SECTION 1

What Is Physics?

SECTION OBJECTIVES

- **Identify activities and fields that involve the major areas within physics.**
- **Describe the processes of the scientific method.**
- **Describe the role of models and diagrams in physics.**

THE TOPICS OF PHYSICS

Many people consider physics to be a difficult science that is far removed from their lives. This may be because many of the world's most famous physicists study topics such as the structure of the universe or the incredibly small particles within an atom, often using complicated tools to observe and measure what they are studying.

But everything around you can be described by using the tools of physics. The goal of physics is to use a small number of basic concepts, equations, and assumptions to describe the physical world. These physics principles can then be used to make predictions about a broad range of phenomena. For example, the same physics principles that are used to describe the interaction between two planets can be used to describe the motion of a satellite orbiting Earth.

Many physicists study the laws of nature simply to satisfy their curiosity about the world we live in. Learning the laws of physics can be rewarding just for its own sake. Also, many of the inventions, appliances, tools, and buildings we live with today are made possible by the application of physics principles. Physics discoveries often turn out to have unexpected practical applications, and advances in technology can in turn lead to new physics discoveries. **Figure 1** indicates how the areas of physics apply to building and operating a car.

Figure 1
Without knowledge of many of the areas of physics, making cars would be impossible.

Physics is everywhere

We are surrounded by principles of physics in our everyday lives. In fact, most people know much more about physics than they realize. For example, when you buy a carton of ice cream at the store and put it in the freezer at home, you do so because from past experience you know enough about the laws of physics to know that the ice cream will melt if you leave it on the counter.

Any problem that deals with temperature, size, motion, position, shape, or color involves physics. Physicists categorize the topics they study in a number of different ways. **Table 1** shows some of the major areas of physics that will be described in this book.

People who design, build, and operate sailboats, such as the ones shown in **Figure 2,** need a working knowledge of the principles of physics. Designers figure out the best shape for the boat's hull so that it remains stable and floating yet quick-moving and maneuverable. This design requires knowledge of the physics of fluids. Determining the most efficient shapes for the sails and how to arrange them requires an understanding of the science of motion and its causes. Balancing loads in the construction of a sailboat requires knowledge of mechanics. Some of the same physics principles can also explain how the keel keeps the boat moving in one direction even when the wind is from a slightly different direction.

Figure 2
Sailboat designers rely on knowledge from many branches of physics.

Table 1 Areas Within Physics

Name	Subjects	Examples
Mechanics	motion and its causes, interactions between objects	falling objects, friction, weight, spinning objects
Thermodynamics	heat and temperature	melting and freezing processes, engines, refrigerators
Vibrations and wave phenomena	specific types of repetitive motions	springs, pendulums, sound
Optics	light	mirrors, lenses, color, astronomy
Electromagnetism	electricity, magnetism, and light	electrical charge, circuitry, permanent magnets, electromagnets
Relativity	particles moving at any speed, including very high speeds	particle collisions, particle accelerators, nuclear energy
Quantum mechanics	behavior of submicroscopic particles	the atom and its parts

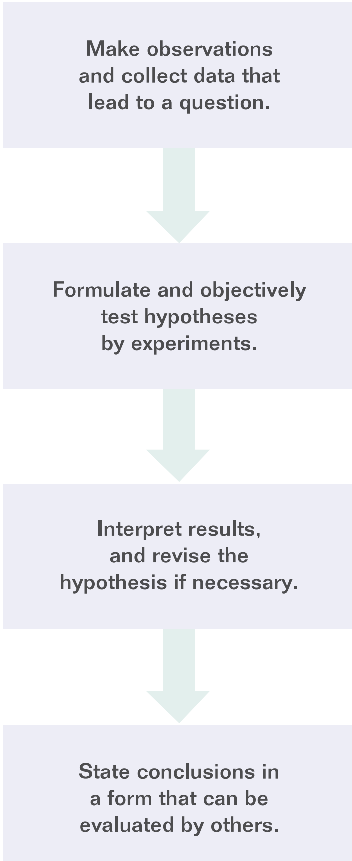

Figure 3
Physics, like all other sciences, is based on the scientific method.

THE SCIENTIFIC METHOD

When scientists look at the world, they see a network of rules and relationships that determine what will happen in a given situation. Everything you will study in this course was learned because someone looked out at the world and asked questions about how things work.

There is no single procedure that scientists follow in their work. However, there are certain steps common to all good scientific investigations. These steps, called the *scientific method,* are summarized in **Figure 3.** This simple chart is easy to understand; but, in reality, most scientific work is not so easily separated. Sometimes, exploratory experiments are performed as a part of the first step in order to generate observations that can lead to a focused question. A revised hypothesis may require more experiments.

Physics uses models that describe phenomena

Although the physical world is very complex, physicists often use **models** to explain the most fundamental features of various phenomena. Physics has developed powerful models that have been very successful in describing nature. Many of the models currently used in physics are mathematical models. Simple models are usually developed first. It is often easier to study and model parts of a system or phenomenon one at a time. These simple models can then be synthesized into more-comprehensive models.

