Physical Universe

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Man and His Physical Universe

Man and His

Preface

THIS TEXT is designed to provide a sound foundation in the physical sciences for those students who have not decided to major in science. If the student eventually chooses a career in science, this broad view will have provided a helpful perspective. If he decides to major in some other field, he will have an introduction to science that is sufficient for him to continue as an informed layman.

The twin problems of content and treatment are particularly critical for the author of a textbook in physical science: the amount of material that could legitimately be included would fill several volumes; and the treatment must be sound without being too technical. My decisions on content started from the conviction that students will learn more readily and retain more effectively material with which they have a continuing association. The weather, photography, the stars, and geological formations are examples of such material and are important aspects of physical science. The intelligent layman encounters articles about recent progress in atomic theory, the basis for Nobel prize awards, and the findings of space research. Not only in the physical sciences but also in the life sciences, current explanations are being given more and more on the molecular level. Some understanding of chemical change and atomic structure is necessary for the modern citizen. There are many gaps in the field, but the teacher must remember that if he does his job well the student will continue to learn after classes are over.

In the presentation of these subjects I have tried to keep the technical details of special vocabulary and symbols to a minimum. This can be done without sacrificing accuracy. I have tried to be moderate in what was excluded as well as what was included. There are some formulas and symbols, and some use is made of high-school-level mathematics in order to avoid circumlocutions that would insult the student.

The usual order of treatment is to begin with facts of everyday experience, then to go on to facts that can be presented by demonstration, then to present additional factual material in the text, and, from all this, to develop the models and theories that are currently accepted as the best representations of the nature of the physical world. To the extent that it is possible, modern scientific developments are explained in terms of these models and theories. To a limited extent, subjects are put in their historical and cultural setting.

There has been no attempt to segregate the subject matter of the different branches of physical science. Chemistry and physics are introduced wherever appropriate in all the units. Astronomy is mostly confined to the unit on the solar system and geology to the unit on the geological history of the earth. Weather forecasting and photography, treated broadly, serve to introduce many important scientific subjects. There are many small problems, rather than one central one, covered in the unit on electricity and magnetism, and the subject of atomic structure draws on a wide background. The scientific process and critical thinking are emphasized frequently, but it seems useful to devote a special chapter to these subjects at the midpoint of the course; at that time they can be treated in the context of the course, familiar examples can be evoked, and the stage can be set for further examples.

In this second edition, the order of the units has been changed and each unit has been completely rewritten. The subject of the weather starts the student off on familiar ground and introduces many fundamental concepts that are developed and used in later units. The units on the solar system and geology have been moved to the end of the book, so that more explanations in terms of physics and chemistry could be included. Chemical symbols and equations have been introduced and used sparingly. Every topic has been refreshed, with new findings and interpretations replacing outdated ones.

In one of the several outside book reports required each year from my students in this course, I found the following comment: "The book I am reviewing is written a great deal in the manner of a textbook. It is completely factual with little attempt to bring out any great interest." It is my earnest hope that such a criticism is not deserved by this book. A textbook for physical science should be interesting and exciting—certainly the subject is. It is also hoped that those students who read this book will gain a new respect for scientists and their contributions to our culture, and that they will have a developing interest in and an understanding of science as they go through life.

Oakland, California
January, 1963

RICHARD WISTAR

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UNIT FIVE: THE SOLAR SYSTEM AND BEYOND

UNIT SIX: STORY OF THE EARTH

Unit One

Weather

Chapter 1

Our Atmosphere as a Gas

THE TOPIC of weather forecasting has been chosen to open this book because it is a subject that can lead us naturally and quickly from the known to the unknown. An understanding of this topic will draw on a broad background of important scientific principles, and your day-by-day practice of predicting will help keep these principles and their more general applications fresh in your mind. Many aspects of physical science will be developed carefully in an effort to show you how we arrived at our present ideas and what we still do not understand. The final results of this long inquiry are important, but a study of the path by which we reach them is even more so.

What we observe as the "weather" is the series of events occurring at the bottom of a sea of air many hundreds of miles deep. This sea is complex in structure and extremely complicated in behavior. Since we live at the bottom of the atmosphere we will talk about its height rather than its depth. Let us consider the problem of determining the height of the atmosphere. What evidence can we look for? We know that even moderate exercise makes us short of breath near a mountain top, and that explorers of really high mountains must take oxygen masks although they are only six miles above sea level. Man and animals in spacecrafts circling the earth at a few hundred miles up must be in completely sealed cabins. The friction of the atmosphere heats incoming meteors to incandescence at 185 miles, and the glow of the northern lights disappears above 600 miles.

The thin layer that lies within 30,000 to 40,000 feet of the surface is called the troposphere. Here the air is moving along the surface of the earth, churning up and down and swirling in great whirlpools. The temperature tends to decrease with altitude, reaching the freezing point below 20,000 feet. Above 40,000 feet the vertical mixing largely ceases, so it is the troposphere that we need to study to understand the weather. Since all of the atmosphere is a gas, we must study the behavior of gases; besides varying amounts of water vapor and dust, the air consists of 78% nitrogen, 21% oxygen, and 1% rare gases. Hurricanes and thunderstorms are obvious examples of the tremendous amounts of energy involved in weather phenomena; to understand these and many other aspects of the weather, it is first necessary to acquire a background in the basic elements of physics.

