporting data.

Scientific theory—An in-depth explanation of a range of phenomena in the natural world that has been thoroughly tested and is supported by a significant amount of evidence

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 "unit" of matter were atoms. Once something has become a theory, it is well accepted by scientists because it agrees with many observations and experiments.

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.

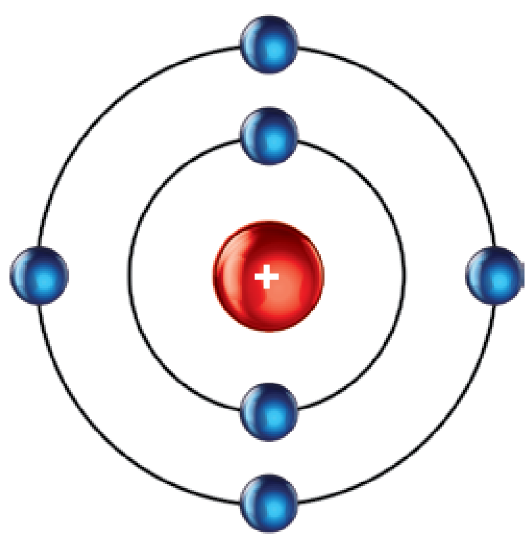


FIGURE 1.12
Carbon Atom
This 1913 model of a carbon atom is based on the atomic theory.

Scientific law—a description of a natural phenomenon or relationship that is supported by a significant amount of evidence and often include 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.

For example, 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, then it must be changed or discarded.

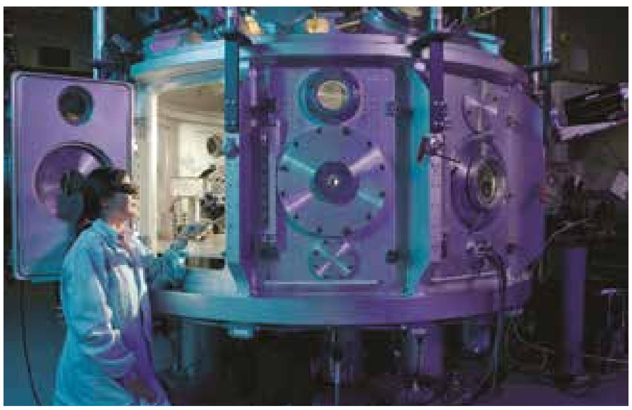


FIGURE 1.13
Chamber for Subatomic Particle Experimentation
Experiments on positrons collect evidence to support their existence but cannot prove their existence.

There is one last thing we 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 laws describe (but don't explain) a broad range of phenomena or observations. Theories are more developed explanations than hypotheses and they apply to a broad range of observations. Theories usually include explanations for many hypotheses and laws.

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 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 or Newton's law of gravity, there's always the chance that some evidence collected in the future (maybe when we have better instruments) 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.

When the Scientific Method Isn't Possible

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—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 and so have gathered evidence about what the dinosaur ate while it was alive. They haven't observed the dinosaur eating but used the evidence they gathered from the fossilized dropping to make an inference. An inference is an educated guess that explains evidence or observations.

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

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

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.

Models

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.**

> **Scientific model**—Useful simplification used to make it easier to understand things that might be too difficult 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 than the Bohr model shown in Figure 1.15. Bohr used Rutherford's model but added the new information that the nucleus was composed of subatomic units. A model's job is to help you mentally picture objects to large or small to see or 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, models of the atom changed quite a bit from 1803 until our current model designed in 1926. Study Figure 1.15 to see how the model of the atom changed as new information came to light.

