# PHYSICS

## A Descriptive Interpretation

Charles H. Bachman

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C. H. BACHMAN

Professor of Physics, Syracuse University

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# Preface

This book follows the pattern assumed by a physics course that I have developed over the last half dozen years. The purpose of the course, and therefore of the book, is to present to non-science students as complete and up-to-date a view as possible of the subject of physics and to encourage them to apply this knowledge in recognizing and understanding physical principles in things about them. No mathematical background can be expected of these students. Physical principles must be presented descriptively; intuition, experience, and analogy must be depended upon extensively.

Actually I had a number of objectives in mind as I prepared this material. First, I wished to incorporate "modern" physics with "classical" physics in such a way as to minimize the distinction and form a logical unified presentation of the whole. Second, I proposed to accomplish the task in a descriptive way without recourse to mathematics and problem working. Third, I tried to maintain a scientifically accurate presentation. Fourth, I hoped to foster student interest by the use of everyday examples whenever possible.

The method of approach used here includes an early discussion of the electromagnetic spectrum, which I believe to be one of the most pedagogically useful topics of physics. This discussion leads naturally to a discussion of particle physics, which in turn forms a good background for the treatment of the classical branches of the subject.

After the two chapters on earth physics and astrophysics the information of the first half of the book is applied to help in understanding the operation of a number of familiar examples. The human body offers many interesting examples of physics applications. These examples, together with some familiar engineering applications, are useful both in bringing forward again principles which were covered earlier, and also sometimes in introducing new concepts. One example of a new concept is the vector concept of forces. When applied in body mechanics to a discussion of backaches, this subject evokes as much student interest as television.

The material of my book is covered in a two-semester course of three classes per week. It breaks naturally in content at about the midpoint. The first fifteen chapters form a reasonably complete one-semester course, although, as has been pointed out, some material has purposely not been introduced until the second half.

The manuscript, as is usual, has been revised many times, with much stenographic labor, and my appreciation is expressed to all who participated. I am grateful for the understanding and the abilities of Mr. John Davis, whose art work both lightens and enlightens many of the illustrations. I also wish to thank Professor H. W. Berry, who read the manuscript and recommended many changes resulting in greater accuracy and clarity. And finally it is a pleasure to acknowledge the help of my wife, who typed the first copy of the manuscript from tape-recorded lectures and who has been a continual source of encouragement.

C. H. BACHMAN

*Syracuse University*
*January, 1955*

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# PART 1

# Introduction— Some Fundamental Working Knowledge

# CHAPTER 1 Conception of the Universe

## 1.1. Methods of Studying Physics

In many highly organized activities we find large numbers of spectators compared to the number of participants. Although most of these spectators would create a sorry spectacle if they were to join the football team or the symphony orchestra, as the case might be, still they participate vicariously and with great enjoyment. The enjoyment depends, among other things, upon their understanding of the activity. An ex-football player, who knows the rules and feeling of the game, gets added enjoyment from watching a contest. An experienced violinist will get a richer return from the symphony program. Not all people can have the experience of participating in an activity, but it is possible to study the rules, the techniques, the history, and associated lore and so get greater enjoyment as a spectator. Here we shall study in order to appreciate physics—not to become physicists.

It is not easy to define physics. It might be said that physics has to do with the make-up and behavior of all materials. Admittedly this definition covers a lot of territory. The amount of knowledge included under the term physics is so great that a systematic approach is essential. It would be convenient if nature had segregated all phenomena in an orderly way for purposes of study. Instead, she has mixed them thoroughly for her own ends. Our present needs will be served if we divide the body of physical knowledge into three groups: microcosmic, macrocosmic, and cosmic. Typical examples are shown in Figs. 1.1, 1.2, and 1.3.

(*a*) Microcosmic involves phenomena smaller than those to which our senses normally respond.

