1-1 What Is Physics?

The activity of trying to understand is much the same in any area of knowledge. Imagine yourself as a small child, watching an older sibling playing soccer or baseball. Eventually, by careful observation and reasoning, you begin to figure out the rules of the game. In much the same way, we are all observers of the great game of nature, and after much observation we may find that certain rules appear to be followed without exception: the sun always rises in the east and sets in the west, a rock released in midair always falls down, hot and cold objects mixed together always reach a common in-between temperature. *Physics is the activity of trying to find the rules by which nature plays.*

Underlying physics, therefore, or any science for that matter, is the belief that there *are* rules, that nature is in some sense orderly. But that doesn't mean that the rules are easy to figure out.

Case 1-1 ◆ *Inferring the Rules of Baseball from an Obstructed Viewpoint*

Imagine yourself always watching baseball from the same overpriced but lousy seat in the ballpark. Your seat has an obstructed view (see Figure 1-1); you can see the batter, but not the catcher, the home plate umpire, or the path by which either takes or leaves the field. You are also too far away to hear what is happening on the field. Even if you start out knowing absolutely nothing about the game, you might quickly *infer* that there is a catcher from the way the ball keeps coming back from the unseen region. STOP&Think To **infer** something is to think that it is implied by the evidence. On what basis might you infer the existence of a home plate umpire? ◆

Figure 1-1 An obstructed view of a baseball game. The batter is visible, but not the umpire or catcher.

Figuring out the whole conceptual structure of balls and strikes is more difficult, but at length you think you have it worked out. Although you cannot see the scoreboard, you know whether the home crowd reacts positively or negatively after each pitch. You become more confident about your understanding each time a batter walks off the field after a third strike. Then one day a batter swings and misses at a third strike and runs to first base. This is an *anomalous* event—one that doesn't fit the previously established pattern. Baseball, it turns out, has a dropped third strike rule: If the catcher fails to catch the pitch on a third strike, the batter can attempt to advance to first base, and must be thrown out like any other base runner.

If you have never seen the catcher, though you've inferred that one exists, it is more difficult to figure out what is happening. You must build a mental picture of what the catcher is doing that is consistent with what you *can* see. But that picture is tentative, always subject to revision—literally picturing anew—if it turns out to conflict with some later observation.

Your understanding of the rules governing balls and strikes must also be considered tentative. You can never be sure you have seen all there is to see and that there will not be some unexpected event like a dropped third strike to make you reconsider. When that does happen, it is not the rules of baseball that have changed, only your understanding of what those rules are.

Our view of nature is also obstructed. There are aspects of the game of nature that our senses cannot detect. For example, humans never see ultraviolet radiation or X rays, but we infer from the exposure of photographic film that they exist. The details of the exposure in turn let us draw inferences about the objects that emit them, even objects thousands of light years away.

Models: Although hobbyists, architects, and others may build models out of wood, Plexiglas, and so on, that people can see and hold, physicists build models in their heads. The model is the idea itself; it is a theory.

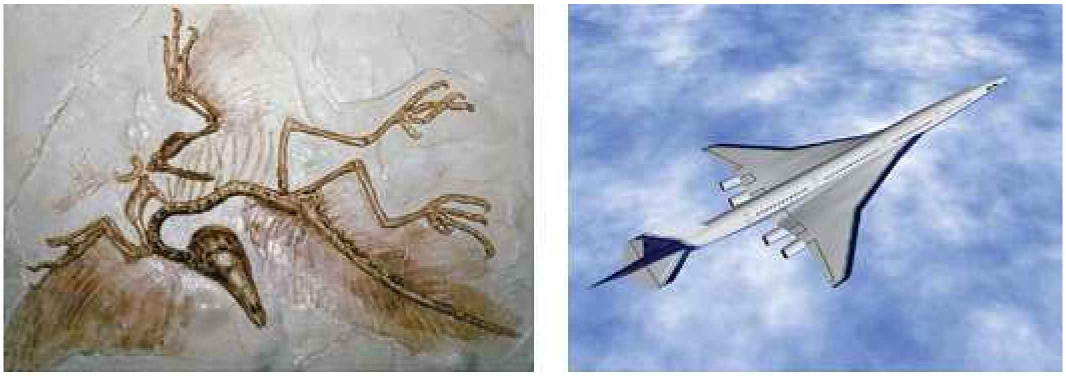
As we do for the baseball game, we assume that the rules of nature exist and are unchanging. But as in Case 1-1, the activity of reaching an understanding of those rules is endless. Our present understanding must always be viewed as tentative. It is a **model,** a mental picture in which the pieces of the picture obey the rules we've deduced. It is a good model to the extent that the objects in the real world behave as our mental picture would lead us to expect. In other words, we consider a model or theory valid, and potentially useful and productive, if it fits with all the evidence *so far.*