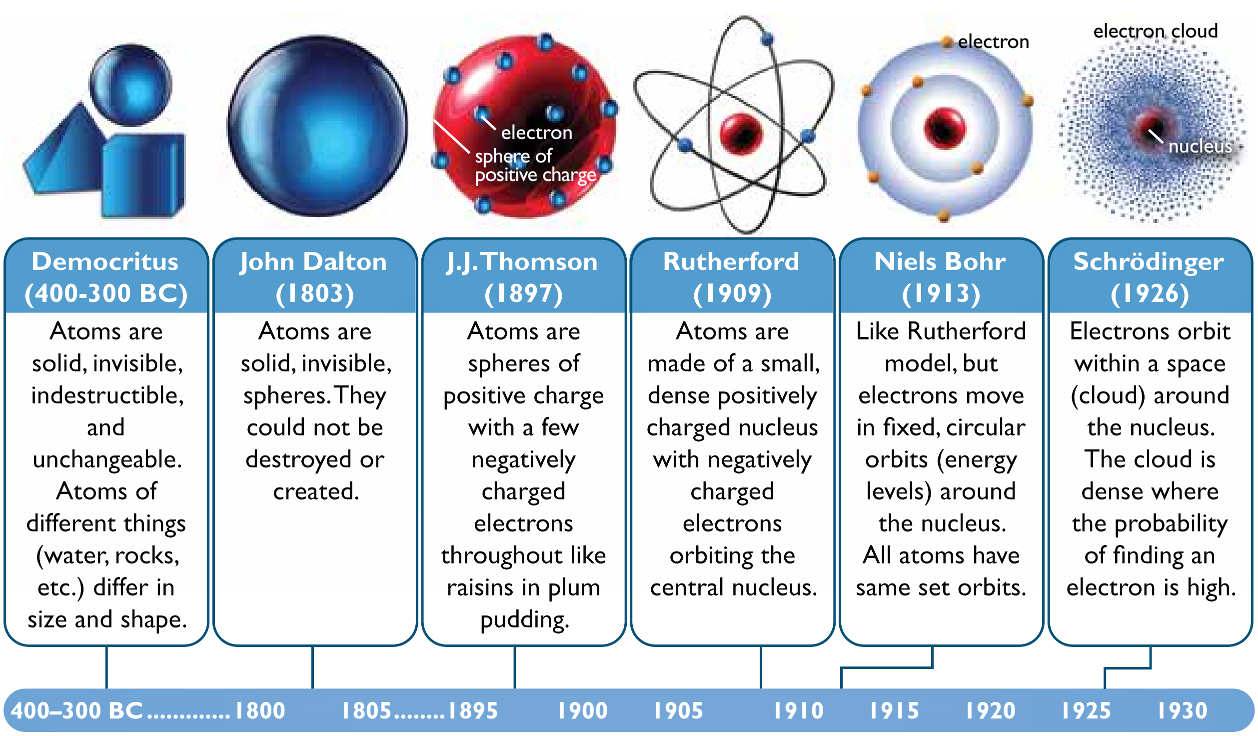


FIGURE 1.15
Atomic Models Timeline

Review what you learned in this section by completing On Your Own questions 1.8–1.10.

ON YOUR OWN

1.8 Match the term with the definition.

a. hypothesis	A well supported description of a natural phenomenon
b. scientific theory	A possible, testable explanation for an observation
c. scientific law	A well supported explanation of a range of phenomena

1.9 Why do we say science cannot prove anything?

1.10 What is meant by a model in 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*. 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.**

FIGURE 1.16
Making Measurements
Making measurements is one way to collect quantitative data.

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 centimeters (cm) by 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, 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 skilled and was able to make the emergency landing with no casualties.

FIGURE 1.17
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—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. SI units have only 3 base units (although we will learn about more); the *meter* for length, the *kilogram* for mass, and the *second* for time. Believe it or not, with just these 3 simple measurements we can measure just about everything in creation!

TABLE 1.1
Physical Quantities and Their Base SI and English Units

Physical Quality	Base 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. We will talk more about the slug in a later module.

Notice how the SI unit for mass is the *kilo*gram. You may have thought the base unit should be the gram. Well a kilogram is equal to 1000 grams, so you're not far off. The reason the base 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, such as *kilo*-, 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 boldface 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 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
Unit	**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

Remember that each of these prefixes, when added to a base unit, makes an alternative unit for measurement. 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 that 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, time, volume, 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. In the metric system, the unit for mass is the **gram** (abbreviated g). Suppose you find that a certain amount of salt balances two 5 g mass cylinders (Figure 1.18). 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 little fact, we can say that a gram is a rather small unit. Most of the things that we will measure will have masses of 10 to 10,000 grams. For example, when full, a 12 ounce can of soda pop has a mass of about 400 grams. We will talk more about mass in a later module.

FIGURE 1.18
Mass Balance
The mass of the salt is 10 grams. What is the unit used?

FIGURE 1.19
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.

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.

Length

The basic 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*. The English unit for distance is foot (of course there are other English units: inches, yards, miles, to name a few).

FIGURE 1.20
Running
How fast can you run 1 kilometer?

Large distances are measured in kilometers. The prefix *kilo-* means one-thousand. (Look back at Table 1.2 as often as you need to until you are very familiar with the prefixes.) One kilometer (1 km) is equal to 1000 meters (about 3,281 ft or about 0.62 miles). An average runner can complete a 5 km race in under 20 minutes.