When developing a model, physicists must decide which parts of the phenomenon are relevant and which parts can be disregarded. For example, let's say you wish to study the motion of the ball shown in **Figure 4.** Many observations

model

a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept

Figure 4
This basketball game involves great complexity.

can be made about the situation, including the ball's surroundings, size, spin, weight, color, time in the air, speed, and sound when hitting the ground. The first step toward simplifying this complicated situation is to decide what to study, that is, to define the **system.** Typically, a single object and the items that immediately affect it are the focus of attention. For instance, suppose you decide to study the ball's motion in the air (before it potentially reaches any of the other players), as shown in **Figure 5(a).** To study this situation, you can eliminate everything except information that affects the ball's motion.

system

a set of particles or interacting components considered to be a distinct physical entity for the purpose of study

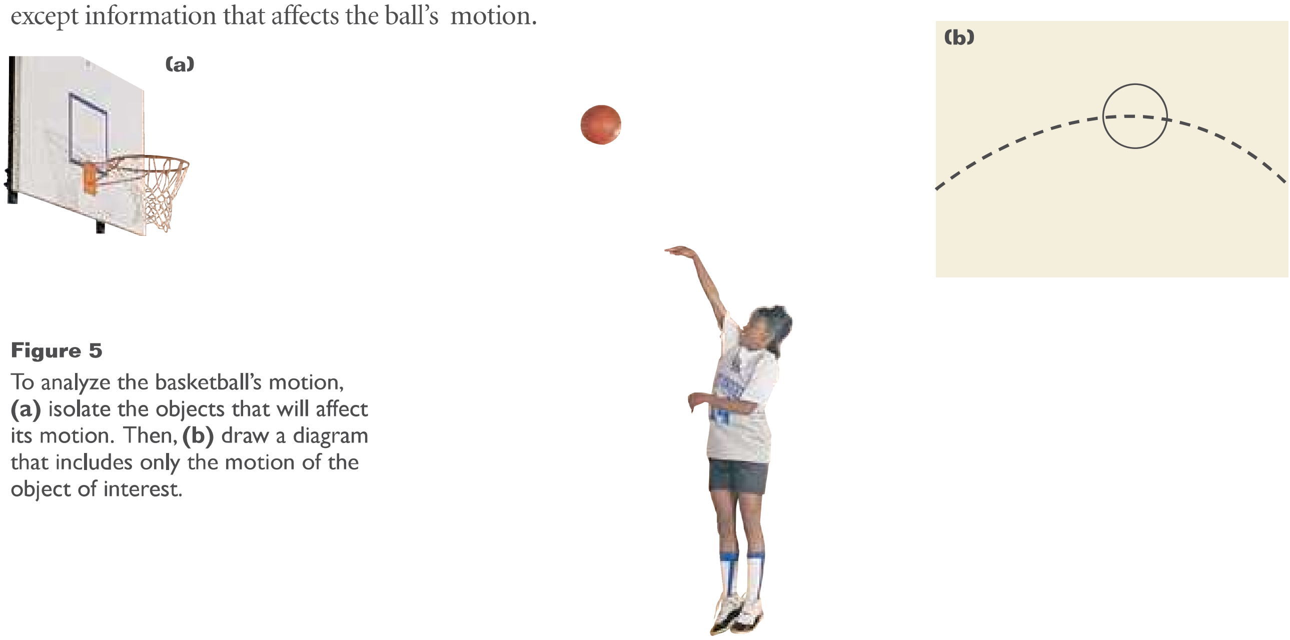

Figure 5
To analyze the basketball's motion, **(a)** isolate the objects that will affect its motion. Then, **(b)** draw a diagram that includes only the motion of the object of interest.

You can disregard characteristics of the ball that have little or no effect on its motion, such as the ball's color. In some studies of motion, even the ball's spin and size are disregarded, and the change in the ball's position will be the only quantity investigated, as shown in **Figure 5(b).**

In effect, the physicist studies the motion of a ball by first creating a simple model of the ball and its motion. Unlike the real ball, the model object is isolated; it has no color, spin, or size, and it makes no noise on impact. Frequently, a model can be summarized with a diagram, like the one in **Figure 5(b).** Another way to summarize these models is to build a computer simulation or small-scale replica of the situation.

Without models to simplify matters, situations such as building a car or sailing a boat would be too complex to study. For instance, analyzing the motion of a sailboat is made easier by imagining that the push on the boat from the wind is steady and consistent. The boat is also treated as an object with a certain mass being pushed through the water. In other words, the color of the boat, the model of the boat, and the details of its shape are left out of the analysis. Furthermore, the water the boat moves through is treated as if it were a perfectly smooth-flowing liquid with no internal friction. In spite of these simplifications, the analysis can still make useful predictions of how the sailboat will move.

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hypothesis

an explanation that is based on prior scientific research or observations and that can be tested

Models can help build hypotheses

A scientific **hypothesis** is a reasonable explanation for observations—one that can be tested with additional experiments. The process of simplifying and modeling a situation can help you determine the relevant variables and identify a hypothesis for testing.

