PHYSICS, ENERGY and OUR WORLD

HIGHSMITH

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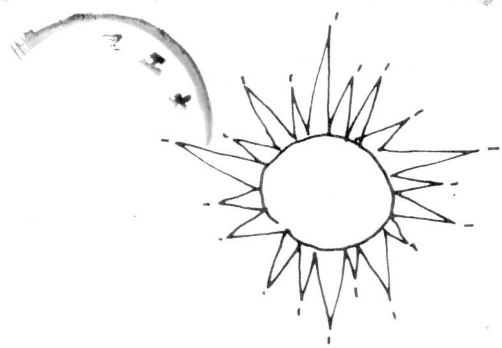

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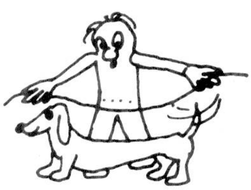

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To all students of life who have found joy in learning,
especially to Mary, Carol, John, and Steve
—the ones I have known best.

preface

TO THE STUDENT

Welcome to the world of physics. Pay no heed to the rumors that physics is a difficult subject studied only by geniuses. Physics should be for everybody, and the understanding of it not only will give a lot of personal satisfaction but will also help you to have a fuller and richer life—for in understanding the many aspects of Nature better, you cannot help having a deeper appreciation for her handiwork in our environment.

The topics in this book were selected to promote a better understanding of the world we live in rather than to prepare one for a particular college course. Some chapters, such as "Pollution and the Energy Crisis," show the many aspects of some problems facing our society. Many topics are discussed just to help one enjoy and appreciate life a little better.

The book was written with a light touch, and some of the illustrations which at first glance seem "corny" have a double or triple meaning. On the other hand, some of them may be just what they seem, although that was not my intention.

You will need very little mathematics to get through the book because the book has been designed to avoid tedious computations. There are several *devices* to help you wade through the subject. First, there are "Chapter Goals" at the beginning of each chapter which alert you to the important concepts and definitions which will be discussed. Second, there is a checklist of important terms at the end of each chapter. This checklist serves as a review for what you should

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have learned in reading the chapter, and is a handy device for review before a test. Third, there are "Questions to Reinforce Your Reading." The Group A questions were designed to help you pick out the more important concepts and make it a little easier to learn the language of physics. If you answer all of these questions before class you will find it much easier to understand what is going on, and you will find yourself "talking in physics." There are also Group B questions, which are discussion questions or numerical applications of the concepts. Every once in a while you will find a starred question. If you enjoy working these problems, there is nothing basically wrong with you except that you have fought off the urge to become a physics major too long.

Don't get discouraged if it takes a little time to crawl through some sticky fundamental notions in the subject—remember that it took the best minds of civilization a couple of thousand years to arrive at most of them.

TO THE TEACHER

Physics, Energy, and Our World was written for students whose main interest lies outside the field of physics. The book assumes that the students will have very little mathematical skill. It was written to enhance the general education of students by showing them the many and varied applications of physics in our world today.

Some knowledge of physics is necessary for the average citizen to make intelligent judgments in our highly technologically oriented society, and the subject matter was chosen with this fact in mind. Topics such as air and water pollution, the exploration of space, the energy crisis, weather, noise pollution, and nuclear energy were included to help students become more aware of the world as our generation finds it.

After the student masters the basic mechanics presented in the first seven chapters plus Chapter 11, the instructor can individualize the course as he chooses, since there is more than enough material for a one semester course.

P. E. HIGHSMITH

acknowledgments

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contents

chapter 1

the nature of physics

CHAPTER GOALS

This chapter surveys some aspects of the scientific enterprise and the role of physics. The fundamental quantities of length, mass, and time are discussed, along with different systems of measurement. As you read this chapter, concentrate on the following questions.

* How does science differ from technology that is based upon science?
* What is a physicist?
* What is a fundamental quantity?
* What is a derived quantity?
* What are the three systems of measurement?
* Why are the dimensions of a quantity important?
* What are a standard meter, a standard kilogram, and a standard second?
* How are large and small numbers treated?

Have you ever escaped from the haze and lights of the city on a dark clear night, looked up at the thousands of stars, and wondered about the scheme of things in this Universe of ours? No doubt, ancient man looked a lot at these commercial-less late, late shows and made many astronomical observations. Somewhere along the line he noticed that the full moon rises near sunset and sets near sunrise, and that there are a definite number of days between full moons. In all probability some unknown ancient tried to figure out the connection between the shape of the moon and the time it rises or sets or some other related event. It's too bad that we don't know his name, because he was our first scientist.

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FIGURE 1–1 Scientific thought began when man sought relationships between phenomena.

WHAT IS A SCIENTIST?

To some people, a scientist is a mad little man in a white coat who is forever building machines or creating monsters with which to torment or control the world. He is the builder of "the Bomb," "the polluter," and the greatest menace to freedom of the human spirit. (For examples of this image, see George Orwell's *1984,* Aldous Huxley's *Brave New World,* and Kurt Vonnegut's *Cat's Cradle.*) To others he is the benevolent Santa whose gifts of discoveries will provide a sure path to Utopia. In reality, he is very human with all the strengths and weaknesses of his fellow men.

