Blast Off!

The *Mars Pathfinder* hurtled into space to demonstrate a lower-cost way to deliver scientific equipment to the distant surface of Mars and send back data to Earth. What role does physics play in missions to Mars?

Look at the text on page 10 for the answer.

CONTENTS

CHAPTER

1 What is physics?

What do you think of when you see the word *physics*? Do you recall friends saying how hard it is? Do you think of chalkboards filled with equations such as $E = mc^2$? Does the word conjure up images of an atomic bomb's mushroom cloud? Perhaps you think of scientists in white lab coats. Maybe Albert Einstein, Marie Curie, or Stephen Hawking comes to mind.

Physics does have a reputation for being difficult. Physics does use mathematics as a powerful language. Also, much of physics requires that you be as accurate as possible. However, physics also involves ideas, theories, and principles expressed in ordinary words. Once you are familiar with physics, you will find that you can explain the actions of a rocket, a roller coaster, and a baseball crashing through a window by using the same handful of physics principles.

Yes, many physicists worked together to develop the atomic bomb. Physicists also played a role in developing the computer chips used in PCs and video game systems; the graphite-epoxy materials used in guitars and golf clubs; the CDs and DVDs on which your favorite music, computer games, and movies are recorded; and the lasers you use to play them. Physics plays a primary role in the development of new technologies for leisure, work, medicine, sports, and nearly any other field you can name.

Albert Einstein, Marie Curie, and Stephen Hawking are examples of remarkable physicists. But there are remarkable physicists everywhere. Many are women and men who work at universities, two-year colleges, and high schools; industrial and governmental labs; hospitals; and Wall Street. A physicist could easily be your next-door neighbor—or you could become one yourself!

WHAT YOU'LL LEARN

- You will learn to ask the questions "How do we know?" "Why do we believe it?" and "What's the evidence?" in order to examine and solve problems.
- You will have the satisfaction of understanding and even predicting the outcomes of physical occurrences all around you.

WHY IT'S IMPORTANT

- An understanding of physics will help you make informed decisions as a citizen in an increasingly complex world.

PHYSICS Online

To find out more about physics and missions to Mars, visit the Glencoe Science Web site at
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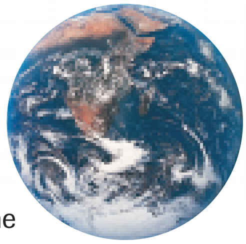
Physics: The Search for Understanding



Physics is a branch of knowledge that involves the study of the physical world. Physicists investigate objects as small as subatomic particles and as large as the universe. They study the natures of matter and energy and how they are related. Physicists and other scientists look at the world around them with inquisitive eyes. Their observations lead them to ask questions about what they see. What makes the sun shine? How were the planets formed? Of what is matter made? Physicists make observations, do experiments, and create models or theories to try to answer these questions. Finding explanations for the original questions often leads to more questions and thus more observations, experiments, and theories. The goal of all scientists is to obtain a compelling explanation that describes many different phenomena, makes predictions, and leads to a better understanding of the universe.

OBJECTIVES

- **Define** *physics.*
- **Relate** theory, experiment, and applications to the role they play in physics research.
- **Demonstrate** that, while there is no single scientific method, there are common methods used by all scientists.

Sometimes the results of the work of physicists are of interest only to other physicists. Other times, their work leads to the development of devices such as lasers, communication systems, computers, and new materials that change everyone's life. As an example of how physics works, let's look at the role of the planet Mars, shown in **Figure 1–1,** in the development of the scientific method and the exploration of Mars.

The Wanderers

Have you ever seen the planet Mars? Mars is among the brightest planets in the night sky. Ancient people were keen observers of celestial objects in order to define the time of year and find the direction of travel on Earth. These observers noticed that five bright "wanderers," or planets, generally followed an eastern course through the constellations, yet, unlike the stars, they also moved westward for periods of time. The deep-red color of one of those planets caused the Babylonians to associate it with disaster and the Romans to name it after their god of war, Mars. Early records of the motion of Mars helped develop the early concepts of the solar system centuries before the invention of the telescope.

FIGURE 1–1 NASA scientists used 102 images taken by the *Viking Orbiter* to form this mosaic of Mars.

