Physical Science for Today

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Preface

Divorcing science from the world of people is as futile as trying to grow a garden without plants. Whether or not we like it, our man-made environment is the product of science and technology with all of the attendant blessings, frustrations, and problems. The primary objective of this book, then, is to concentrate on those areas of physical science with which we are most intimately enmeshed and relate them to the real world of the individual.

The individual finds himself in a world beset with many problems whose solutions appear almost beyond reach. Dr. Albert Schweitzer said, "Man has lost the ability to foresee and to forestall. He will destroy the earth." It is hoped that this book will, by associating the problems with their scientific geneses, aid the student in foreseeing possible solutions and forestalling the disasters predicted by many knowledgeable people—such as Dr. Schweitzer.

This book is intended for use in introductory physical science courses. Its purpose is not to present an encyclopedic array of scientific facts, principles, theories, and laws for which the non-science major has little interest and less real use. The author has attempted to include only that subject matter essential to an understanding and appreciation of those portions of the student's world being discussed. Another primary objective is to raise pertinent questions as a basis for critical thought, inquiry, and discussion. Any topic touched upon in this text can be investigated in depth with the aid of the usual supplementary resources—including encyclopedic textbooks of science.

In light of the first two paragraphs of this introduction, one may well ask what justification there was for devoting about 25% of this small volume to the areas of astronomy and space exploration. Part of the answer to this query lies in the individual's search for meaning for his existence and his natural curiosity about the universe. Also, we are spending a significant portion of our resources on the exploration of space—second only to our defense expenditures. This expenditure is commendable since the major stated function of the effort is simply to learn more about the universe that is the home of man.

This book should help the student understand the relationship between physical science and man and should assist him in his search for more knowledge of the universe and in his desire to improve the environment.

Contents

1

Where Are We?

Where are we? Who are we? Have you ever asked yourself these kinds of questions? At one time or another every thinking person has speculated about his place in the cosmos and his identity with the world of man.

Philosophers, scientists, poets, theologians, assorted crackpots, and ordinary people such as you and I have wrestled with these puzzlers over the centuries and still the answers pretty much elude us. What is the universe? How did it come into existence? What power was capable of this gigantic creation? What was the origin of this power? We simply do not, unfortunately, have information on which to base inferences that might lead to some understanding of what lies behind these mysteries.

The small amount of concrete knowledge that has accumulated over the years has to do only with the physical nature of the universe—insofar as we can detect and comprehend it. The other, more nebulous considerations must, for this time, be left to the philosophers and theologians.

1.1 A Small Chip in an Angry Sea

Generally speaking, the universe is hostile to man. Almost everything that comes naturally to us from space is capable of harming us and if it were not for some unique properties of the earth, we could not exist here at all. (Some of these physical characteristics will be met in subsequent chapters.)

The very insignificance of this planet in the vastness of the known universe is enough to numb the minds of most. Long ago Sir James Jeans said that there are more stars in the universe than there are grains of sand on all the beaches of all the world's oceans, and if stars (among which our sun is quite ordinary) were the size of sand grains, we would need an exceptionally good microscope to find something as small as the earth. The particle of sand representing the sun would be one million times larger (in volume) than the speck of dust standing in for the earth. In terms of comparative diameters, the two would look something like the Figure 1.1 diagram.