WEATHER LORE

It would be hard to find a field of public activity that equals that of weather forecasting in the mixture of truth, half truth, and falsehood that has been handed down in our folklore.

We have such sayings as:

An evening gray and morning red
Will send the shepherd wet to bed.
Evening red and morning gray
Two sure signs of one fine day.

And such signs as, "When rheumatic people complain of more than ordinary pains it will probably rain," "Smoke from the chimney descending to the ground means rain," "A ring around either the sun or the moon indicates rain within two days." These are consistent with what we know to be dependable signs of good or bad weather.

Then we have Izaak Walton's (1593–1683) advice to fishermen:

When the wind is in the north,
The skillful fisher goes not forth;
When the wind is in the east,
'Tis good for neither man nor beast;
When the wind is in the south,
It blows the flies in the fish's mouth;
When the wind is in the west,
There it is the very best.

This could be true for some parts of the country, but it would be false for many others.

Finally, there are sayings which do not contain a grain of truth:

In this month is St. Swithin's day [July 15]
On which, if that is rain, they say
Full forty days after it will
Or more or less some rain distill.

"If the new moon appear with the points of the crescent turned up the month will be dry. If the points are turned down it will be wet." The direct opposite of this is also quoted. The fact that the crescent of the new moon never does point down has apparently escaped the attention of the people who perpetrate this one. A final example of nonsense that is still believed in by many people is the rule:

Go plant the bean when the moon is light,
And you will find that this is right;
Plant the potatoes when the moon is dark,
And to this line you always hark.

The development of science has enabled us to predict the weather with a considerable degree of accuracy. The results still leave much to be desired, but as our understanding of the situation increases the dependability of the forecasts becomes greater. Today the United States Weather Bureau collects data from stations all over the country and from ships at sea. After analyzing this information it advises owners of farms and stores about coming storms, freezes, hot spells, etc. Farmers have learned the value of using these forecasts in deciding whether to work late to get in a crop, to light their smudge pots, to insulate fruit in freight cars, etc. Stores plan sales campaigns; power companies, airlines, and road crews plan their work; small boats look for storm warnings; and you and I decide upon a picnic on the basis of the weather forecast we read in the paper or listen to over the radio.

AIR PRESSURE AND THE BAROMETER

Observing Air Pressure

We are not ordinarily aware of the atmosphere around us. We breathe it in and out subconsciously. We walk around in it without hindrance. Nevertheless, however invisible they may be, stiff winds uproot trees. Steam from boiling water condenses and then disappears—it must go somewhere. On a cold winter day the window panes collect moisture on the inside—it must come from the atmosphere.

The air around you weighs about 1.20 grams per liter (1.2 ounces per cubic foot) at room temperature and normal atmospheric pressure. This value can be determined rather easily by using a precision balance to weigh a glass container (a separatory funnel) before and after removing the air from it with a vacuum pump. The air in an ordinary two-story house would weigh close to a ton, because of the column of air pressing down on us that reaches high above the earth. Another example of atmospheric pressure can be seen when you turn a partly filled glass of water upside down in a dishpan, the water inside the glass can be made to stand higher than the level of the water in the pan (Figure 1–1). What is holding up this column of water? If the pressure at *D* and *C* are not the same, water will be pushed from the place where the pressure is greater to the one where it is less. Since the water is free to travel, between *C* and *D*, and it is not doing so, we can assume that the pressure is the same in both places. The atmospheric column several hundreds of miles high is pressing down at *D*. At *C*, the pressure is the combination of that exerted by the column of water, *B*, and that of the air trapped above it at *A*. We can repeat the experiment with the glass completely full of water, and the whole column of water will still be held up. Is there any limit to the height of a column of water which would stay up in a glass tube under these circumstances? According to this analysis, the downward pressure of the column of water cannot be greater than the downward pressure of the atmosphere.

The Greeks and the medieval scientists did not approach the problem this way. They said that if a glass tube was filled

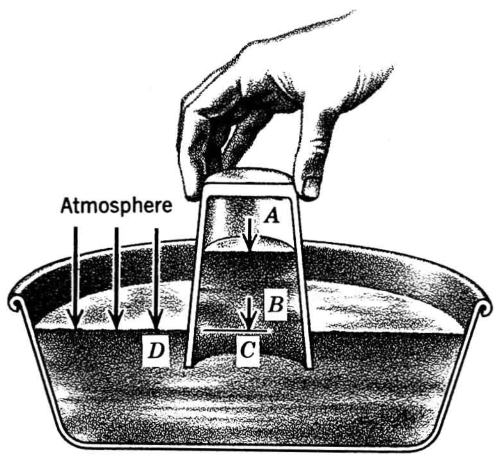

Figure 1–1. The atmospheric pressure at D exactly equals the pressure at C, which is made up of the sum of the pressure of the trapped air, A, and the column of water, B.