Are the stars and planets like Earth? About 2500 years ago, Greek philosophers tried to determine what the world was made of by making observations of everyday occurrences. Some of these scholars believed that all matter on or near Earth was made up of four elements: earth, water, air, and fire. Each element was thought to have a natural place based on its heaviness. The highest place belonged to fire, the next to air, then water, and, at the bottom, earth. Motion was thought to occur because an element traveled in a straight line toward its own natural place.

a b

FIGURE 1–2 The telescope **(a)** and the lens **(b)** with which Galileo first observed the moons of Jupiter are on display at the Museo di Storia della Scienza in Florence, Italy.

Ancient people observed that the sun, moon, stars, and planets such as Mars didn't behave this way. As far as anyone could see, these celestial bodies were perfect spheres and moved in circles about Earth forever. They certainly didn't obey the same laws of motion as objects on Earth, and so it seemed that they couldn't be made of the four elements; rather, they were formed of a fifth element, quintessence.

The writings of these early Greeks, lost to Europe for hundreds of years, were studied and translated by Arabic scholars. In the twelfth century, the writings made their way to Europe and were accepted as truth that did not have to be questioned or tested. One of the first European scientists who claimed publicly that the ancient books were no substitute for observations and experiments was Galileo Galilei (1564-1642).

Galileo and Scientific Methods

In 1609, Galileo built a telescope shown in **Figure 1–2,** powerful enough to explore the skies. He found that the moon wasn't a perfect sphere, but had mountains, whose heights he could estimate from the shadows they cast. He discovered four moons circling the planet Jupiter, that the Milky Way was made up of many more stars than anyone had thought, and that Venus had phases. As a result, Galileo argued that Earth and the other planets actually circled the sun.

As Galileo studied astronomy and the motion of objects on Earth, he developed a systematic method of observing, experimenting, and analyzing that is now referred to as a **scientific method.** Rather than writing his results in Latin, the language of scholars, he wrote them in his native Italian so that any educated person could read and understand them. For these reasons, Galileo is considered to be the father of modern experimental science.

Pocket Lab

Falling

The Greek philosophers argued that heavy objects fall faster than light objects. Galileo stated that light and heavy objects fall at the same rate. What do you think? Drop four pennies taped together and a single penny from the same height at the same time. Tear a sheet of paper in half. Crumple one piece into a ball. Repeat your experiment with the paper ball and the half sheet of paper. What did you observe each time?

Analyze and Conclude Who was correct, the Greeks or Galileo?

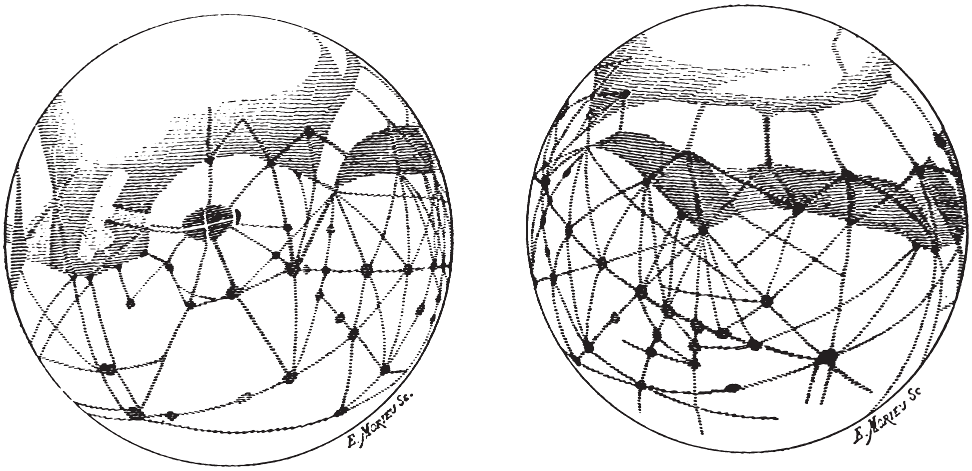


FIGURE 1–3 During the 17th, 18th, and 19th centuries, it was widely believed that Mars was inhabited. Dark linear features were interpreted as canals.

