1-1 Physics, Models, and Units

You will most likely be devoting several months to learn physics. Physics is the study of something, but of what? Take a minute and write one sentence describing what you think physics is.

Physics encompasses many different topics, but a nice one-sentence description is that physics is the study of how the world works. Physics could just as easily be described as the study of how the universe works, or the study of how things work. Physics can be very practical, explaining how a toaster works, for instance. It can also be mind-blowing stuff, as we will see when we talk about the quantum nature of the atom and Einstein's theory of relativity. It is also important to keep in mind that physics is a science. Physics can, in some sense, also be thought of as a logical, systematic approach to analyzing physical situations.

Another important question to ask is, what is this book, *Essential Physics*? This is your guide to specific areas of physics. In some sense it is a history book as well as a science book, covering much of the same ground that was covered by natural philosophers, scientists, and physicists over the past 2500 years or so. This book is certainly not a comprehensive look at all of physics – you can always dig deeper to find more information – but it should at least give you a reasonable basis for understanding the world around you.

Models in Physics

In this book, we will see plenty of questions about spaceships in outer space, balls, cars, people, etc. When we come to analyze situations involving such objects, however, we will often use simplifying assumptions (such as assuming that no air resistance acts on a ball in a particular case) and we will often use models in which we replace the object by something simpler.

There are several reasons for using simplifying assumptions, including:

- The assumptions can allow us to solve a particular problem in a straightforward way.
- Anything we neglect should only have a minor impact on the result if we were to account for it.
- We may not know enough about the situation to include whatever it is we're neglecting. In some cases we will address that as we go through the book, such as neglecting friction initially and then learning how to account for friction.
- The mathematical methods that would be required to solve the problem more generally are above the level of this book.

When we use a model that neglects something like air resistance, the answer we come up may not match what really happens. If the model is good, though, the answer should be a reasonable approximation of what happens. It's important to think about how an answer would change if other factors were included. For instance, if we neglect air resistance and calculate that a particular baseball hit by Josh Hamilton just clears the outfield fence for a home run, that ball would, in reality, probably be caught by an outfielder, because air resistance tends to slow an object down and reduce how far it travels.

If you start to think that we neglect too much in this book and you're interested in doing more, that's terrific. This book is merely an introduction to physics, and there is plenty of exciting physics involved with going above and beyond what we'll cover here.

Applying a model often means treating complicated objects, such as the car shown in Figure 1.1, as a simpler object, such as a particle. A modern car is rather complicated. Its shape is designed to reduce air resistance; it generally has anti-lock brakes and air bags to increase passenger safety; its engine operates under the laws of thermodynamics; and its onboard computer and accompanying electric circuits are the analog of a human's brain and central nervous system. To understand the motion of such a car along a road, however, we can generally ignore many of these complicated systems. In the early chapters of this book, for instance, we will treat cars, people, etc., as particles. We will use this **particle model** a great deal, mainly so we can focus on the big picture rather than on subtle details that depend on the precise object. As we continue through the book, our models will become more sophisticated, but when we use models we're keeping a saying of Albert Einstein's in mind: make the problem as simple as possible, but no simpler.

Figure 1.1: A photograph of a 2006 Volkswagen Jetta. A modern car is an incredibly complex object, but to understand the motion of a car like this along a straight road, we can treat the car as a particle.
Photo credit: Wikimedia Commons.

Units

Physics is an experimental science. Each time we measure something, we need to be aware of the units of the measurement. Take a minute and measure the length of this page. What do you get? It would be meaningless to say 8.5, or 21.2, or 212, but if you said 8.5 inches, or 21.2 centimeters, or 212 millimeters, that would be fine. Those three measurements are equivalent, and you could measure the length of the page in other length units, too, such as feet, miles, furlongs, kilometers, or light-years. Just remember that a measurement requires both a number and a unit.

In this book we will primarily use SI (système international) units. SI has several base units, including the meter (m) as the unit of length, the kilogram (kg) as the unit of mass, and the second (s) as the unit of time. Being based on powers of ten, SI is easy to use, unlike the English system of units in which you have to remember conversion factors such as how many cups are in a gallon. In the metric system the prefix tells you which power of 10 to use. Table 1.1 gives some examples of conversion factors, with a more complete table inside the front cover of the book.

Name	Prefix	Power of ten	Example
mega	M	x 10^6	92.9 MHz – frequency of an FM radio station
kilo	k	x 10^3	110 km/h – speed limit on some Canadian highways
centi	c	x 10^{-2}	30 cm – approximately equal to 1 foot
milli	m	x 10^{-3}	500 mg – mass of Vitamin C in a Vitamin C capsule
micro	µ	x 10^{-6}	150 µm – diameter of a human hair
nano	n	x 10^{-9}	400 to 700 nm – wavelength range of visible light

Table 1.1: Common prefixes in the metric system.

Essential Question1.1: What is a good definition of a physical model?

Note that each section in the book ends with an Essential Question. The answer to each Essential Question is given at the top of the following page, but you should resist the temptation to immediately turn the page to look at the answer. Spending some time yourself thinking about the answer will really help you to learn the material.