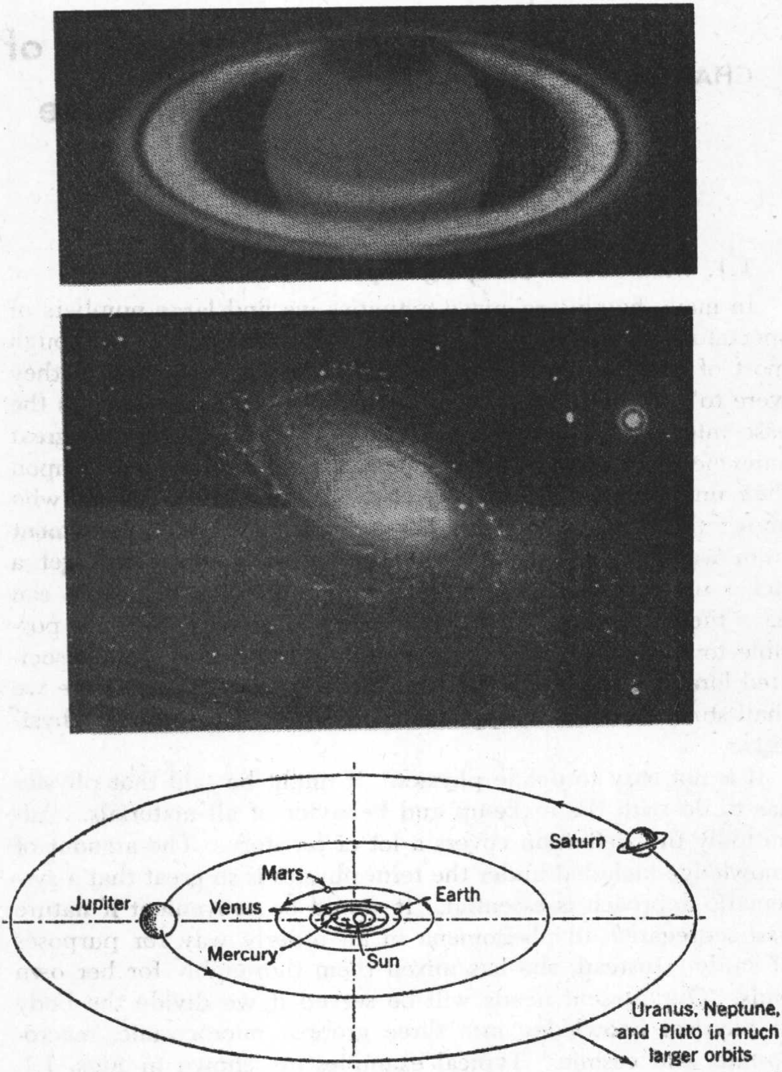



Fig. 1.1. The cosmic world consists of the vast space of the universe and all the bodies contained within it. Examples are: (*Top*) The planet Saturn and its system of rings. (*Center*) The spiral nebula in Ursa Major (the big dipper). (*Bottom*) Our solar system. (Photographs by Mt. Wilson and Palomar Observatories.)