Smaller lengths can be measured in centimeters (cm). The prefix *centi-* means one hundredth, so a centimeter is 1/100 of a meter. The fingernail on your pointer finger is about 1 cm wide. There are 2.54 cm in 1 inch. Even smaller lengths can be measured in millimeters (mm). The prefix *milli-* means one thousandth, so a millimeter is 1/1000 of a meter and there are 10 mm in 1 cm. A penny is about 1 mm in thickness.

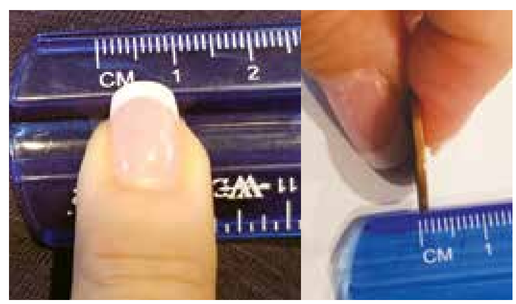


FIGURE 1.21
Centimeters and Millimeters
How many millimeters wide is your fingernail or the thickness of a penny?

Take a close look at your metric ruler. Notice that there are 30 cm in a metric ruler. Now identify the centimeter and millimeter marks. How many millimeters are there on your metric ruler? 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.

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 the 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. An average sized refrigerator has a volume of a little over 1 m^3. For smaller solids, cubic centimeters (cm^3) may be used.

The units of liters are often used to describe the volume of liquids (think 2 liter bottle of soda). 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 1.22). 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.

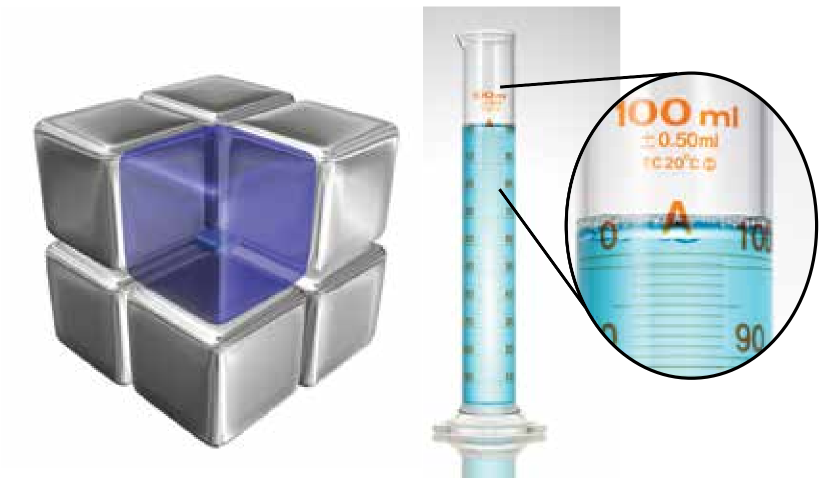


FIGURE 1.22
Cubic Meters and Milliliters
Solids are measured in cubic meters, cubic centimeters, or cubic millimeters. Liquids are often measured in liters or milliliters.

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.

20 drops of water has a volume of about 1 mL (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 North America 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 1/1000 of a second and is also an SI. 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 1.23) are the most commonly used instruments for measuring time because they are quite accurate, inexpensive, and easy to use. Now days all smart phones come with a stopwatch app, so making time measurements has never been easier.

FIGURE 1.23
Stopwatch
Stopwatches are the most common instrument of time measurement.

Temperature

In science, temperature is a measurement of how much heat 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 scientific research is degrees Celsius (°C). The Celsius scale (then 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 1.24).

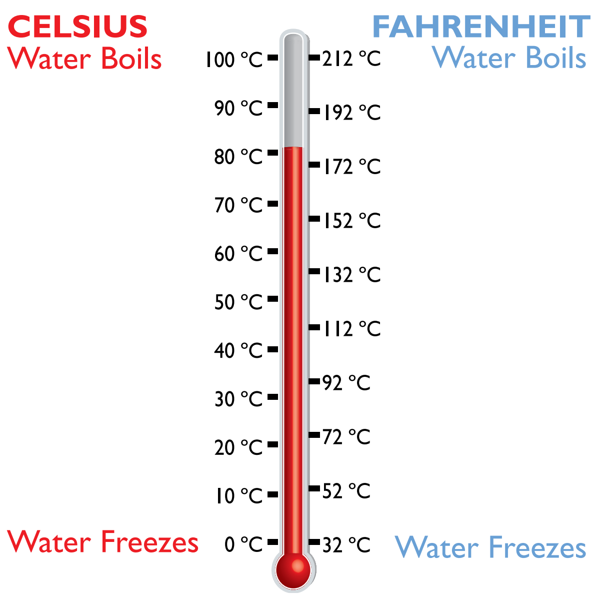


FIGURE 1.24
Thermometer Scale
The Celsius scale is used more commonly in science than the Fahrenheit scale. Can you see why?

