PREFACE AND GUIDE TO USING THIS BOOK

Modern medicine is a rapidly evolving and diverse field that relies increasingly on technological developments. Many of these developments involve the sophisticated application of the fundamental principles of physics. As a result, there is a growing need for an educated community of scientists, engineers, and technicians who have some background in the relationship between these principles and the applications. Our book is intended to meet this need. Equally important is that we hope it is useful for students majoring in diverse subject areas (psychology, natural sciences, nursing, engineering, ...) who are curious about this field and/or intend to find careers in related subjects.

Every reader of this book has either heard of or experienced personally one or more of the ubiquitous applications in modern medicine. Did you not wonder how such things work? For example, two of the book's three authors have seen high-resolution ultrasound images of their children in the mother's uterus; this is a truly remarkable technique! The reader should recognize similarly that when the first X-ray images were obtained, just about a century ago, the observers were equally dazzled by those pictures. Indeed, they were even *more surprised* because at the time no one knew what an X-ray was.

Our book is designed to provide a useful introduction to the various methods of modern medicine as well as a resource "handbook," helpful for understanding future developments. The contents should be comprehensible to undergraduate students who have a background equivalent to a 1-year physics course at the introductory level, as is taught at most colleges and universities. Parts of the book (especially chapters 1 and 2) do not require even this background. Readers with a more extensive exposure to physics may skip chapter 3 or refer to it while reading later chapters.

The idea for this book emerged out of a course, Applications of Modern Physics in Medicine, created and taught for the last 11 years by one of the authors (Mark Strikman). He found that this course's ability to bring students to the cutting edge of science (e.g., applications that are just now entering hospitals) is particularly stimulating for both him, the teacher, and the students. The success of this course (i.e., increasing enrollment and favorable student reviews), our enthusiasm for the subject, and the recognition of the need for such a book are together responsible for our interest in writing it. While the subject is of immense scientific interest for its own sake, we hope that the book will have particular appeal for the growing number of students who are considering careers in medical physics, biophysics, medicine or nuclear engineering. In addition, it should appeal to current practitioners of the diverse medical technologies in use today. Furthermore, it is possible that the book will be used as

a supplement to courses in nuclear physics and engineering, as well as biophysics courses. Finally, we hope that individuals with a reasonable physics background who experience medical problems and receive diagnoses and treatments will be interested in learning more about the underlying science presented here.

The overall subject content of this book corresponds closely to that of the Penn State one-semester physics course from which the book emerged. In detail, however, the book's content differs in many ways from the course, especially in topic emphasis and in choice of model calculations, as well as level of presentation. Any course using this book as a text could apply it in a variety of ways, depending on the students' backgrounds and interests. For students seeking just a qualitative overview of this subject, chapters 3 and 4 can be omitted. For other kinds of students (those with particularly strong backgrounds in physics), the extended review of modern physics presented in chapter 3 may not be necessary, although our experience suggests that students appreciate the opportunity to fill gaps in their understanding of some topics (and most students have more than a few such gaps). Chapter 4 goes into considerable detail about the nature of particle propagation in matter. In some cases, this level of presentation may not be particularly useful, so it might not need to be covered. Chapter 5 is concerned with the interactions between radiation and living tissues. This is important for understanding why some methods are used, while others are not, in assessing or treating medical conditions in various parts of the body. The last three chapters provide the principal aspects of medical physics, applying the principles described in chapters 3–5. Hence these final chapters merit particular attention in any version of a comprehensive approach to this subject; they are not to be missed.

In writing this book, we have been excited to learn about the wide variety of techniques used in the development of the tools of modern medicine. At the same time, trying to understand these techniques is a humbling experience because the literature is not always transparent, often assuming a strong physics or medical background on the part of the reader. This problem is especially true of the most recent discoveries, reported by scientists who are narrowly focused and eager to get their work published quickly in the most prominent scientific journals. We hope that our attempts to understand and explain these topics have been clear and accurate. Readers wishing to comment critically on the text are invited to contact the authors; their input will be appreciated.