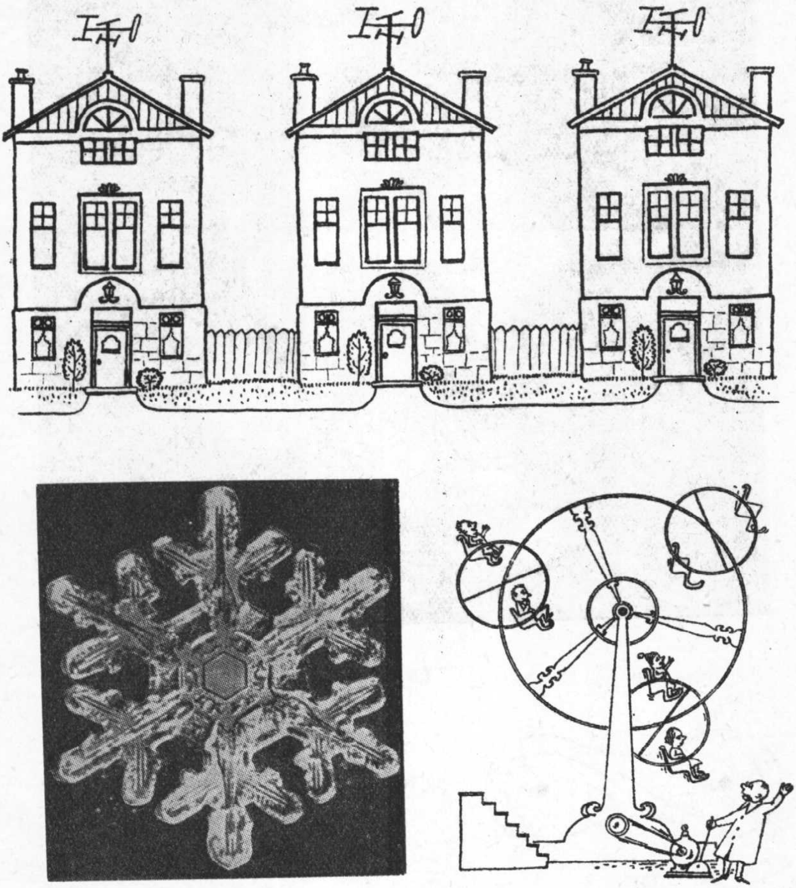
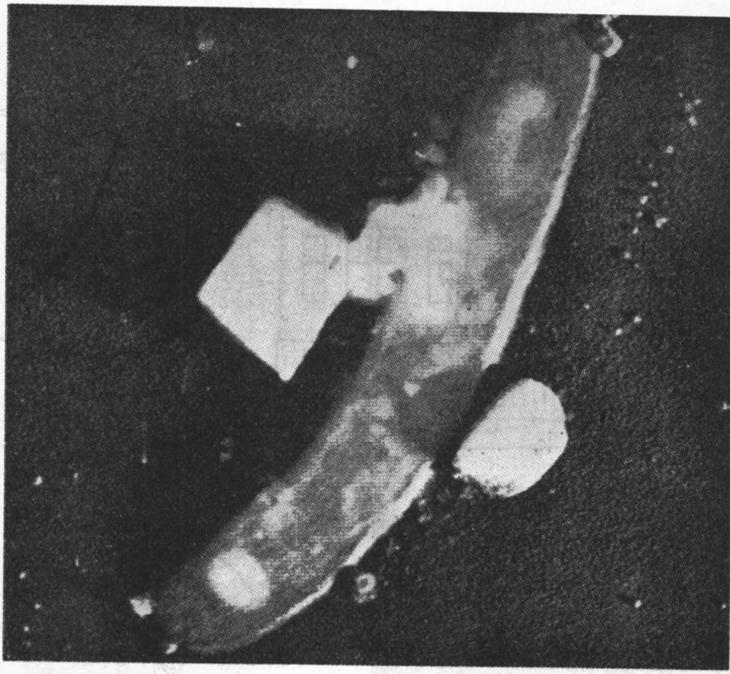
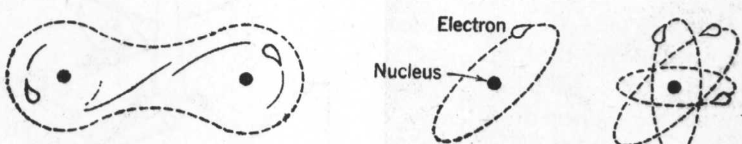


Fig. 1.2. The macrocosmic world of our familiar surroundings contains much order and symmetry. (Snowflake photograph by V. J. Schaefer.)