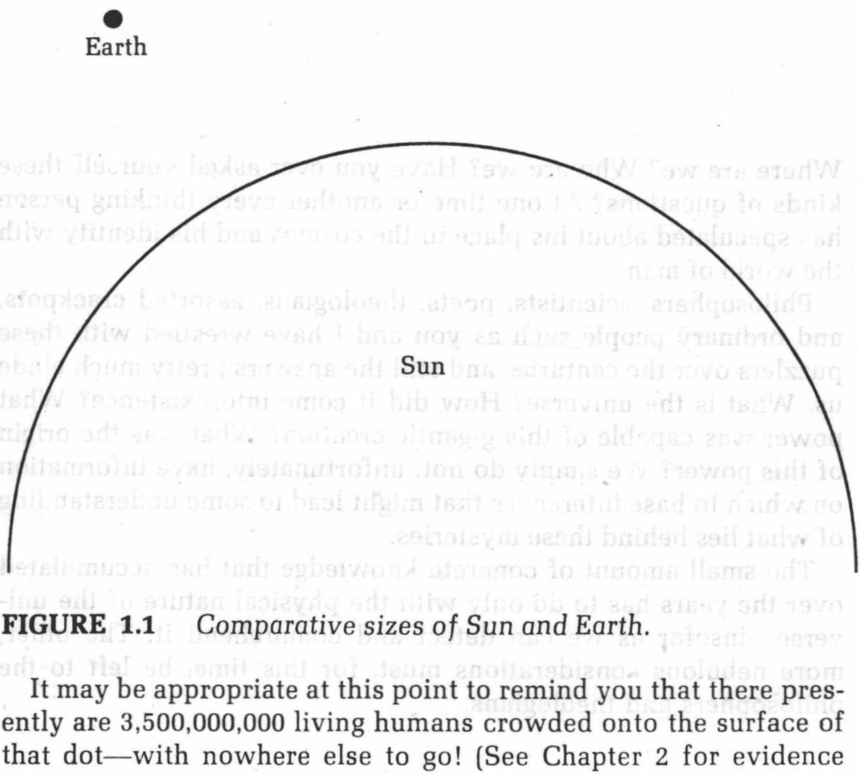

FIGURE 1.1 *Comparative sizes of Sun and Earth.*

It may be appropriate at this point to remind you that there presently are 3,500,000,000 living humans crowded onto the surface of that dot—with nowhere else to go! (See Chapter 2 for evidence supporting this statement.)

1.2 Earth Dimensions

Even though it is small and insignificant relative to other astronomical bodies, the earth is quite large when viewed up close—for example, by you or me standing on its surface. It is so large, in fact, that we ordinarily have little indication that it actually is almost spherical. From where I sit, to be sure, it looks quite flat! (Have you ever tried to convince anyone that the earth is round? How would you go about it without having to appeal to an authority?)

Some of the early Greeks not only believed in the rotundity of the earth but one of them actually measured its circumference and came surprisingly close to the approximately 25,000 miles we now know it to be.* How far is 25,000 miles? A 600 miles per hour jet could fly around the earth in a little more than 40 nonstop hours. A man on a bicycle averaging 10 mph, 12 hours per day would make the trip in about 7 months—if he could find a smooth, circumferential road. And if you walked briskly at 3 mph, it would take you almost two years to circle the globe. By way of contrast, astronauts in orbit go once around in 90 minutes!

Have you watched an eclipse of the moon and noticed the curved edge of the earth's shadow as it moved across the lunar surface, or seen photos of the earth taken from satellites and by the astronauts on their moon trips? Are these reasonable proof that the earth is spherical? We can see that the moon and sun and other planets seem to be spherical in shape; should the earth be different? Why are astronomical bodies spherical? Why should they not be cubes or pyramids?

1.3 Earth Motions

Since we are not directly aware of the movements of the earth, we must rely upon secondary and indirect evidence to convince ourselves that it actually does move. More than a century ago, Jean Foucault proved that the earth rotates. He suspended a heavy ball

* Eratosthenes (third century B.C.) measured the earth's circumference (Figure 1.2) by observing that on the day when the sun was directly overhead at Syene, its altitude at Alexandria was about 7° south of the zenith (the point directly overhead). Knowing the distance between the two cities and assuming that the earth was a sphere, he concluded that the circumference was $360°/7° \times 490$ miles—the distance between the two cities.

