1.1 Physics: A Window on the Universe

SECTION OUTCOMES

- Use appropriate scientific models to explain and predict the behaviour of natural phenomena.
- Identify and describe science- and technology-based careers related to physics.

KEY TERMS

- physics
- scientific inquiry
- observation
- qualitative
- quantitative
- theory
- model

MISCONCEPTION

From X-rays to Nerve Impulses
Many people think that physics is very difficult and highly mathematical. While mathematics is very much a part of physics, the basics of physics need not be difficult to understand. No matter what field of study is most interesting to you, it is likely that physics concepts will help you better understand some facet of it. You may be especially interested in another science, such as biology or chemistry. As your study of science progresses, you will discover that each science depends on the others. For example, chemists use X-rays to study the structure of large molecules. Biologists use the theory of electricity to study the transmission of nerve impulses.

What makes physics so exciting is that you will be involved in thinking about how the universe works and why the universe behaves as it does. When asked to define science, Albert Einstein once replied, "science is nothing more than refinement of everyday thinking." If you substitute "physics" for "science" in Einstein's definition, just what is the refinement he is referring to? Using the language of mathematics to construct models and theories, **physics** attempts to explain and predict interactions between matter and energy. In physics, the search for the nature of these relationships takes us from the submicroscopic structure of the atom to the supermacroscopic structure of the universe. All endeavours in physics, however, have one thing in common; they all aim to formulate fundamental truths about the nature of the universe.

Your challenge in this course will be to develop a decision-making process for yourself that allows you to move from Einstein's "everyday thinking" to his "refinement of everyday thinking." This refinement, the systematic process of gathering data through observation, experimentation, organizing the data, and drawing conclusions, is often called **scientific inquiry**. The approach begins with the process of hypothesizing. A good scientist tries to find evidence that is *not* supported by a model. If contradictory evidence is found, the model was inadequate.

Throughout the textbook, you will find scientific misconceptions highlighted in the margins. See if your current thinking involves some of these misconceptions. Then, by exploring physics through experimentation throughout the course, develop your own understanding.

How did our present understanding of the universe begin? What was the progress over the centuries before present time? The thinking that we know about started with Artistotle.

Two Models from Aristotle

Over 2300 years ago, two related models were used as the basis for explaining why objects fall and move as they do. Aristotle (384–328 B.C.E.) used one model to account for the movement of objects on Earth, and a second model (see the diagram opposite) for the movement of stars and planets in the sky. We do not accept these models today as the best interpretation of movement of objects on Earth and in space. However, at the time they were very intelligent ways to explain these phenomena as Aristotle observed them.

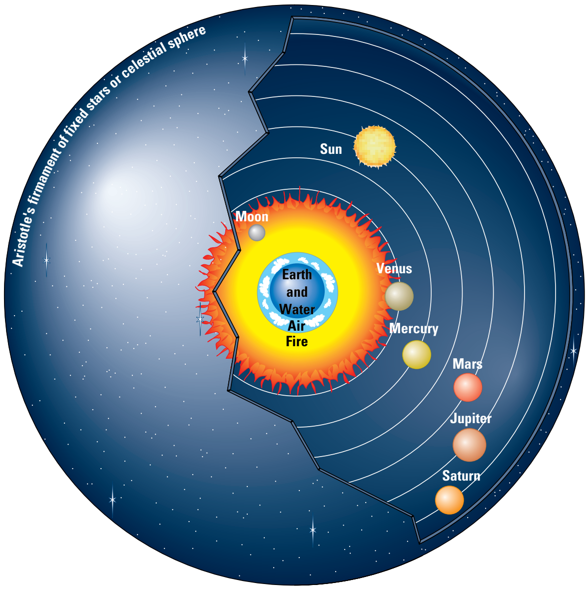

Figure 1.1 In Aristotle's cosmology, Earth is at the centre of the universe.