(*a*)




(*b*) (*c*)

**Fig. 1.3.** The microcosmic world is that of infinitesimal structure. (*a*) Electron micrograph showing a cubic salt crystal and tuberculosis bacillus magnified 27,000 times. (Courtesy E. F. Fullem.) (*b*) Imagined molecular model. (*c*) Imagined atom models.

(*b*) Macrocosmic deals with the world we encounter directly.

(*c*) Cosmic refers to the vast space about us—solar and interstellar phenomena.

We shall learn about the phenomena and material in each of these worlds by asking a few simple questions:

1. In what structural form do we find the material?
2. What physical conditions are encountered—what forces are involved, what motions, masses, temperatures, pressures, etc.?
3. What means are available for observation and measurement?
4. What are the apparent laws of behavior and organization?

Before going into detail we shall take a bird's-eye view of the three divisions and apply these questions in a general way just for orientation purposes. We shall start with the macrocosmic world because it is most familiar to us.

## 1.2. The Macrocosmic World

This is the world we know through our experiences. Using our several senses we have learned much concerning the material world about us and how it operates. Some of this we have gathered firsthand, and some has been given us by other observers.

We know that this world consists, structurally, of solids, liquids, and gases. There are many kinds of each of them, all differing in some characteristic, possibly color, taste, hardness, melting point, etc. Some of the materials have natural regular structure, as crystals or wood, and some have man-made regularity, such as a brick wall or a woven fabric. On the other hand, many materials show nothing but completely random orientation. All are formed of elements or combinations of elements. Some materials exhibit different structure under varying physical conditions; for example, water is found as solid, liquid, or gas.

The physical conditions for the most part are not extreme. We can produce or experience temperatures from a few hundred degrees Fahrenheit below zero to a few thousand degrees above zero (water boils at 212°F and freezes at 32°F)—pressures up to a few hundred times that exerted upon us by our atmosphere—time from a second to a few tens of years. So common to us that we sometimes forget it, is the gravitational force that governs much of our lives (see Fig. 1.4). Though not all, these are among the most common physical conditions encountered in our macrocosmic experience.

For measurements and observations we depend primarily upon our senses, and sometimes we achieve great accuracy and sensitivity by them. On the other hand, there are times when the senses are completely inadequate. In any case we must use them as the final port of entry to our mental storehouses. To increase their effectiveness we have developed many aids such as rulers, clocks, scales and balances, barometers, thermometers, speedometers, and a host of other devices.

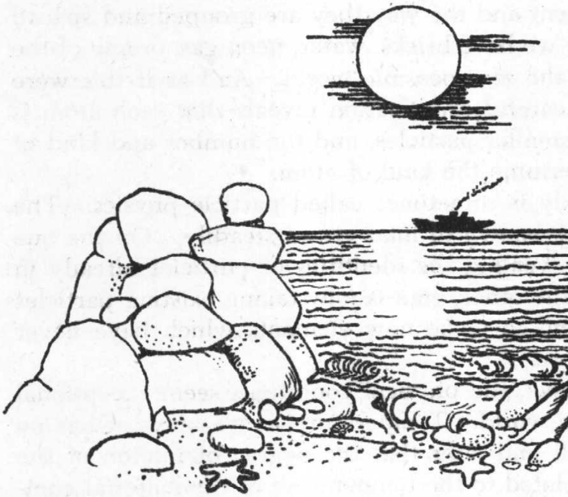
The laws of behavior of our macrocosmic world are not decrees which man has established for the guidance of nature. They are rather laws for our guidance, telling us how nature will behave under certain conditions. Such laws describe the behavior of falling bodies, the flow of electric current through conductors, or the reflection of light from a surface.

## 1.3. The Microcosmic World

At one time or another each of us has probably experienced difficulty in seeing something or detecting it by touch because it was too small. The exploration of this microcosmic world, the world of small things, has been one of the most fascinating fields of physics.