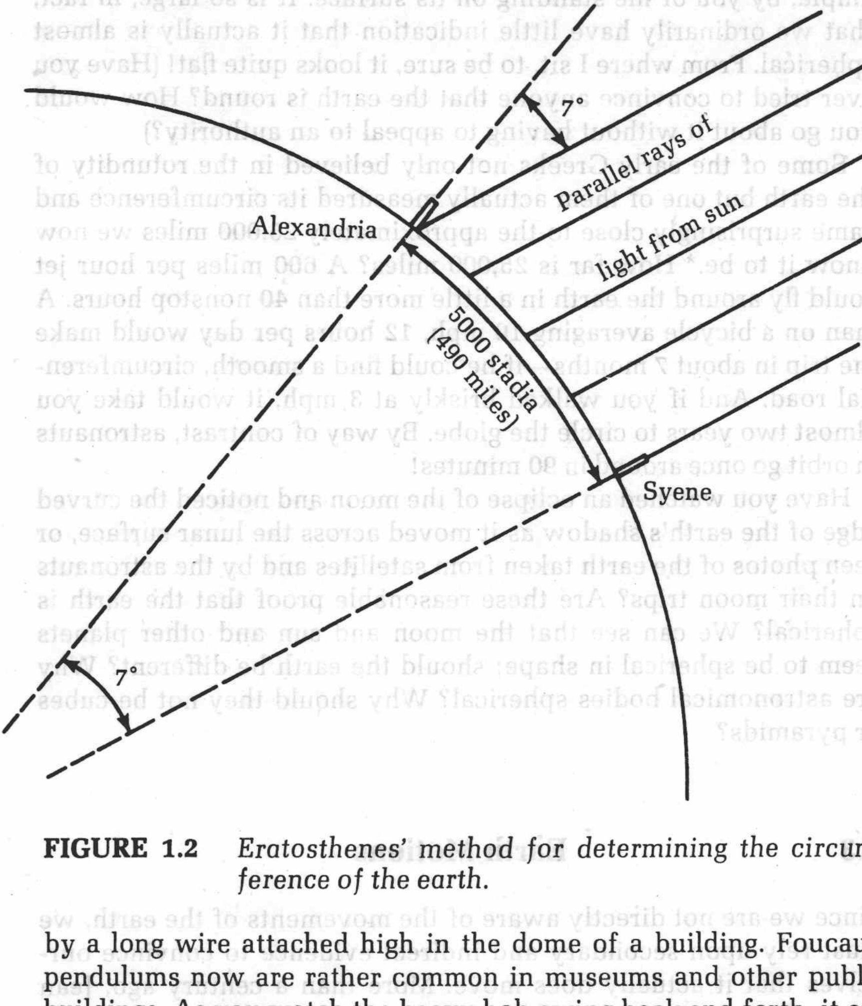

FIGURE 1.2 *Eratosthenes' method for determining the circumference of the earth.*

by a long wire attached high in the dome of a building. Foucault pendulums now are rather common in museums and other public buildings. As you watch the heavy bob swing back and forth, it appears to slowly change direction. Since there is no external force affecting the pendulum, the only explanation is that the earth is turning under the freely oscillating weight!

There are certain natural events occurring on the earth which indicate that the world turns. Can you name some of them? Astronomers tell us the earth is moving in about a dozen different ways simultaneously: rotating daily, revolving annually, wobbling like a tired top, being moved slightly by the moon, traveling through space with the sun, etc.

The planet earth revolves around the sun once each 365.25 days. (The odd 1/4 makes necessary an extra day in February every