Galileo's methods are not the only scientific method. All scientists must study problems in an organized way. They combine systematic experimentation with careful measurements and analyses of results. From these analyses, conclusions are drawn. These conclusions are then subjected to additional tests to find out whether they are valid. Since Galileo's time, scientists all over the world have used these techniques and methods to gain a better understanding of the universe. Knowledge, skill, luck, imagination, trial and error, educated guesses, and great patience all play a part.

Mars in Recent Times

As telescopes improved, Mars became much more interesting to astronomers and to people in general because they thought it looked much like Earth. Astronomers found what appeared to be ice caps that advance and recede, color changes they attributed to vegetation cycles similar to Earth's seasons, and dark areas believed to be seas. To some early observers, strange markings on the surface of Mars, shown in **Figure 1–3,** were mistakenly interpreted as being channels or canals possibly made by intelligent beings. This interpretation became so prevalent that a 1938 radio drama, depicting a Martian invasion of Earth, caused widespread panic in the United States.

When rockets capable of reaching our neighboring planet were developed in the 1960s, both the United States and the former Soviet Union launched a series of probes designed to orbit Mars, take photographs, and land on the planet to return data. A timetable of these probes is shown in **Table 1–1.**

The first of the recent probes, *Mars Pathfinder,* surrounded by protective airbags, bounded down on Mars on July 4, 1997. The entire mission cost less than the production of one Hollywood movie. A 10-kg robot rover, named *Sojourner,* was released to explore nearby rocks. Millions of people used the Internet to retrieve photos directly from the NASA websites into their home computers. The new era of Martian exploration had begun.

TABLE 1–1

	Missions to Mars	Accomplishments
1964	U.S. *Mariner 4*	First photos from 16 898 to 9846 km above surface.
	USSR *Zond 2*	Failed to send back data.
1969	U.S. *Mariner 6*	Examination of Martian equatorial region from an altitude of 3430 km.
	U.S. *Mariner 7*	Examination of the Martian southern hemisphere and south polar ice cap from an altitude of 3430 km.
1971	USSR *Mars 2*	Martian orbit.
	USSR *Mars 3*	Lander on Martian surface.
	U.S. *Mariner 9*	Photographs of entire Martian globe from orbit.
1973	USSR *Mars 5*	Martian orbit.
1975	U.S. *Viking 1*	Panoramic views and close-up photos from the Martian surface.
	U.S. *Viking 2*	Automated experiments on the Martian surface.
1988	USSR *Phobos 2*	Martian orbit.
1993	U.S. *Mars Observer*	Lost during mission.
1996	U.S. *Global Surveyor*	Record of surface features, atmospheric data, and magnetic properties from Martian orbit.
	U.S. *Mars Pathfinder*	Surface landing and release of a mobile vehicle to explore *Ares Vallis.*
1998	U.S. *Mars Surveyor Orbiter*	Lost during mission.
1999	U.S. *Mars Surveyor Lander*	Lost during mission.
		Goals
2001	U.S. *Mars Odyssey*	To map elemental composition, mineralogy, and morphology of the Martian surface, and to measure the radiation environment.
2002 and beyond	U.S. orbiters and landers	To replace communications relay satellites with new orbiters; to continue analyses of Martian atmosphere and surface with orbiters and landers.
	U.S. sample-and-return spacecraft	To return Martian rock and soil samples to Earth.

Why study Mars? Mars had seemed in many ways to be similar to Earth. But the probes have confirmed that its climate is very different. Mars is an ideal laboratory for scientists interested in geology and atmospheric physics.

From the study of Mars, scientists may learn more about the types of conditions that could lead to dramatic climatic or atmospheric changes on our own planet, and about the formation and evolution of the entire solar system. These studies may help us understand why Mars grew cold with almost no atmosphere early in its history while Venus and Earth did not.

The search for water is central to future explorations. Mars's northern polar cap contains water in the form of ice, a vital ingredient for future human exploration. Furthermore, there is evidence that gigantic floods helped shape the surface of Mars billions of years ago. What happened to that water? Is it combined with rocks, is it frozen underground, or has it escaped into space?

F.Y.I.

The 1997 Mars rover *Sojourner* was named after Sojourner Truth, a nineteenth-century African American woman who traveled the United States preaching against slavery. Sojourner means "traveler."