A scientist is concerned with finding relationships between diverse phenomena of nature. In finding these relationships, he hopes to be able to predict the results of an event before the event happens, or to find a connection between things of which he was unaware. When man can predict an event (such as the ocean tides) he has some edge over his environment,

FIGURE 1–2 One view of the scientist.

since he can prepare for the event—he can moor his boat higher upon the shore.

SCIENCE AND TECHNOLOGY

Sometime in antiquity, man found that the rounder an object was, the easier it was to push. This scientific relationship no doubt led to the invention of the wheel, an instrument of technology based upon science. Man found many uses for his new technology:

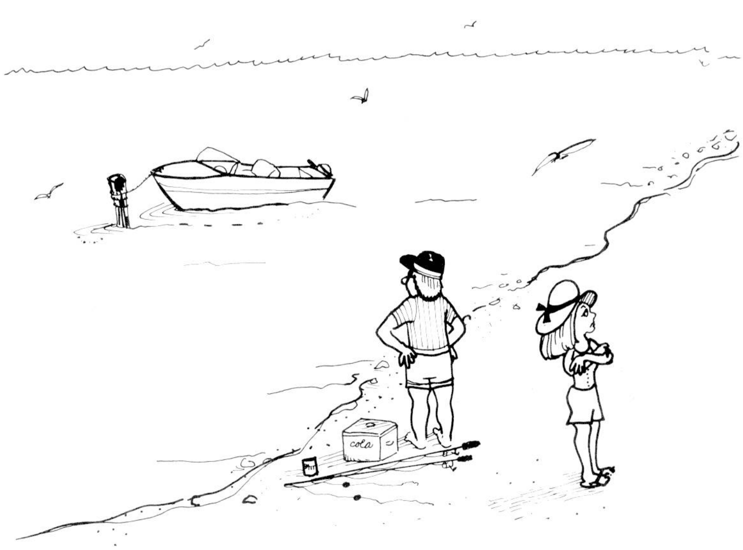

FIGURE 1–3 There are advantages to being able to predict events.

FIGURE 1–4 Early technology.

Copyright by Sidney Harris, reprinted from American Scientist, January-February 1973, Vol. 61, Number 1.

he could use the wheel to help haul in the harvest for the people he liked and he could use the same wheel to run over the people he did not like. Thus, the people in the days of antiquity discovered that scientific technology is neither good nor bad: its goodness or badness depends solely on who is operating the "wheel" and for what purpose.

Many people confuse science and technology because discoveries in the field of science often open up new areas of technology, and because many times scientists must use technology to test their theories. However, there is a difference: the scientist is primarily interested in finding cause and effect relationships between phenomena, while technology uses relationships to build machines and tools or to devise procedures which could (and should) benefit society.

FIGURE 1–5 The goodness or badness of technology depends upon its use. Left, cobalt radiation therapy is used to treat cancer. (Courtesy of Spartanburg General Hospital, Spartanburg, South Carolina.) Right, the aftermath of the atomic bombing of Hiroshima, Japan, in 1945. (Courtesy of Compix, United Press International.)

PHYSICS AND THE OTHER SCIENCES

There are many kinds of scientists because there are many fields of science. Science is divided into two large categories: the study of living things or the life sciences, which include biology, botany, paleontology, and zoology; and the study of non-living things or the physical sciences, which include physics, chemistry, astronomy, geology, and meteorology. Physics is the most basic of the sciences because it involves the study of matter and energy in great detail, and any scientific phenomenon that man can detect is composed of mass or energy in some combination.

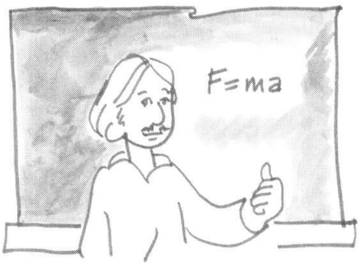

FIGURE 1–6

Many people are afraid to study physics because of rumors that it is a difficult subject, studied only by geniuses who are a little odd. Relax—one does not have to be a Mozart, a Beethoven, or a Bach to appreciate and use music in his daily life, and one doesn't have to be a Newton or an Einstein to appreciate and use physics in his daily life. If you are willing to tackle some fundamental ideas in physics, although you might not become a physicist, you will certainly be able to understand how a physicist looks at the world and to use physics in many aspects of your life or profession.

But what is physics? A brief look at different textbooks will convince you that there are many parallel definitions of the subject. One high school student defined it as "what physicists do late at night." One college text defined it as "a science whose objective is to study the components of matter and their mutual interactions. . . ." All such definitions are more or less correct, but incomplete. Just as the artist, the musician, or the playwright seeks to interpret the world around him in a particular way, so the physicist interprets the world from his point of view. Since the point of view is different, the results are usually different, but the truly educated person should be able to appreciate the genius of Newton, of Maxwell, and of Einstein as they interpreted the world, just as they appreciate the way in which Michelangelo, Shakespeare, or Beethoven interpreted the world.