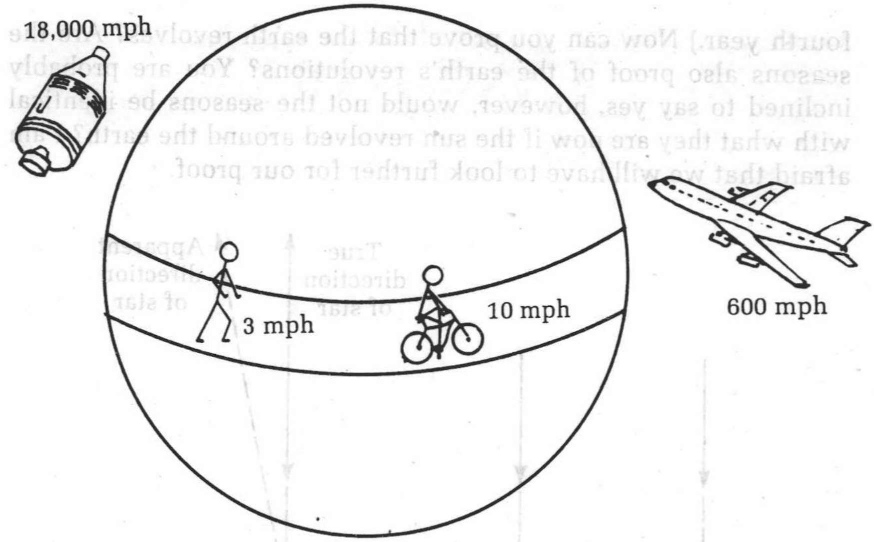

FIGURE 1.3 *How long will it take each of these to circle the globe?*

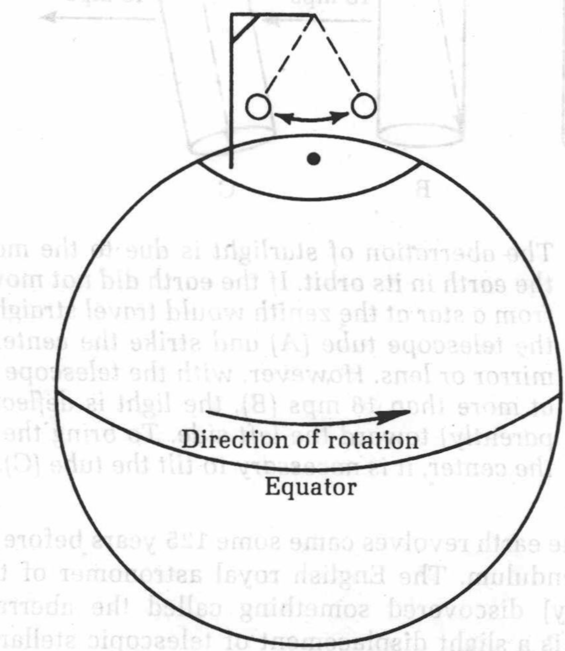

FIGURE 1.4 *As the pendulum bob swings back and forth in the same direction over the north pole, the earth makes a complete turn under it in 24 hours.*

fourth year.) Now can you prove that the earth revolves? Are the seasons also proof of the earth's revolutions? You are probably inclined to say yes, however, would not the seasons be identical with what they are now if the sun revolved around the earth? I am afraid that we will have to look further for our proof.

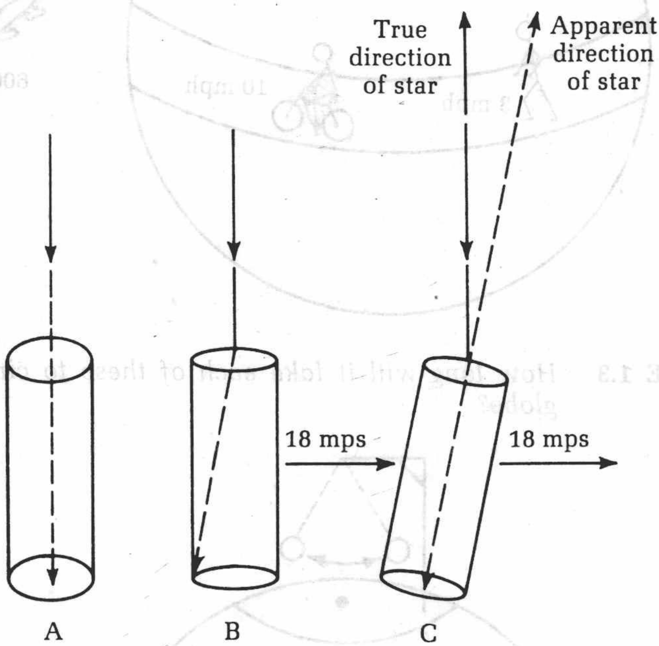

FIGURE 1.5 *The aberration of starlight is due to the motion of the earth in its orbit. If the earth did not move, light from a star at the zenith would travel straight down the telescope tube (A) and strike the center of the mirror or lens. However, with the telescope moving at more than 18 mps (B), the light is deflected (apparently) toward the left side. To bring the light to the center, it is necessary to tilt the tube (C).*