This book provides two levels of description. In some cases, for example, chapters 1 and 2, the presentation is primarily qualitative and nontechnical. In other cases, it is fairly technical and quantitative. We believe that most of the discussion does not require a mastery of physics as we have described the various techniques in primarily qualitative terms. We hope that nonphysicists are not intimidated by the technical discussion presented in some cases. While the book includes a relatively large number of equations, one does not need them to understand how any of the methods work.

In the medical physics course taught at Penn State, students were presented with some quantitative problems, meaning that a certain level of mathematical competence was needed. Some students had difficulty coping with the breadth of the physics subject matter, which is not surprising—given the breadth of the subject matter. Many students found especially challenging, if not annoying, the wide variety of systems of units (such as ergs, calories, Btu, joules, and electron volts for energy), reflecting the extended history of the subject and the diverse origins of the various

methods used in medicine. In many cases, we have tried to present numerical calculations several ways to accommodate these different sets of units.

This book includes many problems, all of which are original. They vary considerably in difficulty, so students should be aware of this variation and course instructors should take care in designing homework assignments. Solutions to all the problems are included in an Instructor's Manual, provided by Princeton University Press to faculty teaching a course based on this textbook. There is also a companion Web page: modernphysicsinmedicine.com, which is freely available to the general public. Readers will find there a wide variety of informative resources. Included are Mark Strikman's lecture notes from the most recent version of the Penn State course, Applications of Physics in Medicine. These notes will be updated frequently. Also found on the Web site is a comprehensive bibliography of the subject, also revised as needed. Finally, a number of publications can be found there. Among these are articles of primarily historical interest, such as "ancient" publications in the research literature, as well as articles from current semipopular literature, which helps to make aspects of medical physics accessible to interested individuals.

In writing this book, we have benefited from help provided by many scientists and physicians, as well as input from the students who experienced the Strikman course or have seen early drafts of this text. We are pleased to acknowledge Mary Callahan, MD, for her very helpful guidance in the interpretation of CT and other scans. We are also grateful to Adriene Beltz, Béatrice Bonga, Mark Conradi, James Gerardo, MD, Paul Goldhagen, David Hammond, Roger Herman, Neal Holter, MD, Brian Horton, Hye-Young Kim, Sasha Krol, Stephen Lefrak, MD, Susan Lemieux, Dinah Loerke, Angela Lueking, Scott Luria, MD, Katrina McGinty, MD, Jessica McNutt, Igor Mishustin, Pierre-Jean Nacher, Kate Noa, Matt Noll, Igor Pshenichnov, Brian Saam, Alex Sell, Shachar Shimonovich, David Townsend, Susan Trolier-McKinstry, Paul Wagner, Elisabeth Weiss, MD, Dmitriy Yablonskiy, and Michael Zhalov. These individuals provided guidance, helpful input, and/or critical evaluations of the many drafts of the text. Nathalie Huchette, of the Marie Curie Museum, kindly provided a photograph, from 1934, used in chapter 1, which advertised the alleged health benefits of exposure to radiation. Kate and Ryan Elias helpfully provided ultrasound images of their daughter, as did Angela Lueking of her son. Dave Cole helped greatly with his photographs and with the organization of the Web page. Eleanor Coppes and Kate Noa have done a remarkable job of transferring our vague concepts and mental images into clear drawings. Mark Strikman would like to acknowledge support of the Penn State Physics Department, which provided one semester's release time for organizing the course that made this book possible. The individual editors of our book at Princeton University Press have been conscientious and supportive; we are most grateful to Ingrid Gnerlich and Samantha Hasey. Finally, and significantly, we are happy to acknowledge our spouses, Nonna, Denise, and Pamela, who have patiently endured our absence while writing the book *and* provided occasional critical advice about how to write it.