Physics & Society

Research Dollars

Some scientific discoveries are made by chance, but most are the result of years of carefully planned research. Most scientists are paid to conduct research—exploring ideas, creating hypotheses, performing experiments, and publishing findings. Professors at universities and their students spend a significant amount of time in the laboratory. Other scientists work for government-funded laboratories or for private companies and spend virtually all of their time doing research.

Who will pay?

Where does the money to pay for this research come from? In the case of university professors, much of the support comes from grants supplied by the government, private foundations, or private companies. Government-funded laboratories receive money from the federal budget. Private companies fund their own projects, often using profits earned by inventions developed in previous, successful research. Sometimes, private companies are hired by government agencies to participate in large projects.

What will be funded?

Decisions about funding with limited research dollars are often based on how well a scientist can express to others the importance of the research project. Written and oral communication skills are vital to every scientist. The scientist must have a good understanding of how the proposed project will carry forward previous research.

Every scientist must spend time studying and evaluating the work of other scientists. He or she must also be able to clearly communicate why the work is needed and who could benefit from its results. Becoming a scientist requires not only an education in a chosen field of study, but also the ability to think critically and communicate effectively.

Who will benefit?

Not everyone agrees about the kinds of research that should be funded, or even how much money should be spent on scientific research in general. This is especially true when research funds come from the government. Taxpayers often disagree with government spending decisions. Some people believe that their money would be better spent on solving more immediate human problems, such as feeding the hungry, sheltering the homeless, and curing disease. Others argue that the benefits humans derive from exploratory research are well worth their cost.

Investigating the Issue

1. **Communicating Ideas** Read several articles from publications such as *Science News* or *Scientific American* about advances in scientific research. Write a brief essay about the research areas that you feel are most interesting or important.
2. **Debating the Issue** Should the U.S. government support research in outer space, or should the money go toward research in areas with more humanitarian applications?

PHYSICS Online

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If Mars were a warmer, wetter world early in its history, what happened to cause such climatic devastation and render it lifeless, barren, and frigid? Have there ever been life forms on Mars? Living systems on Mars today would have to be able to survive without oxygen, store water for long periods of time, and live underground or have protection from solar radiation and large temperature fluctuations. In 1976, the *Viking* landers found no evidence of life. But in 1996, scientists claimed to have evidence of primitive life forms in meteorites found in Antarctica that they strongly believed had Martian origins.

Who will study Mars? The Mars exploration team is made up of many women and men. Some represent the sciences, including physics, chemistry, geology, and astronomy. Others are electrical, mechanical, aeronautic, or computer engineers. Still others are technicians, graphic designers, managers, and administrators. All share some common characteristics. They are curious, creative, and interested in mysteries and in solving problems. They love their work, but they also have many outside interests such as music, drama, sports, and mountain climbing. When they were younger they took science and mathematics courses, but they were also involved in many activities in and out of school.

The members of the Mars exploration team had to join their individual experiences and learn to work together, as shown in **Figure 1–4.** They report that it can be harder to work with a team than on their own, but that the team can do more, and so the rewards can be greater. They also have found that it's more fun when they can share ideas and experiences with others.

HELP WANTED

NASA RESEARCHERS

Seeking researchers for NASA's Jet Propulsion Laboratory (JPL) and other space centers in the United States. Positions are available in engineering, aeronautics, robotics, computer systems, fluid and flight mechanics, chemistry, materials and structures, and telecommunications. Also hiring researchers in lunar and planetary studies, meteorology, radiation, and related areas. Some projects require specialists in physiology, psychology, botany, and biology.

Contact:
JPL
4800 Oak Grove Drive
Staffing Office
Mail Stop 249-104
Pasadena, CA 91109-8099

F.Y.I.

Mae Jemison relied on experience as engineer, physician, educator, and first African American woman astronaut to found The Jemison Institute for Advancing Technology in Developing Countries.

FIGURE 1–4 Jet Propulsion Laboratory scientists prepare the *Mars Pathfinder* for placement atop a Delta II launch vehicle.

There is room on the team for you. Thanks to the Internet, you can send E-mail to the Mars exploration team and ask questions. You also can follow the probes' progress: you can see the photos before they appear in the newspapers and obtain more complete coverage of the results than that which is provided in the ten seconds that fits into local television news. You can choose your course of study so that you can become part of future space exploration.