Aristotle and Motion

The model for explaining movement on Earth was based on a view advanced by the Greeks, following Aristotle's thinking. Aristotle accepted the view of Empedocles (492–435 B.C.E.) that everything is made of only four elements or essences — earth, water, air, and fire. All objects were assumed to obey the same basic rules depending on the essences of which they were composed. Each essence had a natural place in the cosmic order. Earth's position is at the bottom, above that is water, then air and fire. According to this model, every object in the cosmos is composed of varous amounts of these four elements. A stone is obviously earth. When it is dropped, a stone falls in an attempt to return to its rightful place in the order of things. Fire is the uppermost of the essences. When a log burns, the fire it trapped from the sun while it was growing is released and rises back to its proper place. Everything floats, falls, or rises in order to return to its proper place in the world, according to Aristotle. These actions were classified as natural motions. When an object experiences a force, it can move in directions other than the natural motions that return them to their natural position. A stone can be made to move horizontally or upward by exerting a force in the desired direction. When the force stops so does the motion.

The model for explaining movement in the sky was somewhat different. Greek astronomers knew that there were two types of "stars," the fixed stars and the planets (or wanderers), as well as the Sun and the Moon. These objects seemed not to be bound by the same rules as objects formed of the other essences. They

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Richard Feynman (1918–1988), a Nobel Prize winner and the father of nanotechnology, was one of the most renowned physicists of the twentieth century. In 1959, while presenting a paper entitled "There's Plenty of Room at the Bottom" on the then little-known characteristics of the submicroscopic world, Feynman remarked: "There is nothing besides our clumsy size that keeps us from using [that] space." When he spoke those words, nanotechnology was still a distant dream. That dream now appears to be verging on reality. Indeed, twenty-first century medicine and computer science could well see the first applications of nanotechnology, as both disciplines race to develop tools that will one day allow them to manipulate individual atoms.

TRY THIS...

Physics in the News

Using print and electronic resources, research a current or historical article that discusses some aspect of physics. Summarize the article in two or three paragraphs, highlighting why you think the topic is significant. Provide as much information about the source of the article as possible.

Language Link

Even today the term quintessence (fifth essence) has come to mean on the highest plane of existence. Use the term, quintessence, or its adjectival form, quintessential, to describe an important event or person in your own life.

moved horizontally across the sky without forces acting on them. The Greeks placed them in a fifth essence of their own. All objects in this fifth essence were considered to be perfect. The Moon, for example, was assumed to be a perfect sphere. Aristotle's model assumes that perfect crystal, invisible spheres existed, supporting the celestial bodies.

Later, when Ptolemy (87–150 C.E.) developed his Earth-centred universe model, he used this idea as a base and expanded upon it to include wheels within wheels in order to explain why planets often underwent retrograde (backward) motion. A single spherical motion could explain only the motions of the Sun and the Moon.

To European cultures, Aristotle's two models were so successful that for almost 2000 years people accepted them without question. They remained acceptable until challenged by the revolutionary model of Copernicus (1473–1543) and the discoveries of Galileo Galilei (1564–1642).

Figure 1.2 The telescope through which Galileo first observed Jupiter's moons and other celestial bodies in our solar system.

Galileo and Scientific Inquiry

In 1609, using a primitive telescope (Figure 1.2), Galileo observed that the Moon's surface was dotted with mountains, craters, and valleys; that Jupiter had four moons of its own; that Saturn had rings; that our galaxy (the Milky Way) comprised many more stars than anyone had previously imagined; and that Venus, like the Moon, had phases. Based on his observations, Galileo felt he was able to validate a revolutionary hypothesis — one advanced previously by Polish astronomer Nicolaus Copernicus — which held that Earth, along with the other planets in the Solar System, actually orbited the Sun.

What the Greeks had failed to do was test the explanations based on their models. When Galileo observed falling bodies he noted that they didn't seem to fall at significantly different rates. Galileo built an apparatus to measure the rate at which objects fell, did the experiments, and analyzed the results. What he found was that all objects fell essentially at the same rate. Why had the Greeks not found this? Quite simply, the concept of testing their models by experimentation was not an idea they found valuable, or perhaps it did not occur to them.

Since Galileo's time, scientists the world over have studied problems in an organized way, through observation, systematic experimentation, and careful analysis of results. From these analyses, scientists draw conclusions, which they then subject to additional scrutiny in order to ensure their validity.