The SI base unit for thermal energy (heat energy) is the Kelvin (K), named after Lord William Kelvin, who developed the scale in 1854. The Kelvin scale uses the same unit of division as the Celsius scale, and you will learn much more about it in future chemistry and physics courses. In this course we will be using the Celsius scale for heat measurements. You can use Table 1.3 to familiarize yourself with the common SI units, their symbols, and prefixes.

TABLE 1.3 Common SI Units and Prefixes		
Used for	**Name**	**Symbol/Abbreviation**
Prefix meaning: 1000 Prefix meaning: 1/100 Prefix meaning: 1/1000	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

*Not an SI unit, but may be used along with SI units

Converting Units

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.

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 centimeter is the same thing as 0.01 meter. 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 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. Pay attention to which way the conversion factor should be written as a fraction so that you can cancel the units properly:

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

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)/(1 cm) 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 through 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 1000. So 1 kilogram is equal to 1000 grams. (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. 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:

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

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):

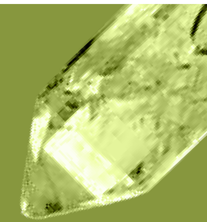
$$\frac{14{,}351\text{ \sout{g}}}{1} \times \frac{1\text{ kg}}{1{,}000\text{ \sout{g}}} = \mathbf{14.351\text{ kg}}$$

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 done 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 2 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 1.11–1.12.

ON YOUR OWN



1.11 Give the name and symbols for the following base SI units (Hint: look back at Table 1.1):
a. time b. mass c. length

1.12 If a glass contains 0.121 L of milk, what is the volume of milk in 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 depends on the rate of exchange. Farmers use a variety 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 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 1.25 as an example. These are two data tables of a pendulum experiment similar to the one shown in Figure 1.10.

TABLE 1.4 Testing Length of a Pendulum Released from the Same Spot					
Length (m)	Mass (g)	Trial 1 Time for 10 Full Swings (s)	Trial 2 Time for 10 Full Swings (s)	Trial 3 Time for 10 Full Swings (s)	Average Time for 10 Full Swings (s)
1.0	45	19.7	20.1	20.3	**20.0**
0.8	45	17.0	16.9	17.0	**17.0**
0.6	45	14.7	14.8	14.7	**14.7**
0.4	45	11.8	12.1	12.0	**12.0**
0.2	45	8.5	8.4	8.2	**8.4**

TABLE 1.5 Testing Mass of a Pendulum Released from the Same Spot					
Mass (g)	Length (m)	Trial 1 Time for 10 Full Swings (s)	Trial 2 Time for 10 Full Swings (s)	Trial 3 Time for 10 Full Swings (s)	Average Time for 10 Full Swings (s)
30	1.0	20.0	20.9	20.3	**20.4**
45	1.0	19.7	20.1	20.3	**20.0**
60	1.0	19.9	19.7	20.1	**19.9**
75	1.0	20.4	19.5	20.1	**20.0**
90	1.0	19.2	20.0	19.9	**19.7**

FIGURE 1.25
Data Tables of a Pendulum Experiment
Good data tables show all the trials conducted, have titles, and clearly show what data is collected including units.

Notice how each data table has a title that explains the data contained in the table. You can also clearly identify what data is contained in each row and column by their titles. Look over the titles and the data listed. Can you tell which variables where kept constant in each experiment? Well the table titles tell us that the pendulum balls were released from the same spot, so we know that the height of release was held constant. In Table 1.4, notice that the mass of the pendulum doesn't change, so that was held constant in that experiment while the length was the independent variable because it was intentionally manipulated. In the second experiment shown in Table 1.5, notice that the variable of length is held constant while the mass becomes the independent or manipulated variable. In both experiments the average time for 10 full swings is the responding or dependent variable.

Are you wondering why we took the average of 3 trials for each length or mass? That's a good question and an important point of science experiments. Whenever we do experiments it's always a good idea to do multiple trials. In other words, make the same measurement in your experiment many times (at least 3 times, but more is better). When we do multiple trials of the same experiment, we look to see if our data are consistent. If they are consistent, then we can be more confident that our data is reliable and resulted from our manipulated variable and not by some random event or measurement errors.