The Scope of Physics

Because the behaviors we encounter in the natural universe are so overwhelmingly diverse, physics must cover a broad range of topics, though it turns out that underlying much of that diversity are the rules in a few fundamental areas. You will find that the areas listed here overlap and interconnect in surprising ways.

Nature's sound and light show. The study of electricity and magnetism provides insight into some of nature's most dramatic “special effects.”

The study of *motion and forces* encompasses the orbits of planets and the paths of comets, the spin on a curve ball or the hovering of a Frisbee, and the aerodynamics of a supersonic jet or of the prehistoric forerunners of present-day birds (Figure 1-2).



(*a*) (*b*)

Figure 1-2 Flyers old and new. The study of motion and forces can help us understand the aerodynamics of (*a*) the archaeopteryx, a prehistoric ancestor of today's birds, or (*b*) the next-generation supersonic passenger jet as envisioned by NASA.

The study of *electricity and magnetism* provides insight into phenomena as diverse as:

- Atmospheric effects, such as lightning and the aurora borealis, or northern lights.
- The technology underlying television, personal computers, use of solar energy, and a vast array of basic and not-so-basic appliances and instrumentation.
- The details of chemical reactions, including those (collectively called your *metabolism*) that occur in your body.
- Properties of new materials, such as high-temperature superconductors.
- The transmission of signals in your own nervous system by means of charged particles moving in electric fields.
- The *electrophoresis* technique used in genetics and in blood identification in criminal and paternity cases to compare samples of DNA by looking at the different flow rates of its component parts in an electric field.

Optics, the study of light and related emissions (from X rays to radio waves), relates to:

- The working of your eyeglasses or microscope.
- The diverse ways in which different living things see (e.g., bees view the world through compound eyes and can see ultraviolet though we cannot; see Figure 1-3).
- Why things look as they do (a rainbow, say, or a blue sky or a red sunset).

(a) (b)

Figure 1-3 Bees see differently than humans. (*a*) The compound eye of the bee is very different than our own and produces a mosaic of images. (*b*) Bees can detect ultraviolet, but the human eye cannot. The flower that appears solid yellow to the human eye appears very different when photographed on ultraviolet-sensitive film.

Studies of *heat and temperature* apply equally to matters of auto engine efficiency, the risks of hot tubs, home insulation, determining whether dinosaurs were warm- or cold-blooded, the risks to global climate of increasing carbon dioxide and other gases in the atmosphere, or the heat generation processes in the interiors of stars.

Physicists at the cutting edge of physics still need a thorough understanding of these basic areas, called **classical physics,** whether they are studying the smallest known components of the universe in elementary particle physics or the largest in astrophysics and cosmology. Whether working on one of the world's largest high-energy particle accelerators (Figure 1-4*a*), or on the Hubble Space Telescope (Figure 1-4*b*), they are constantly considering how the basic underlying rules play out in new and unexpected contexts. But they are also asking where our understanding breaks down and where we may have to infer new or revised rules.

(a) (b)

Figure 1-4 At the frontiers of human knowledge. (*a*) The 3-km-long high-energy particle accelerator at Stanford probes the tiniest constituents of matter. (*b*) The Hubble Space Telescope probes the depths of interstellar space.