As you progress through this course, keep the following ideas about theories, models, and observations in mind. Use them to stimulate your own thinking, and questioning about current ideas.

Conceptual Problem

- A log floats partially submerged on the surface of a lake. The log is obviously wood, a material which clearly grows out of the essence "earth" and is a fairly dense solid like other earth objects. If you were an ancient Greek who believed in the Aristotelian Cosmology, how could you explain why the log floats rather than sinking like rocks or other earth materials?

Thinking about Science, Technology, Society and the Environment

In the middle of the twentieth century, scientific progress seemed to go forward in leaps and bounds. The presence of figures like Albert Einstein gave science in general, and physics in particular, an almost mystical aura. Too often physics was seen as a pure study isolated from the "real" world. Contrary to that image, science is now viewed as part of the world and has the same responsibilities, perhaps even greater, to the world as any other form of endeavour. Everything science does has a lasting impact on the world. Part of this course is to explore the symbiotic relationship that exists between science, technology, society and the environment (STSE).

To many people, science and technology are almost one and the same thing. There is no doubt that they are very closely related. New discoveries in science are very quickly picked up by technology and vice versa. For example, once thought of as a neat but rather impractical discovery of physics, the laser is a classic example of how science, technology, society, and the environment are inseparable. The laser's involvement in our lives is almost a daily occurrence. Technology has very quickly refined and improved its operation. Today, laser use is widespread. Supermarket scanners, surveying, communications, holography, metal cutters, surgery, and the simple laser pointer are just a few examples of the innovations that technology has found for the laser. Clearly it would be impossible to separate the importance of science and technology to society. Figure 1.3 on the following page shows just a few of the many applications of physics in today's world.

Often the same developments have both positive and negative impacts. Our society's ever increasing demand for energy has strained our environment to its limits. Society, while demanding more and more energy, has also demanded that science and technology find alternate sources of energy. This has led to the technological development of nuclear, solar, wind, hydro, geothermal, and fossil fuel energy sources. Society's and the environment's relationship with science and technology seems to be a two-edged sword.

TRY THIS...

Was Aristotle Right?

Do heavy objects fall faster than lighter ones? Drop an eraser and a sheet of paper simultaneously from about eye level to the floor. Which gets there first? Is there anything about the motion of the paper that makes you think that this was not a good test? Now crumple the paper up into a small ball and repeat the experiment. Is there a significant difference in the time they take to reach the floor? Describe the variables that you attempted to test.

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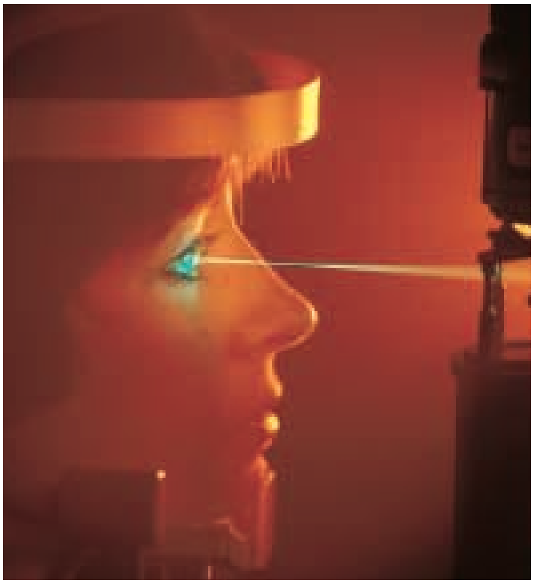
Aristotle's models had been used to explain the nature of falling for centuries. According to Aristotle, since a large rock has more of the essence "earth" in it than a small one it has a greater tendency to return to the ground. This causes the big rock to weigh more and thus it must fall faster than a small rock. This is a classic application of a model to explain a phenomenon. However, it should not surprise you to find that since the model is in error so is the explanation based on the model.

Web Link

www.mcgrawhill.ca/links/atlphysics

To learn more about careers in physics, go to the Internet site above and click on **Web Links** to find out where to go next.

Figure 1.3 Some applications of physics discoveries



Laser eye surgery is one of many applications that technology has found for lasers.