Proof that the earth revolves came some 125 years before Focault devised his pendulum. The English royal astronomer of the time (James Bradley) discovered something called the aberration of starlight. This is a slight displacement of telescopic stellar images due to the speed (about 18 miles per second) of the earth through space as it revolves around the sun. The discovery of **stellar parallax**

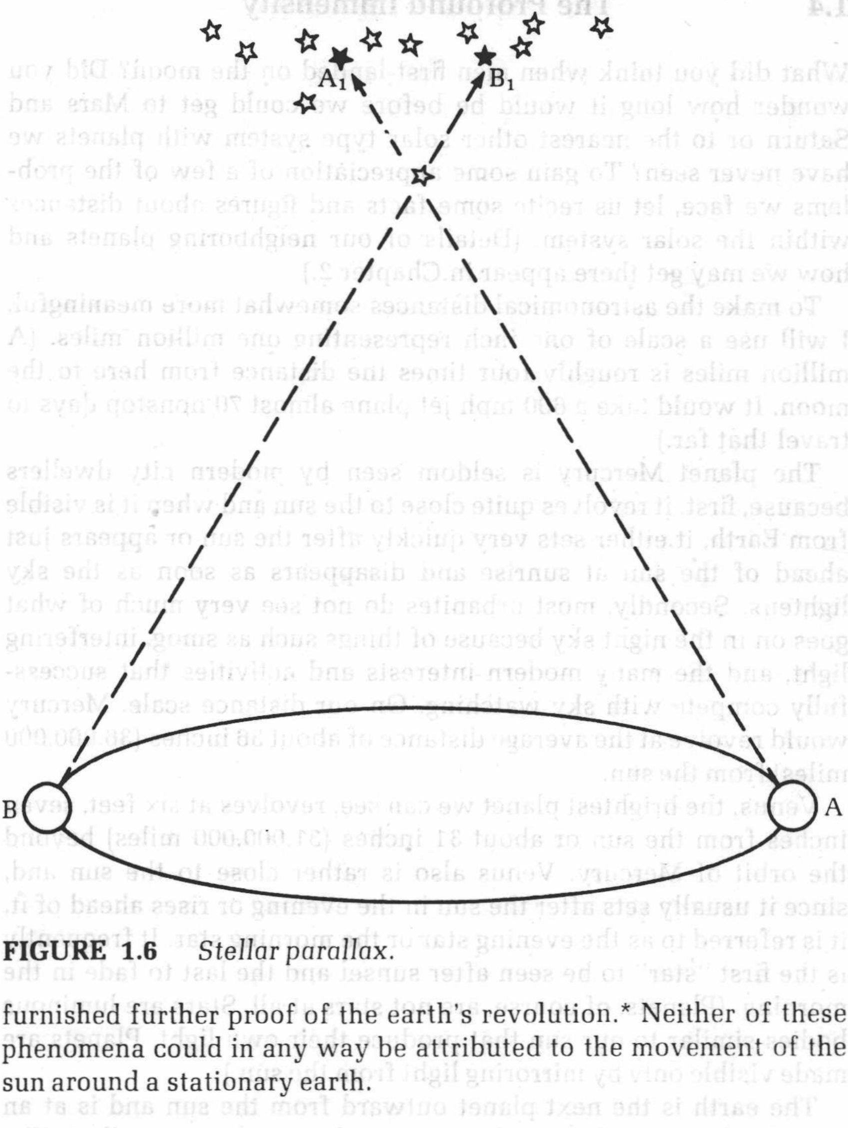

FIGURE 1.6 *Stellar parallax.*

furnished further proof of the earth's revolution.* Neither of these phenomena could in any way be attributed to the movement of the sun around a stationary earth.

* Stellar parallax (Figure 1.6) is the apparent motion of nearer stars against the background of more distant stars. This phenomenon is due to the movement of the earth along its annual orbit which has an average diameter of about 186,000,000 miles.

1.4 The Profound Immensity

What did you think when men first landed on the moon? Did you wonder how long it would be before we could get to Mars and Saturn or to the nearest other solar type system with planets we have never seen? To gain some appreciation of a few of the problems we face, let us recite some facts and figures about distances within the solar system. (Details of our neighboring planets and how we may get there appear in Chapter 2.)