Is physics important? Most physicists are not involved directly in the Mars explorations. Most of the people directly involved in the Mars missions are not physicists, nor did they major in physics in college.

But the Mars missions are based on physics, starting with the design of the rocket engines, the gyroscopic directional controls, and the precision clocks that are needed to indicate where the spacecraft is and how fast it is moving. The solar panels and nuclear electrical sources that keep the probes in contact with Earth during flight are based on physics. Physics is also involved in the design of the cameras, computers, radio transmitters, and receivers that send the photos back to us.

Science and technology constantly interact. Sometimes, scientific results produce new equipment for use outside the scientific community. The efficient design of the mechanical arms that allow the rovers to sample the surface of Mars may be used to make artificial limbs for people with disabilities. Similarly, new equipment produces new scientific results. Advances in computer technology allow faster, lighter computers to be placed on board the spacecraft. As shown in **Figure 1–5,** the applications of such discoveries affect all our lives.

Blast Off!

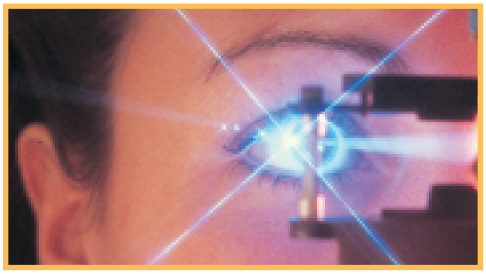
Answers question from page 2.

All participants in the Mars missions use the problem-solving skills that they learned in physics and other science courses every day. They can't find answers in the back of a book or by asking a friend! They have learned the skills that enable them to go forward from a predicament to a decision by choosing relevant information, making logical decisions, and applying old applications to new situations and new applications to old situations. Above all, they have learned how to work as a team: dividing the work but making sure that everyone understands, exploring all possibilities but agreeing on one method, and checking to make sure that the problem really was solved. Finally, they have learned how to make presentations, orally or in writing, that communicate what they have learned to their coworkers, their friends, and the general public.

The goal of this course is not to make you a physicist. It is to show you the way that physicists view the world and to give you an understanding of the physical world around you. It may be that you will become interested in a rewarding career in science or technology. Whatever your chosen career, you will be able to make better-informed decisions in an increasingly complex age. You will learn to ask the questions "How do we know?", "Why do we believe it?", and "What's the evidence for that?" when you are presented with new information or new problems.

FIGURE 1–5

We are surrounded in our daily lives by physics success stories. Examine a few highlights below.



1 Originally thought to serve no useful purpose, lasers are now used in industry and construction, data storage and retrieval, medicine, telecommunications, navigation, and defense.

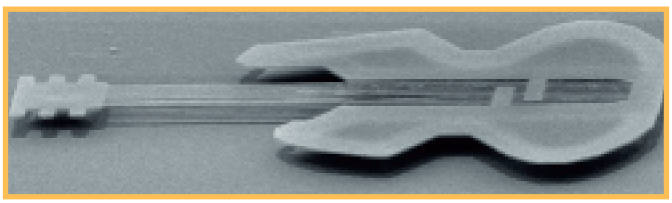
2 Wartime research into radar and miniature electronics led to the development of microwave ovens.

3 Razor blades are coated with thin film materials using plasma physics techniques. The blade handles are attached by laser welding. Computerized vision systems quality check each batch.

4 Billions of dollars are saved by consumers as automobiles are built with lighter composite materials and polymers, with microcomputers to control fuel injection systems, and with more efficient fuel cells and batteries.

5 Built during the 1940s, the ENIAC computer weighed 30 tons. Research on thin films, magnetic materials, and semiconductors has led to small, affordable personal computers.

6 Energy efficient houses are a result of physics research on heat transfer, thin films, plasma sources, vacuum technology, optics, and new materials.



7 The nanotechnology that built this guitar will allow scientists to study processes and perform functions on a submicroscopic level.

Egg Drop Project

Problem

Instruments destined to explore Mars or the moon must be packaged so that they are not damaged upon takeoff or landing. You and your partners will create a model for that package. You will design a container for an egg that will keep the egg from breaking when dropped from a height of approximately 5 meters.