This tiny "guitar" (about the size of a red blood cell) was built using nanotechnology. This technology will help scientists explore the processes by which atoms and molecules can be used individually as sub-microscopic building blocks.

Hybrid autos that run on both electricity and gasoline can greatly reduce pollution. Cars built of carbon composite materials are lighter and stronger than cars made of traditional materials. Computer-controlled ignition and fuel systems increase motor efficiency. All these factors can assist in protecting the environment.

Physics research into thermal properties of materials and technological advances in structural design have combined to produce energy efficient houses that greatly reduce our demand for heating fuels.

Innovations in technology have resulted in the ability to put more and more powerful computers into smaller and smaller spaces.

Technology reaches into the most mundane aspects of our lives. Micro-layers of Teflon™ on razor blades make them slide more smoothly over the skin.

Thinking Scientifically

Knowledge begins with observations and curiosity. Scientists organize their thinking by using observations, models, and theories, as summarized below.

Theory

A **theory** is a collection of ideas, validated by many scientists, that fit together to explain and predict a particular natural phenomenon. New theories often grow out of old ones, providing fresh, sometimes radical ways of looking at the universe. One such example, still in the process of development, is the GUT, or Grand Unified Theory, being sought by researchers across the different fields of physics. Through the GUT, physicists hope one day to be able to describe all physical phenomena in the universe by using the same set of laws.

Model

A **model** is a representation of phenomena and can come in a variety of forms, including a list of rules, pencil lines on a piece of paper, an object that can be manipulated, or a mathematical formula. An observation may be explained using more than one model; however, in most cases, one model type is more effective than others.

Observations

An **observation** is information gathered by using one or more of the five senses. Observations may yield a variety of explanations, as participants in the same event often report different things. It takes hundreds of observations of a single phenomenon to develop a theory. There are two kinds of observations that can be made. The first are **qualitative**, which describe something using words: "A feather is falling slowly to the ground." The second are **quantitative**, which describe something using numbers and units: "The rock fell at 2 m/s."

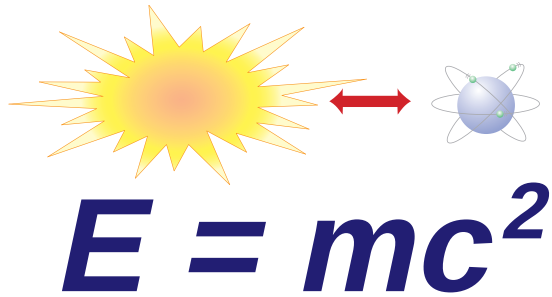


Figure 1.4 You have undoubtedly heard of Einstein's theory of special relativity. One part of the theory states that the speed of light, c, is the only thing in the universe that is constant. All other measurements are relative, depending on the observer's frame of reference. The famous formula (model) associated with the theory is $E = mc^2$.

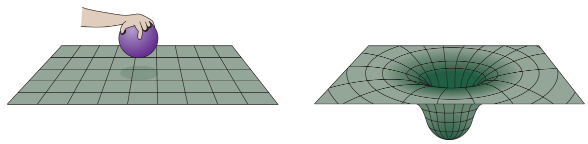


Figure 1.5 This "rubber sheet model" is often used to simulate Albert Einstein's idea of curved space. The model shows that a central mass can cause the space around the mass to curve.

