PHYSICS for Biology and Pre-Medical Students

SECOND EDITION

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To Pat and Denise

PREFACE TO THE SECOND EDITION

The first edition has been widely used in a large number of countries and in the preparation of this second edition we have sought advice from all these quarters. Unfortunately, because of the differing backgrounds with which biological and premedical students enter university in the different countries, some of the suggestions for amendments were self-cancelling. The present volume represents what to us seems the best compromise.

There was a widespread desire for many more worked examples in the text and this has been satisfied. In addition, our own experience has accorded with that of some users that the amount of mechanics was excessive, and this section has been severely pruned. In compensation, the properties of liquids have been more extensively treated, and many more examples of relevance to biology and medicine have been given. A number of comments suggested that, tubes being now obsolete except for highly specialized purposes, the chapter on electronics should be rewritten from a solid state point of view, and this has been done. These are the major changes.

In addition, new techniques and new advances have been included where they seemed of major importance, and some omissions have been repaired. A number of new problems have been added. Several additional diagrams are included, and many of the old ones redrawn. We believe that most users will feel that their main suggestions have been attended to.

Our most sincere thanks are due to the many people who have taken the trouble to write to us with helpful suggestions, in particular to Professor K. Maack Bisgård, Dr. B. Buchmann, Professor J. W. Brommert, Dr. M. J. B. Duff, Dr. J. A. Scott, Mr. S. Steenstrup, Dr. D. Tovee, Dr. J. W. Twidell and Dr. E. J. Williams. We should also like to single out Miss P. M. Mitchell for her sterling work in producing an immaculate typescript from almost unreadable copy.

D.M.B.
January, 1975 S.G.G.M.

PREFACE TO THE FIRST EDITION

This book represents an attempt to overcome the difficulties experienced by lecturers in physics when they give courses in their subject to pre-medical, pre-dental, and biology students. They soon discover that there is no textbook they can recommend which adequately covers the material they would like to present. They are faced with old-fashioned approaches, watered-down versions of texts for physical scientists, and nonmathematical and verbose treatments really meant for arts and social science students. None of these copes with the problem.

The recent advances in physical science and their wide application in all fields means that nowadays biologists, doctors, and dentists are dealing with highly sophisticated physical apparatus, and are forced to know something of quite advanced physical concepts. An attempt to give this group of students a physics course suitable to their future needs often founders on the twin difficulties of the lack of time available and the poor mathematical equipment of the students. In the following text an approach has been taken which goes some way toward solving these difficulties.

All biological, medical, and dental departments in the University of Dundee were canvassed as to what physics they would like their students to learn during their first-year course. A long series of discussions with these departments quickly removed the obviously absurd and the clearly impossible, and finally the real essentials were arrived at. Large portions of traditional physics, such as statics, have been eliminated from the course almost completely, and others barely touched on, in order to make room for several topics which are considered of great importance. Some material only treated in a physics honours course has been introduced, simply and relatively nonmathematically, in order to give the students some understanding of matters which loom large in their later courses.

It was found essential to give the students, who attend no mathematics courses in the University, and some of whom have poor school qualifications in that subject, what we would describe as a reading knowledge of mathematics, particularly simple calculus, vector representation, and statistics. The first two of these topics are introduced as painlessly as possible through the physics, in an attempt to show that math is just a convenient and shorthand method of coping with certain problems that must be tackled. Statistics, necessary for a complete understanding of some of the later material and essential in the future careers of these students, has been allotted a chapter early in the book. Some lecturers may

prefer to leave this subject until a later stage or to omit the chapter completely. The organization of the book is such that the omission of some of the more specialized chapters, such as those on statistics and on specialist microscopy, does not affect the continuity of the rest of the subject matter. These chapters will then serve as reference material for a student at a later stage in his career.

In some fields a "black box" approach has been taken, it being felt that a knowledge of what was inside some of the apparatus the student would eventually use was less important than that he should understand the principles underlying its operation and what he could, and what he must not, do with it. For instance, an attempt has been made to get over some of the ideas of impedance matching, since one of the major sources of requests for advice from other departments lies in this field, which is apparently unknown outside physics and engineering.

The course has now run for three years. Although we would not claim that the students who have passed through it emerged as brilliant physicists, we do believe that their understanding of what physics is about has improved, and that they have displayed a greater interest in a course which they now feel has some relevance to their future careers and is not just an obstacle placed in their way to a degree by a reactionary university.

We should like to express our thanks to Dr. B. L. Andrew, Dr. W. G. Ferrier, and Drs. A. G. R. and M. Law, who looked over portions of the manuscript and made most helpful comments: also to Mr. W. Watson for his expert help in producing the photographs.

D.M.B.

February, 1970 S.G.G.M.

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CHAPTER 1

PHYSICS AND PHYSICAL MEASUREMENT

1.1 INTRODUCTION

Many biological, pre-medical, and pre-dental students regard the course on physics which they are required to pursue as an unnecessary and unfair obstacle in the path to their qualification. Indeed, we have heard a Dean of Medicine declare that the only purpose the physics and chemistry courses served was to weed out the less able undergraduates, since there were few later courses that could do the job with such efficiency. When wrong-headed ideas of this sort abound, it is worth while starting a textbook of physics aimed at these groups of students by stamping vigorously on such misconceptions of the purpose of a study of the subject.

At one time the avowed aim of general scientific courses was to give a good grounding in scientific method and scientific philosophy to all students. A case could still be made out for doing this; but in the modern climate of opinion ancillary physics courses are unlikely to survive if this is their only purpose. Biologists, doctors, and dentists are quite clear that however worthy the aim of improving the general education of their students may be, this is the least of the purposes which the present course serves. Indeed, their desire is for more physics to be taught, because of the difficulty of dealing with modern biology and medical technology without a good grounding of physical knowledge.

Physics has advanced much more rapidly in the last few hundred years than most other subjects. Its methods have proved so fruitful, and its results so far-reaching, that all other sciences have drawn more and more heavily from it. Let us quote some remarks made in a current textbook of biology in wide use.* "Current study in molecular biology indicates that areas such as genetics, evolution, general physiology, and even the classification of organisms can all be carried to the molecular levels. The molecular approach to biology is based on our present-day understanding of physics and chemistry, and their applicability to biological problems. . . . By using the tools of physics and chemistry, it is possible to treat many biological problems with precision and with rigour."

This represents a typical view of the direction in which biological science is moving, and it is likely that the trend will be even more marked in the future.

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* *The Study of Biology*, by J. J. W. Baker and G. E. Allen (Addison-Wesley).