Now look at the data in Table 1.4—what do you notice? Hopefully you can see a pattern. As the length of the pendulum decreases, the average time it takes the pendulum to make 10 full swings also decreases. Check the data in Table 1.5. You should notice that as the pendulum mass increases, the average time for 10 full swings stays about the same. Seeing the data presented in an organized data table helps you to see patterns that you might miss otherwise.

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, line graphs, and circle 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 type 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 1.26.

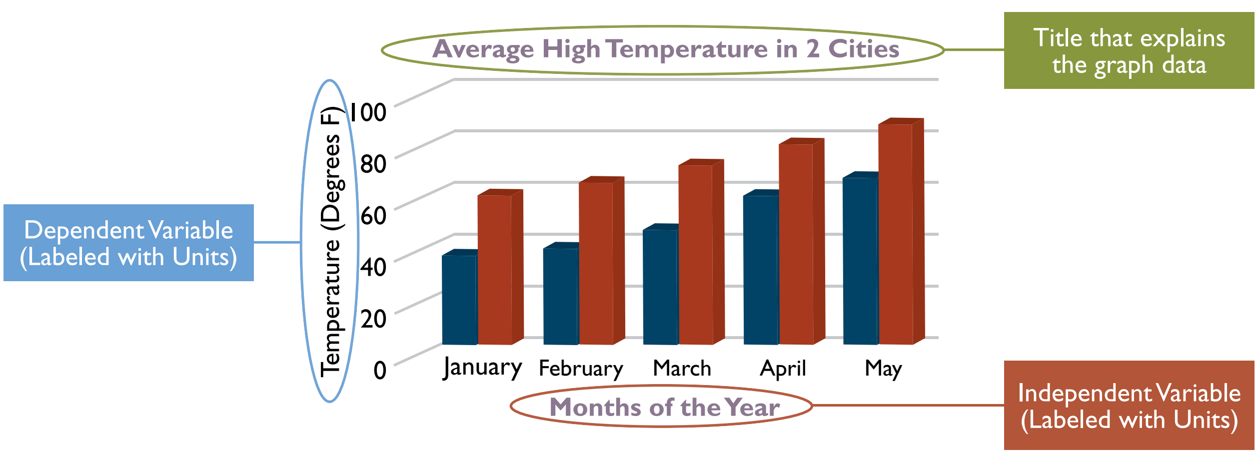


FIGURE 1.26
Bar Graph Comparing High Temperatures for Harrisburg, PA and Las Vegas, NV
Bar graphs compare two or more groups over time.

When you look at the bar graph in Figure 1.26, notice how easy it is to see which city has the highest 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 average temperature (the dependent variable) 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 1.27.

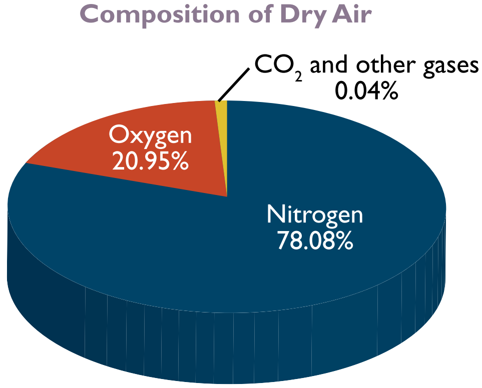


FIGURE 1.27
Pie Chart of the Composition of Dry Air
Circle graphs show how different parts of something relate to the whole.

In Figure 1.27, 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! It was this percentage of air that Joseph Priestley identified as combustible in his candle burning experiments.

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 (also called a scatter plot 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 1.28. So how do you make good line graphs? Let's make one using the data shown in Table 1.2.

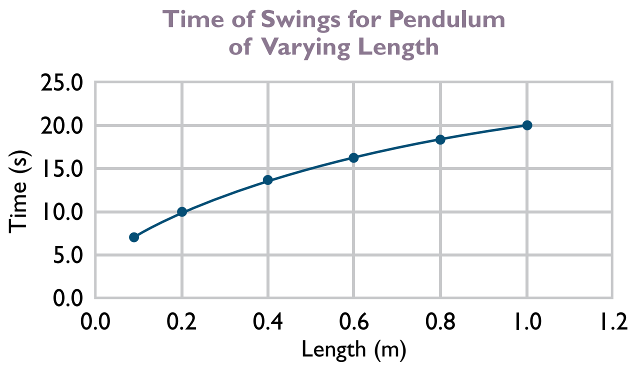


FIGURE 1.28
Line Graph of Swing Time for Pendulum of Varying Length
Line graphs can show even the smallest patterns or trends, so they are most common in science.