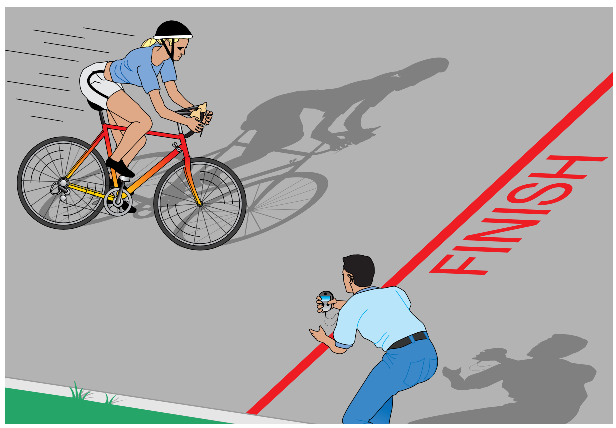


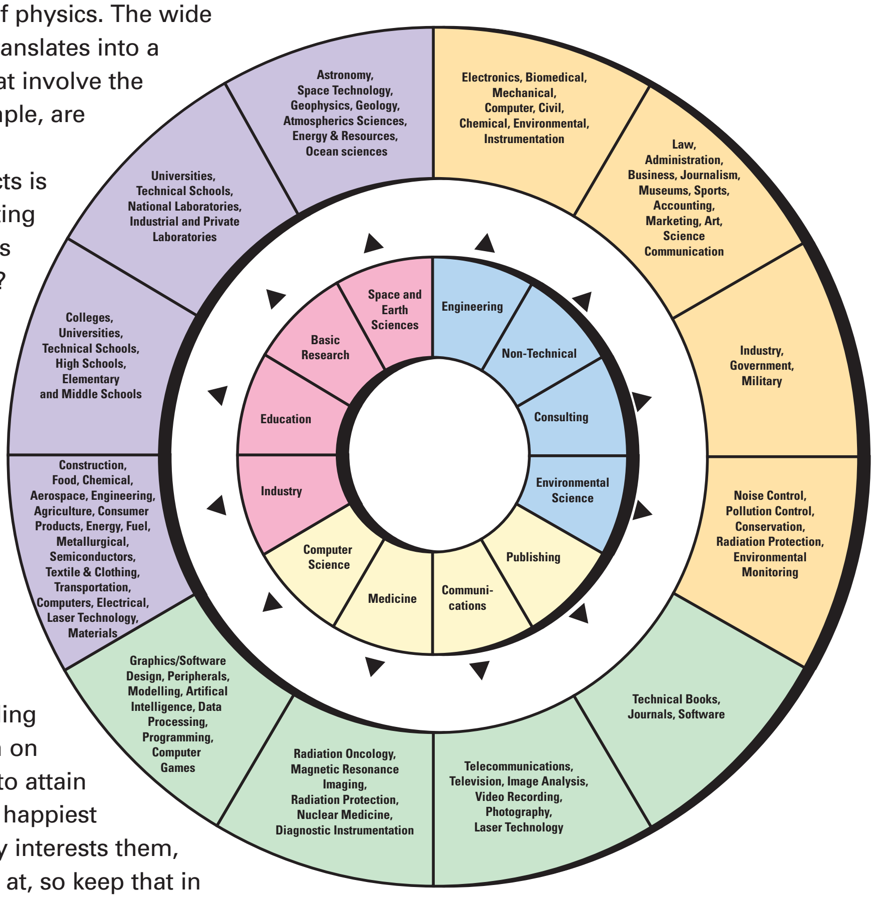
Figure 1.6 Observations can be quantitative or qualitative. The cyclist can determine her speed by applying the mathematical model, $v = \Delta d/\Delta t$, to her observable data of distance and time.

CAREERS IN PHYSICS

TARGET SKILLS

- Initiating and planning
- Conducting research

As you have read in this introductory section to the chapter, your world, from the natural cycles of weather to the high-tech gadgets of communication, relies on basic principles of physics. The wide scope of what physics is translates into a very long list of careers that involve the study of physics. For example, are you interested in theatre? Knowledge of how light acts is crucial to the intricate lighting techniques used in theatres today. Are you a musician? You will be able to achieve better musical effects by understanding more about the nature of sound. Study the diagram shown here to note career opportunities in physics that use much of the knowledge and skills you will gain in this physics course. Consider one or more that might be especially appealing to you, and begin research on educational requirements to attain it. People succeed and are happiest when in a career that really interests them, not just one they are good at, so keep that in mind as you explore opportunities.



1.1 Section Review

1. MC What is nanotechnology? Cite specific examples of how this technology could affect our lives.
2. C How would you define physics?
3. K/U Why do scientists employ scientific inquiry to investigate problems?
4. K/U What is the difference between a theory, a model, and an observation? What is the significance of each?
5. C Describe the difference between qualitative and quantitative observations, and provide an example of each.