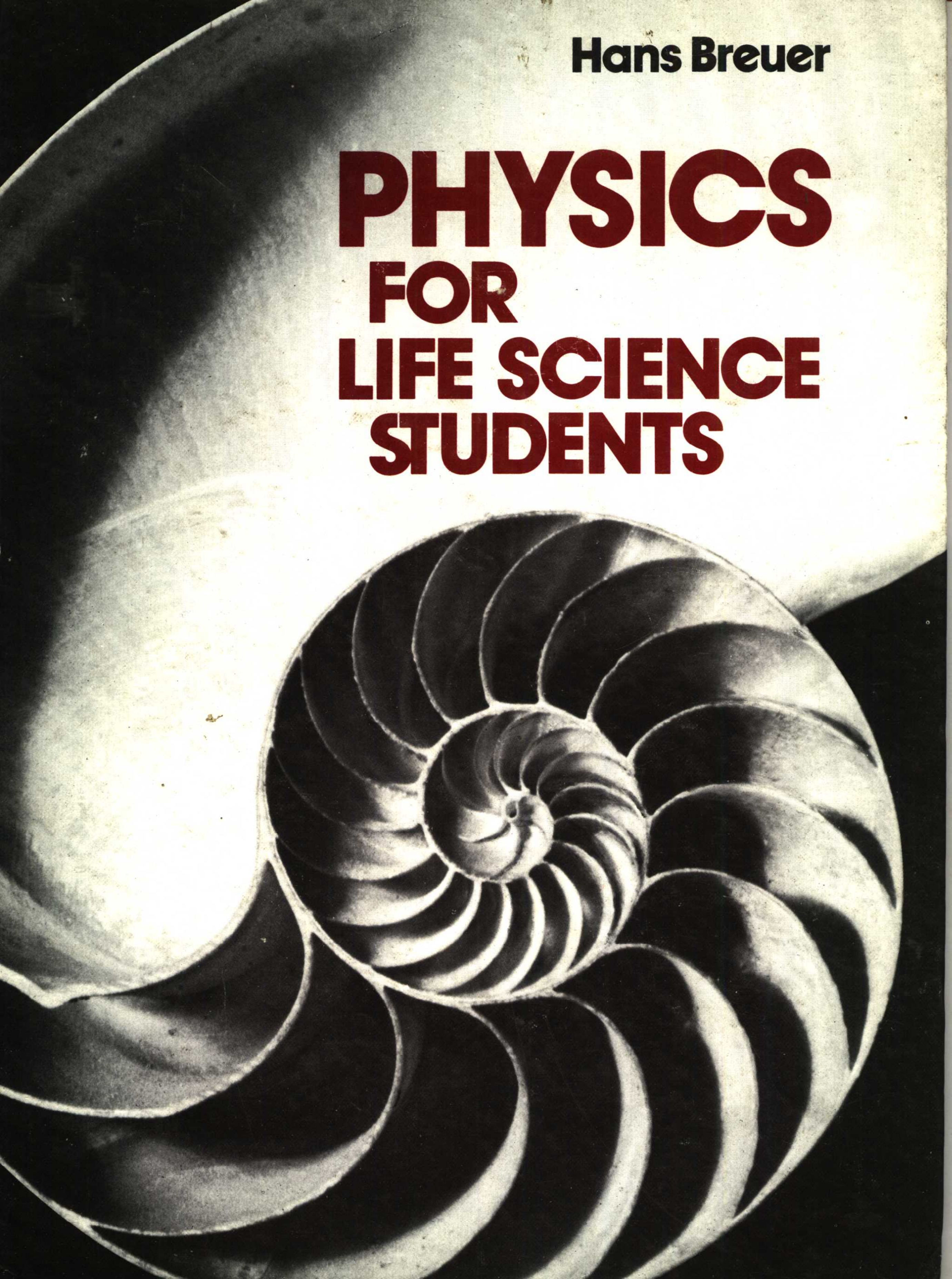
Hans Breuer

PHYSICS FOR LIFE SCIENCE STUDENTS



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TO THE STUDENT

Teaching physics to life science students is a difficult and challenging undertaking. If the physics becomes too abstract or too far removed from topics in biology and medicine, the student may lose interest. On the other hand, if the physics becomes so diluted that its clarity and overall consistency are submerged, then the intellectual rigor has been removed but the book does not fill the student's needs. The organization of this book has been dictated by the objective of avoiding both of these extremes. A careful determination of the relative importance of the various branches of physics for life science students was required. As a result some topics are treated only briefly while others are more detailed, this book being an introduction to physics and not to the life sciences.