To make the astronomical distances somewhat more meaningful, I will use a scale of one inch representing one million miles. (A million miles is roughly four times the distance from here to the moon. It would take a 600 mph jet plane almost 70 nonstop days to travel that far.)

The planet Mercury is seldom seen by modern city dwellers because, first, it revolves quite close to the sun and when it is visible from Earth, it either sets very quickly after the sun or appears just ahead of the sun at sunrise and disappears as soon as the sky lightens. Secondly, most urbanites do not see very much of what goes on in the night sky because of things such as smog, interfering light, and the many modern interests and activities that successfully compete with sky watching. On our distance scale, Mercury would revolve at the average distance of about 36 inches (36,000,000 miles) from the sun.

Venus, the brightest planet we can see, revolves at six feet, seven inches from the sun or about 31 inches (31,000,000 miles) beyond the orbit of Mercury. Venus also is rather close to the sun and, since it usually sets after the sun in the evening or rises ahead of it, it is referred to as the evening star or the morning star. It frequently is the first "star" to be seen after sunset and the last to fade in the morning. (Planets, of course, are not stars at all. Stars are luminous bodies similar to our sun that produce their own light. Planets are made visible only by mirroring light from the sun.)

The earth is the next planet outward from the sun and is at an average distance of seven feet nine inches (93,000,000 miles). The distance from Earth to the sun (93,000,000 miles) is a unit of measurement within the solar system and is known as the **astronomical unit.** Thus, the earth is one unit from the sun. Mars, which revolves beyond Earth's orbit, is 1.52 astronomical units or 142 inches (142,000,000 miles) away from the sun.

Ceres, the largest of the minor planets (also called asteroids or planetoids), is at an average distance of 21 feet, five inches. The known asteroids number several thousand and revolve about the sun generally between the orbits of Mars and Jupiter. None of the asteroids can be seen with the unaided eye.

Jupiter, the largest of the nine major planets, is more than 40 feet (483,000,000 miles) from the sun. Saturn is almost 74 feet out and Uranus and Neptune are at 148 feet, seven inches and 232 feet, 10 inches respectively. These two planets are beyond the one billion mile mark: Uranus is 1,783,000,000 miles from the sun and Neptune 2,794,000,000 miles. (Our 600 mph jet would require more than 530 years to reach Neptune!) Neptune is 30 times farther from the sun than is the earth, which means that it receives only 1/900 as much heat from our star as do we.

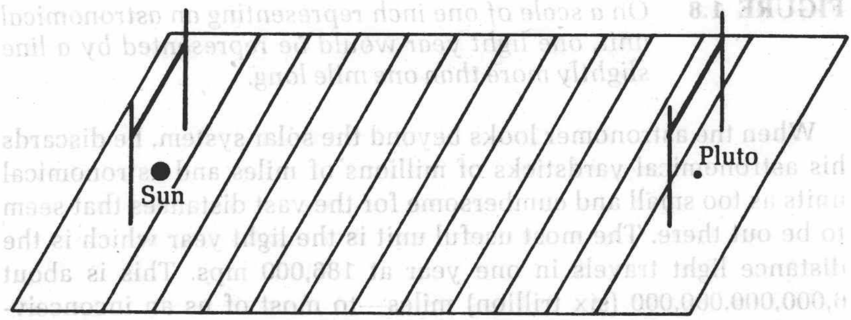

FIGURE 1.7 *Football field scale showing distance between Sun and Pluto.*

The most distant discovered planet is Pluto. It revolves around the sun once during 248 Earth years at an average distance of 3,670,000,000 miles or approximately 306 feet on our model scale. This is a bit longer than a football field and if we represented the sun's size to the same scale (1 inch: 1,000,000 miles), the sun would be a tiny disc the size of a United States quarter dollar barely visible from Pluto at the opposite end of the field. It is almost ridiculous to attempt to represent the sizes of the planets using the same scale that we have been using for distance. The earth, for example, would be a dot only about one-half the size of the period that marks the end of this sentence.

1.5 Beyond the Solar System

If it takes four days to travel to the moon, how long would it take to travel to Mars? Saturn? Proxima Centauri? These distances