The job of the physicist is to conjecture about and study what happens in nature with the goal of predicting phenomena and finding the order that exists between them. For example, early physicists studied and predicted tides, the paths of planets around the sun, and falling objects; Newton tied it all together when he showed that tides, a planet in an orbit, and a falling apple were all different manifestations of the same thing—gravitational attraction.

Although very few physicists make a discovery like Newton's, a physicist feels he has contributed to humanity and the human spirit when he opens even a small door to one of nature's secrets or is able to reach beyond what is known and to build another intellectual plateau from which others will be able to see farther and more clearly. The following pages will acquaint you with some of the ideas man has discovered concerning his universe. The more we know about relationships between the diverse phenomena in our environment, the more we will know of its beauty and the more we can enjoy and appreciate it. Furthermore, our environment is in trouble; if we all work together, it might be saved.

MEASUREMENT

Physics is a science that requires careful measurements. Whether a physicist is studying the very large, such as the universe, or the very small, such as the nucleus of an atom, he tries to measure as accurately as he possibly can. The accuracy of an experiment is limited to the error in the measuring instruments, and ultimately to the way in which the measurement is defined. Furthermore, a measurement communicates information, and this information must be understood by any other physicist. Many common expressions of measurements are clear to certain groups of people but not to others. For example, descriptions of the Indy 500, a man being 6-3, and a girl being 5-2 are readily understood by English-speaking people in the United States but would make little sense to anyone else. In scientific work, the information conveyed with a measurement must tell not only how big a measurement is, but also what it is.

Measurements must include at least two items of information, and can have more. The items that must be conveyed are (1) the magnitude, or the size of the measurement (numbers are used to give this information), and (2) the unit in which we are measuring. For example, in the measurement of 100 seconds, "100" denotes the size of the measurement, and "seconds" is the unit of the measurement.

To describe a measurement, we must use some system of units. To describe a person's height as 6-2 is incomplete and the meaning is unclear, but to describe a person's height as 6 feet, 2 inches gives

FIGURE 1–7 Common scientific measuring instruments. (a) A vernier caliper, designed to measure inside or outside dimensions to 0.1 mm. (b) A micrometer caliper, which measures outside dimensions to 0.01 mm.

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a complete description. Therefore, a complete description must have at least a magnitude (how many) and a unit (how many of what).

We have a great deal of freedom in choosing units. It is equally correct to say the height of a tree is 32 feet, or 980 centimeters, or 9.8 meters, although it is probably easier for us to visualize 32 feet than 980 centimeters or 9.8 meters because we are more familiar with the English system of measurement than with the metric system.

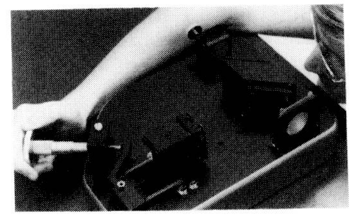

FIGURE 1–8 This Michelson interferometer can easily measure the wavelengths of light (about 400 to 700 billionths of a meter).

FUNDAMENTAL QUANTITIES AND FUNDAMENTAL UNITS

The civilized countries of the world have agreed upon a system of measurement. A very few quantities are considered basic or fundamental, and all other quantities, which are called *derived quantities*, are expressed in terms of these fundamental quantities. There are only three fundamental quantities one needs to know to understand the concepts presented in the first part of this book; these are: (1) length, (2) mass, and (3) time.

There are three systems in which each one of the above fundamental quantities has a *fundamental unit:* the meter-kilogram-second or MKS system, the centimeter-gram-second or CGS system, and the English system.

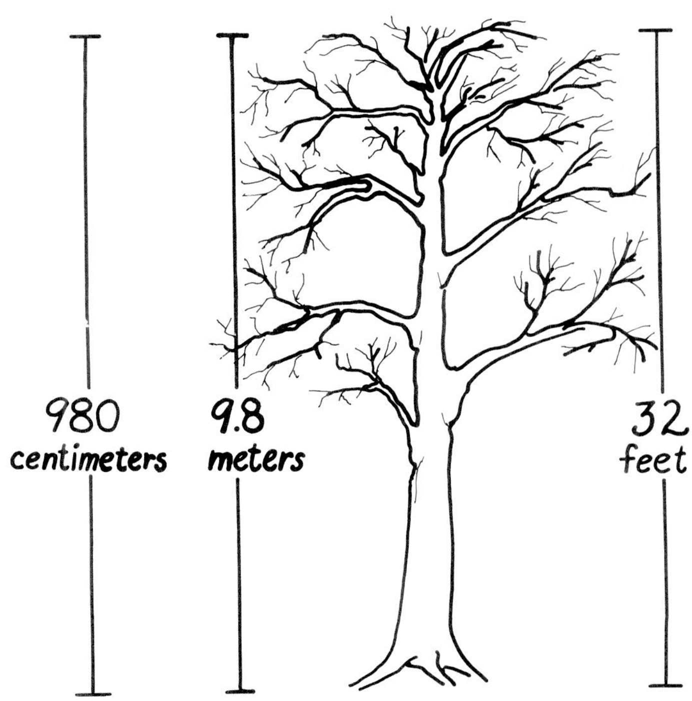

FIGURE 1–9 Common units of length.

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