You may wonder how much mathematics is used and whether it is necessary to know calculus. From my experience working with students of biology, medicine, and physics in Germany, Canada, and the United States, I know that it is not so much the calculus but the algebra that causes mathematical difficulties for the student. Therefore I have shown, in general, every intermediate step in calculations and derivations. You do not need to know calculus when you first open this book. You are introduced to elementary differential and integral calculus "as we go." This is surely simpler for you than surrounding formulas and phenomena with excessive wordiness and confusing analogies when a single line of calculus suffices. The same approach applies to vector notation when introduced. The use of graphical representation also helps to clarify topics—a method that is indispensable to the modern scientist.

Although the use of mathematics underlines and emphasizes the exactness and internal consistency of physics, do remember that the laws of physics are not necessarily the ultimate truth. They are only approximations, even where applied to pure physics. You must, therefore, take a critical stance: "What is the scope of that law?" "Are the basic assumptions fulfilled for these specific applications?" "What limits the accuracy of this particular formula?" Those are some of the questions you should ask yourself constantly. In this text I have stressed such limitations where they are not obvious.

In the life sciences we must be aware of the pitfalls of straightforward application of physical principles. The simplest biological systems have more parameters than the most complex ones in physics. There are also aspects intrinsic to living systems that elude the purely physical approach. For example, one obvious way to calculate a mutation rate is to estimate the radiation damage done by ever-present cosmic radiation to the carriers of genetic information, DNA. Knowing the structure of those double-helix molecules and the flux of cosmic radiation, we could then predict the rate of evolution. The calculation is simple enough, but it leads to an incorrect result. Why? Because there is a biological factor that has been overlooked: whenever one of the identical strands of the double helix is broken by radiation, a mechanism is triggered to repair the damaged strand by using information available from another strand.

Keeping such limitations in mind, you can then use physics as a means of gaining insight into life science phenomena; e.g., why man can see better than the anatomical structure of the retina seems to allow. You can observe conservation principles at work and may even enjoy understanding odd questions such as what an electron, waterbug, and supersonic aircraft have in common.

Some organizational aspects of this book: I have not pretended that you are completely ignorant of physics when you turn to the first page. We all live in a technical world that is largely governed by physical laws, and you are certainly aware of some of them. Besides, you had some introduction to science in high school, some rudimentary knowledge that remains. Therefore, I have used similarities and analogies with material that is covered in detail later in the book; of course, that has to be very basic material.

Throughout the book, the metric convention is used. If space-age organizations like NASA and conservative countries like England "go metric," we should not pretend that inch, pound, slug, and fortnight are still up-to-date units of measurement. However, conversions are given for metric versus nonmetric units. The general style and notation follows the *Style Manual* of the American Institute of Physics and the *Council of Biology Editors Style Manual.*

If you study the table of contents you will find the topics usually covered in an introductory physics text. However, the emphasis is different. Some subjects such as point mechanics, rigid bodies, thermodynamics, magnetostatics, and electrostatics are treated rather briefly. More space and time is devoted to topics that are pertinent for the student of life sciences: deformable media, phases of matter, transport phenomena, and radiation. You will also encounter chapters on unconventional topics such as graphical representation and information handling and processing. Most chapters include a flow chart to serve as a guidepost so that you are always aware of the general structure of the chapter and the interrelationship of topics, even when working at a seemingly small detail. The additional reading material cited at the end of each chapter will serve to give you further insight or more detailed explanations of special features of the chapters. Do not overlook the appendices: part A should be especially useful to you.

It is my hope that you will discover, once having finished this book, that physics is not by nature dry and indigestible to a student of the life sciences.

HANS BREUER

Dakar, Africa

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