Possible Materials

Cushioning materials such as cotton balls, bubble wrap, balloons, and so on
tape, glue
raw egg
pan balance
3-m × 3-m square plastic drop cloth
paper towels and trash bags

Procedure

1. Work with your group to think of several container designs that might protect an egg. Follow the restrictions below.
   - The design must allow easy opening and closing for egg inspection.
   - Before the container is dropped, it must fit into a 25-cm × 25-cm × 25-cm cube.
   - No liquids are allowed.
   - The egg must be raw, its shell uncoated.
   - The egg must survive a drop from approximately 5 meters.
   - Designs with lower mass receive higher scores.
2. Decide which aspects of each idea should be incorporated into your final design.
3. Plan ahead. Set a timetable for experimentation, construction, testing, and redesigning if needed.
4. Make a list of materials you would like to use for your package.
5. Produce a detailed diagram or illustration of your container. Indicate which features you expect will contribute directly to the safety of the egg.
6. Plan for a test drop of a few centimeters. If your egg breaks, revise your design. If you are satisfied with your design, continue.
7. Record the mass of your container (including egg).
8. Complete the actual egg drop. Inspect your egg. Give your container 10 points if the egg is unbroken, 5 points if the shell is cracked, $\frac{1}{2}$ point if the egg is broken. Find your score using the information below.

$$\text{Score} = \frac{2000}{\text{mass of container}} \times \text{earned egg points}$$

9. Dispose of the egg and materials with egg on them as instructed by your teacher. Clean and put away materials that can be reused.

Analyze and Conclude

1. **Compare and Contrast** Which restriction did your team feel was the most limiting?
2. **Analyzing the Results** What was the most effective part of your design? What was the weakest part?

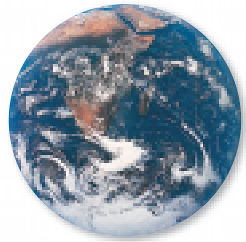
Apply

1. How would your container need to be redesigned so that it could safely carry two raw eggs?

Data and Observations

Group	Design	Container Mass	Score

CHAPTER 1 REVIEW



Summary

Key Terms

- physics
- scientific method

- Physics is the study of matter and energy and their relationships.
- Physics is basic to all other sciences.
- A knowledge of physics makes us, as citizens, better able to make decisions about questions related to science and technology.
- Much scientific work is done in groups in which people collaborate with one another.

Reviewing Concepts

1. Define *physics* in your own words.
2. Why is mathematics important to science?
3. Assume for a moment that the theory of matter held by some of the ancient Greeks is correct. How does this theory explain the motion of the four elements?

Applying Concepts

4. Give some examples of applications that resulted from work done by physicists.
5. Give some examples of applications that have resulted from work done by physicists on the exploration of space.
6. Research the aspects of nature investigated by each of the following kinds of scientists: astrophysicists, astronomers, biophysicists, exobiologists, and geophysicists.
7. Some of the branches of physics that you will study in this course investigate motion, the properties of materials, sound, light, electricity and magnetism, properties of atoms, and nuclear reactions. Give at least one example of an application of each branch.
8. What reason might the Greeks have had not to question the evidence that heavier objects fall faster than lighter objects? **Hint:** Did you ever question which falls faster?
9. Is the scientific method a clearly defined set of steps and procedures? Support your answer.
10. Why will the work of a physicist never be finished?

Critical Thinking Problems

11. It has been said that a fool can ask more questions than a wise man can answer. In science, it is frequently the case that a wise man is needed to ask the right question rather than to answer it. Explain.

Going Further

Class Discussion In 1996, scientists reported that meteorites found in Antarctica were actually from Mars, probably ejected from that planet by the impact of a meteor or comet millions of years ago. These meteorites were especially interesting because they contain structures that were interpreted as evidence of simple life-forms.

As a group, brainstorm ways to develop answers to the three questions "How do we know?", "Why do we believe it?", and "What's the evidence for that?" regarding the composition of these meteorites.

Project Research and describe the history of physics. Be sure to include the contributions of scientists in physics and the impact of their contributions on science, society, and the environment. Evaluate the impact of the research and contributions of these scientists on scientific thought, society, and the environment. How have these contributions impacted your own life?

PHYSICS Online

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