YOU DO SCIENCE

Graphing Activity

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 in Figure 1.25, then, we would make our x-axis be the length of the pendulum because that was the variable the investigator manipulated. The y-axis would then be the average time for 10 full swings 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. You should have a graph that looks like the one below.

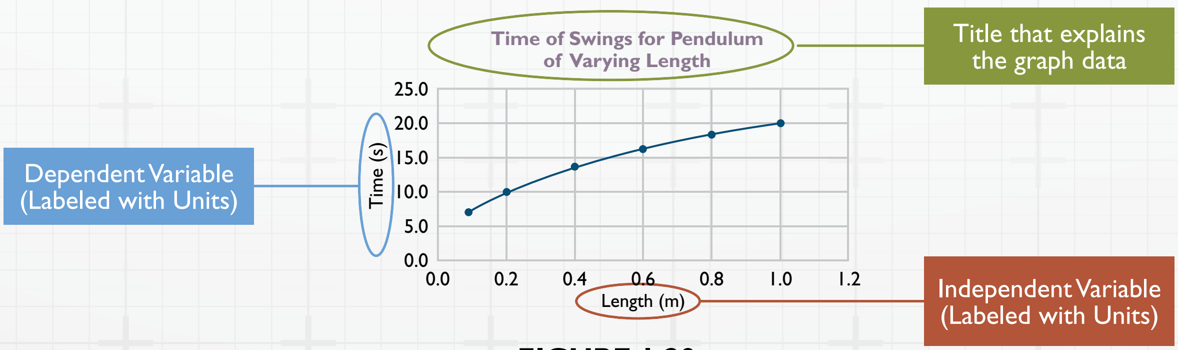


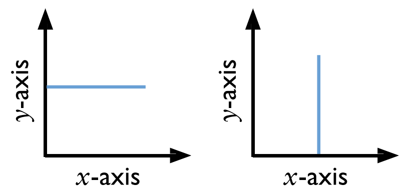
FIGURE 1.29
Important Parts of Line Graphs
Line graphs should have a title, labeled axes (with units), and scales that show all the data using as much of the space as possible.

Notice that the data makes an almost straight line that rises to the right. This tells us that as the length of the pendulum increases, the time to complete 10 full swings also increases. This is called a direct relationship and relationships between variables in experiments are what scientists look for. When you take a physics course, you will be able to do more with this data and see even more detailed relationships than the one shown here. For now, look at Figure 1.29 to remind yourself of what to include in line graphs when you make them for this course. Then try the pendulum experiment yourself by completing Experiment 1.2. You should include making data tables and graphs to analyze your data. You will find more help for this in your student notebook.

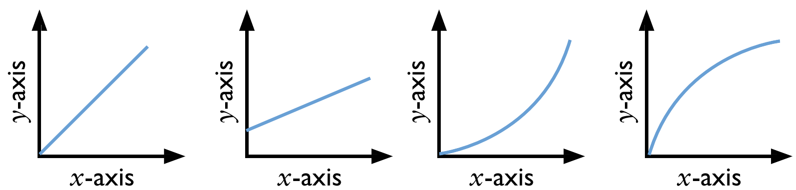
think about this

RELATIONSHIPS IN GRAPHING. In science we look for relationships between variables, specifically between the independent and dependent variables. Graphing is a good way to visualize those relationships. There are three main relationships we look for: no relationship, direct, and inverse (or indirect) relationships.

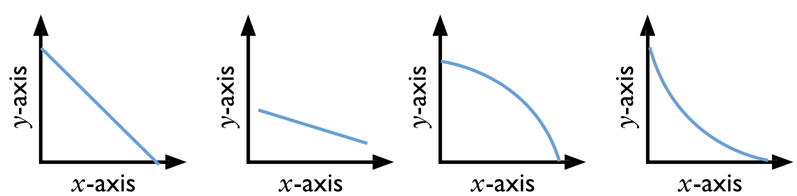
No relationship occurs when you change the independent variable, but the depending variable does not change in response. Or the dependent variable changes even when the independent variable does not. Both situations tell us that the dependent variable does not depend on the independent variable. Graphs that show no relationship between the independent and dependent variables will look something like these:



A direct relationship occurs when you increase the independent variable and the dependent variable also increases in response. Graphs that show a direct relationship between variables look like these:



An inverse (also called indirect) relationship occurs when you increase the independent variable and the dependent variable decreases. Graphs that show an inverse relationship between variables look like these:



EXPERIMENT 1.2

PRACTICE COLLECTING AND ANALYZING DATA WITH PENDULUMS

PURPOSE:

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

MATERIALS:

- String
- Masking tape
- Stopwatch or other 30 second timer (If you have access to a timer you can set the timer for 30 s and do this experiment without a helper. Otherwise you will need a helper track the stopwatch and tell you when 30 seconds has gone by while you count swings.)