Consider the example of Galileo's "thought experiment," in which he modeled the behavior of falling objects in order to develop a hypothesis about how objects fell. At the time Galileo published his work on falling objects, in 1638, scientists believed that a heavy object would fall faster than a lighter object.

Galileo imagined two objects of different masses tied together and released at the same time from the same height, such as the two bricks of different masses shown in **Figure 6.** Suppose that the heavier brick falls faster than the lighter brick when they are separate, as in **(a).** When tied together, the heavier brick will speed up the fall of the lighter brick somewhat, and the lighter brick will slow the fall of the heavier brick somewhat. Thus, the tied bricks should fall at a rate *in between* that of either brick alone, as in **(b).**

However, the two bricks together have a greater mass than the heavier brick alone. For this reason, the tied bricks should fall *faster* than the heavier brick, as in **(c).** Galileo used this logical contradiction to refute the idea that different masses fall at different rates. He hypothesized instead that all objects fall at the same rate in the absence of air resistance, as in **(d).**

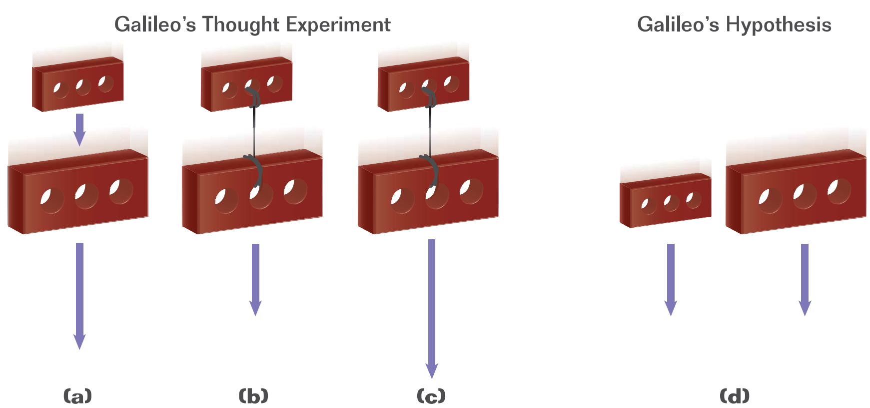

Figure 6
If heavier objects fell faster than slower ones, would two bricks of different masses tied together fall slower **(b)** or faster **(c)** than the heavy brick alone **(a)**? Because of this contradiction, Galileo hypothesized instead that all objects fall at the same rate, as in **(d).**

Models help guide experimental design

Galileo performed many experiments to test his hypothesis. To be certain he was observing differences due to weight, he kept all other variables the same: the objects he tested had the same size (but different weights) and were measured falling from the same point.

The measuring devices at that time were not precise enough to measure the motion of objects falling in air. So, Galileo used the motion of a ball rolling down a ramp as a model of the motion of a falling ball. The steeper the ramp, the closer the model came to representing a falling object. These ramp experiments provided data that matched the predictions Galileo made in his hypothesis.

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Like Galileo's hypothesis, any hypothesis must be tested in a **controlled experiment.** In an experiment to test a hypothesis, you must change one variable at a time to determine what influences the phenomenon you are observing. Galileo performed a series of experiments using balls of different weights on one ramp before determining the time they took to roll down a steeper ramp.

controlled experiment

an experiment that tests only one factor at a time by using a comparison of a control group with an experimental group

The best physics models can make predictions in new situations

Until the invention of the air pump, it was not possible to perform direct tests of Galileo's model by observing objects falling in the absence of air resistance. But even though it was not completely testable, Galileo's model was used to make reasonably accurate predictions about the motion of many objects, from raindrops to boulders (even though they all experience air resistance).

Even if some experiments produce results that support a certain model, at any time another experiment may produce results that do not support the model. When this occurs, scientists repeat the experiment until they are sure that the results are not in error. If the unexpected results are confirmed, the model must be abandoned or revised. That is why the last step of the scientific method is so important. A conclusion is valid only if it can be verified by other people.

Did you know?

In addition to conducting experiments to test their hypotheses, scientists also research the work of other scientists. The steps of this type of research include

- identifying reliable sources
- searching the sources to find references
- checking for opposing views
- documenting sources
- presenting findings to other scientists for review and discussion

SECTION REVIEW

1. Name the major areas of physics.

2. Identify the area of physics that is most relevant to each of the following situations. Explain your reasoning.

a. a high school football game
b. food preparation for the prom
c. playing in the school band
d. lightning in a thunderstorm
e. wearing a pair of sunglasses outside in the sun

3. What are the activities involved in the scientific method?

4. Give two examples of ways that physicists model the physical world.

5. **Critical Thinking** Identify the area of physics involved in each of the following tests of a lightweight metal alloy proposed for use in sailboat hulls:

a. testing the effects of a collision on the alloy
b. testing the effects of extreme heat and cold on the alloy
c. testing whether the alloy can affect a magnetic compass needle