It is true that some of us can distinguish smaller objects than others. Human eyes differ greatly as we shall see later. But we shall not be concerned about such minor differences as we discuss microcosmic phenomena. The smallest things the sharpest eye can see are many thousands, even many millions, of times greater than the distances and the sizes of things we shall encounter in our microcosmic world.

When we ask our four questions in this world we find, first of all, that structurally the concepts of gas, liquid, and solid have no meaning. When we examine microcosmic matter we do not notice such features as color, hardness, ability to pour or to maintain a fixed shape. Instead we see small particles—always with much space between them. They are called atoms, ninety-two different kinds of which are found occurring naturally. The



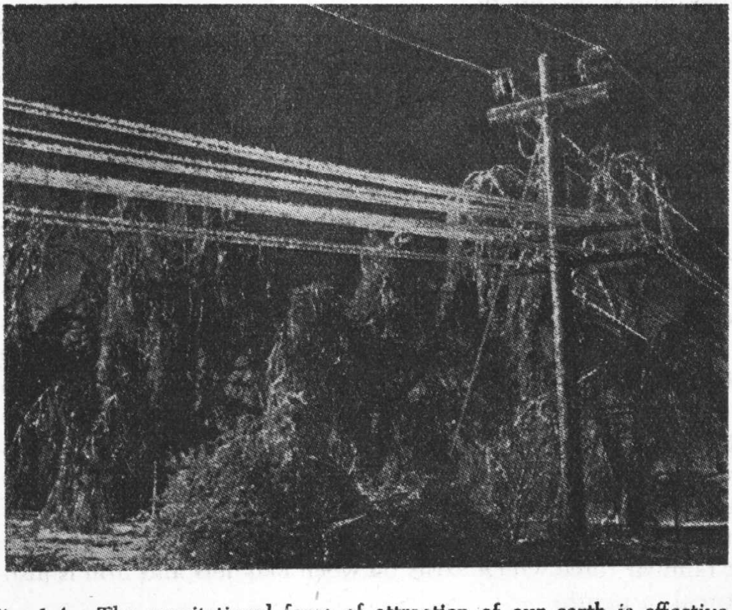


Fig. 1.4. The gravitational force of attraction of our earth is effective on all bodies on its surface as well as on such distant bodies as the moon. (Photograph by V. J. Schaefer.)

type of atoms present and the way they are grouped and spaced determine whether we have bricks, water, neon gas, or any of the other materials of the macrocosmic world. And as if this were not enough, more careful examination reveals that each atom is made up of other smaller particles, and the number and kind of these particles determine the kind of atom.

This field of study is sometimes called particle physics. The number of particles known to man grows steadily. On the one hand, research is revealing the identities of particles already in existence, and, on the other, man is now taking existing particles and combining them to make new elements which have never been found in nature.

As we might expect, the physical conditions seem exceptional in this microcosmic world. Temperature as we know it has no meaning. We shall find later that the degree of motion of the small particles is related to the temperature of the material composed of these particles, but as far as each particle is concerned temperature is meaningless.

As seems obvious the masses of these particles and their dimensions are exceedingly small compared to familiar objects, not by a thousand times or ten thousand but by a million or so. And with the particles being so small, we notice another thing which is not so easy to believe; each particle is separated from its nearest neighbor by what to it seems a tremendous distance.

Very important to the behavior of the particles is the influence they have on each other. We mentioned the importance of the force of gravity to us. This force of gravity is experienced between any two particles, for instance, the earth and our bodies are pulled together. A similar, although much weaker, force exists between each of us, between any two masses, and even in the case of the small particles this attractive gravitational force existing between them plays a part. The forces associated with electricity (see Fig. 1.5) also exert much influence on their behavior. Such a force enables a charged pocket comb to pick up a bit of paper, and at times makes hair stand out when brushed. That familiar force which exists between magnets and iron is also electrical in nature.

It should be obvious that the usual methods of observation will not serve under such circumstances. The natural senses, even