- Pencil
- Paper clip
- 5 Washers
- Half a piece of cardstock paper (cut paper in half lengthwise) or cardboard 8.5″ × 5.5″
- Protractor
- Metric ruler

QUESTION:

How does changing the mass of a pendulum affect the number of swings in one minute? How does changing the length of a pendulum affect the number of swings in one minute?

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 what the independent and dependent variables are in the data section of your lab 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 1.30. Draw a solid line about 20 degrees from the dotted line as shown. Set aside the protractor.

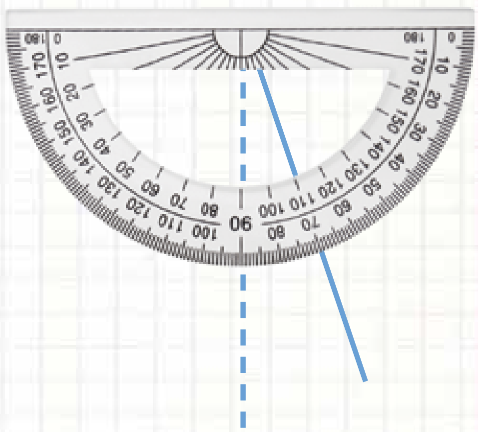


FIGURE 1.30

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.
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 paper clip 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 1.31 for an example).
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 1.31

8. Now you will test the effect of mass on the number of swings. Add one washer to the paper clip. Pull the paperclip back from the rest position (B in Figure 1.32) so that the string lines up with the solid line you drew on the card (position A in Figure 1.32).
9. When your helper says "go," release the paperclip and count how many times the washer-pendulum swings back and forth in 30 seconds. One swing is counted from the release position (A) to the other side (C) and back to the release position (A). Multiply the number you counted by 2. This gives you the number of swings per minute and is known as the **period**. Record the period in your data table.
10. Repeat steps 8 and 9 two more times and record your data.
11. Add another washer to the paperclip. Repeat steps 8 and 9 three times and record your data in the data table.
12. Add a third washer to the paperclip. Repeat steps 8 and 9 three times and record your data.
13. Add a fourth washer to the paperclip. Repeat steps 8 and 9 three times and record your data.
14. Add a fifth washer to the paperclip. Repeat steps 8 and 9 three times and record your data.

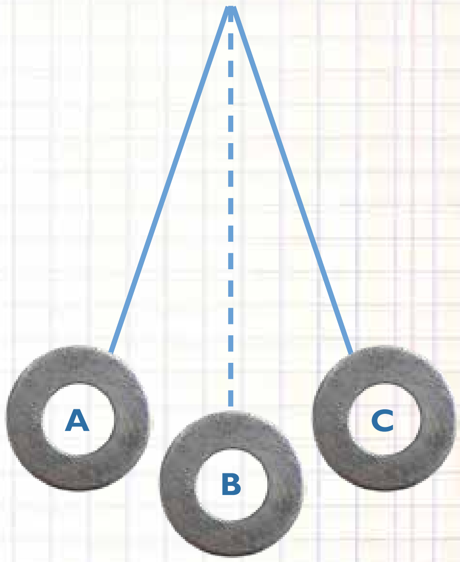


FIGURE 1.32

PROCEDURE—PART 2, LENGTH:

15. Write what the independent and dependent variables are in the data section of your lab notebook.
16. Remove 3 washers from the paperclip. You should have 2 washers on the paperclip for the rest of this experiment.
17. Measure the length of your pendulum. Measure from the top of the paper clip to where the pendulum is attached to the pencil. It should be about 30 cm. Record this measurement in the data table.
18. Repeat steps 8 and 9 three times and record your data.
19. Shorten your pendulum to about 25 cm by winding the string around the pencil until you reach the correct height. Record this measurement in the data table.
20. Repeat steps 8 and 9 three times and record your data.
21. 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.
22. Repeat steps 8 and 9 three times and record your data.
23. Shorten your pendulum to about 15 cm by winding the string around the pencil until you reach the correct height. Record this measurement in the data table.
24. Repeat steps 8 and 9 three times and record your data.
25. 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.
26. Repeat steps 8 and 9 three times and record your data.
27. Clean up and put everything away.

RESULTS:

1. Find the average number of swings (period) for each mass in Part 1 of the experiment by adding the period you found in each trial and dividing by 3.
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 period) 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 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? Does this 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 period (number of swings per minute) of a pendulum. Your graph should have resembled a straight horizontal line like the first graph in the Think About This box. The straight line tells us that there is no relationship between the independent (mass) and dependent (period) variables.

In Part 2, there was a different story. Your graph should look like a slightly curvy line like the one shown in the in Figure 1.28. In analyzing your data from part 2, the graph indicates that there is a direct relationship between the length of a pendulum (independent variable) and the period (dependent variable). In other words as the length of a pendulum increases, so does its period. When you take physics, you will get to determine the mathematical equation that describes this relationship but seeing the results on a graph is the first step.

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 affects the period (number of swings in one minute). What would you predict the period would be if there were 2.5 washers? To determine that you can simply look at the line you drew between 2 washers and 3 washers. Where that line falls tells you what the period is if your mass was 2.5 washers.

Now what if I asked you to predict what the period 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 period would be. This is called **extrapolation** and it is another way we can use graphs to analyze and predict data.

SUMMING UP

This module covered the basics, but hopefully you can see how using science can help us understand and appreciate the beautifully ordered world around us. Knowing how to take measurements, conduct experiments, and analyze data helps us to explore the extraordinary physical world God has given us. We'll be practicing these skills as we work through the rest of the modules.

ANSWERS TO THE "ON YOUR OWN" QUESTIONS

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

1.2 Technology is applied science. Often as technologies advance, new advancements in science can occur.

1.3 Physical science deals with the study on non-living 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.

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 degrees 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 (all other variables are kept constant). The dependent variable responds to the changes of the independent variable.

1.8 a. hypothesis — A well supported description of a natural phenomenon

b. scientific theory — A possible, testable explanation for an observation

c. scientific law — A well supported explanation of a range of phenomena

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 scientific model is a useful simplification that makes it easier to understand things that might be too difficult to directly observe.

1.11 a. second, s

b. kilogram, kg

c. meter, m

1.12 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:

$$\frac{0.121 \cancel{\text{L}}}{1} \times \frac{1 \text{ mL}}{0.001 \cancel{\text{L}}} = 121 \text{ mL}$$

Given Unit	Conversion Factor	Wanted Unit

Thus, **0.121 L = 121 mL.**

0.121 L = ____ gal

1. In this case the conversion factor is given to you.

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

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 mL, we must place L of our conversion factor on the bottom, 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

1. Match the word with its definition.

a. Quantitative observation	Tentative explanation for an observation
b. Qualitative observation	A well-supported, in-depth explanation of a broad range of phenomena
c. Hypothesis	Observations made using 5 senses
d. Variable	Observations made using numbers or measurements
e. Scientific Theory	Conclusions based on observations, previous knowledge, and available information
f. Inference	Any factor that changes in an experiment

2. Which type of data can you graph, quantitative or qualitative data? Why?

3. Give the numerical meaning for the following prefixes:

   a. *centi-*

   b. *milli-*

   c. *kilo-*

4. If you wanted to make the following measurements, what metric unit would you use?

   a. mass

   b. length

   c. solid volume

   d. liquid volume

5. What is a conversion factor (give an example of one)? Why is it helpful in solving problems in physical science?

6. To convert 3.8 cm to m, you should multiply by which conversion factor?

   a. $\frac{1\text{ km}}{1{,}000\text{ m}}$ b. $\frac{1{,}000\text{ m}}{1\text{ km}}$ c. $\frac{0.01\text{ m}}{1\text{ cm}}$ d. $\frac{1\text{ cm}}{0.01\text{ m}}$

7. In the SI symbol km, the "m" stands for ___?

   a. minute b. meter c. *milli-* d. metric

8. The SI unit for power is the watt (W). One kW must be equal to ___?

   1,000 W b. 1,000 m c. 0.001 W d. 0.001 m

9. How many centimeters are in 1.3 meters?

10. If a person has a mass of 75 kg, what is their mass in grams?

11. A meterstick is 100.0 centimeters long. How long is it in inches (in)? (1 in = 2.54 cm)

12. A small pool filled with water is being drained. Table 1.6 shows the volume of water remaining in the pool at different times.

    a. Make a graph showing how the volume of water changes as time passes. Include title, labeled axes, and units. (Hint: time is the independent variable.)

    b. What type of relationship between the independent and dependent variable does your graph show? (Hint: use the Think About This box to help you describe it.)

    c. Predict how long it will take for half the water to drain out. How long will it take to drain the pool?

TABLE 1.6

Time (min)	Volume of Water Remaining in Pool (L)
0	1,000
5	950
10	900
15	850
20	800
25	750
30	700