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医学英文原版改编双语教材

供来华留学生（MBBS）、医学类专业双语及全英语教学使用

McGraw Hill

TEXTBOOK OF MEDICAL PHYSICS

医学物理学

英文改编版

Original Editors

Alan Giambattista

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Chief Editor of Adaptation Edition

Hong Yang （洪洋）

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Preface for Adaptation Edition

This text book is intended for students of medical colleges and universities. As the developing of the national economy and the deep-going of reform and opening, the higher education in our country has achieved great progress, and the contents and manners of teaching are also becoming more and more international. As a result, the bilingual teaching, i.e. teaching in both Chinese and English is a necessary requirement in the higher education. The national ministry of education advocates bilingual teaching, and students like bilingual teaching, and teachers devote to bilingual teaching. It's the right time to widely popularized bilingual teaching in the universities and colleges all over our country. Therefore, suitable textbooks in English are necessary for improvement of bilingual teaching. Although the language of the original English textbook is standard, the width, depth and arrangement of the contents in these textbooks are different from that of the purposed textbooks in our country, which makes it difficult for teachers to teach and for students to learn. In order to improve bilingual teaching, with the help of Science Press and McGraw-Hill companies, more than ten medical physicists who are good in English and have experience of oversea work and bilingual teaching revised this textbook of Medical Physics from the original edition of *Physics-Third edition* published by McGraw-Hill Education. The adapted textbook is featured as follows:

(1) The original edition of the *Physics-Third edition*, published by McGraw-Hill Education, one of the authors was awarded the Nobel Prize for low-temperature physics in 1996. This textbook has a good reputation in the field of medical physics of our country. The adapted textbook of medical physics should be a welcome textbook. The width, depth and arrangement of its contents are corresponding to that of the original book, so that the adapted textbook should be used conveniently for both teachers and students.

(2) Since the English language and words of the original book are retained in the adapted textbook, the grammatical errors or word misuses that often occur in the English textbooks written by non-English speaking authors can be avoided. The students using the adapted textbook should learn not only Standard English but also the scientific mode of thinking in English.

(3) Most of the illustrations in the original book are used in our chapters of the adapted textbook. Only a few that are irrelevant to the contents are cut off, and some new photos are added. Thus the revised textbook keeps the same style as the original edition.

(4) McGraw-Hill Connect® Physics to accompany *Physics* offering online electronic book and myriad of resources are used in our network platform of the adapted textbook.

It's new attempt for us to take the purposed textbook of our country as a frame to compile the English textbook. Whether this attempt is successful remains to be proved by the practice of bilingual teaching. It would be appreciated that the readers, especially the teachers and students using this book could give us precious advice.

Hong Yang
Shenyang 2018.5.29

改编版前言

本教材是供高等医学院校学生使用的教学用书。目前随着国民经济的发展和改革开放的深入，我国高等教育也获得了飞速的发展，教学内容和教学方式正在与国际接轨，双语教学正是高等教育发展的必然趋势。教育部发文倡导双语教学，大学生欢迎双语教学，高校教师积极开展双语教学，在全国高校普遍开展双语教学的条件已经成熟。适宜的外语教材是提高双语教学的必备条件。外文原版教材虽有规范和地道的语言文字，但其内容的广度和深度、编排的层次和逻辑关系与我国的规划教材相差甚远，给教师授课和学生阅读带来了不少困难。为了提高双语教学水平，方便教师授课和学生学习，我们在科学出版社和 McGraw Hill 出版公司的支持下，组织全国十余所双语教学开展较好或有外国留学生的学校中十余名有国外留学经历、外语水平较高、有双语教学经验的专家，以我国规划教材为框架，对在我国影响较大、由 McGraw Hill 出版公司出版的英文教材 *Physics-Third Edition* 进行了改编。本英文改编教材具有以下特点：

(1) 由 McGraw Hill 出版公司出版的 *Physics-Third Edition* 的其中一位作者是 1996 年诺贝尔物理学奖得主。这本物理学教材在我国医学物理学界享有盛誉。经过改编后，其内容的广度和深度、编排的层次和逻辑关系等都与我国的医学物理学教材相对应。这样，中、英文两本教材可对照使用，既方便教师的备课、授课，又方便学生的学习。

(2) 保留了原版教材的语言文字，避免了自编英文教材中常发生的语言文字弊病，不仅使学生学到地道的英文，而且让学生学到另一种语言的思维和表达方法。

(3) 在我们编辑的章节中保留了原书中绝大部分插图，精减了少数与内容不太相关的插图，并增加了部分新图，保持了原书中图随文、图文并茂的特色。

(4) 在医学物理学改编版的网络平台上引用了 McGraw Hill 出版公司提供的原书在线电子书和各种学习指导资源。

对我们来说，以国家规划教材为框架对外文原版教材进行改编，是一种新尝试。这种尝试是否成功，尚待双语教学的实践检验，也请读者特别是使用本书的老师和学生多提意见，对改编中出现的错误，批评指正。

洪 洋

2018 年 5 月 29 日于沈阳

CONTENTS

Chapter 1 Introduction

Shan Jingxin
Hong Yang

"Why should we study physics ?" This is one of the questions most frequently asked by medical students. It seems appropriate to begin this book with an attempt to answer it. In this chapter, the concepts of physics for medicine and biology have also been introduced. The use of mathematics, significant figures in calculations, dimensional analysis and units have been discussed.

1.1 WHY STUDY PHYSICS?

Physics is the branch of science that describes matter, energy, space, and time at the most fundamental level. Whether you are planning to study biology, architecture, medicine, music, chemistry, or art, some principles of physics are relevant to your field.

Physicists look for patterns in the physical phenomena that occur in the universe. They try to explain what is happening, and they perform experiments to see if the proposed explanation is valid. The goal is to find the most basic laws that describe the universe and to formulate those laws in the most precise way possible.

The study of physics is valuable for several reasons:

• Since physics describes matter and its basic interactions, all natural sciences are built on a foundation of the laws of physics. A full understanding of chemistry requires a knowledge of the physics of atoms. A full understanding of biological processes in turn is based on the underlying principles of physics and chemistry. Centuries ago, the study of natural philosophy encompassed what later became the separate fields of biology, chemistry, geology, astronomy, and physics. Today there are scientists who call themselves biophysicists, chemical physicists, astrophysicists, and geophysicists, demonstrating how thoroughly the sciences are intertwined.

• In today's technological world, many important devices can be understood correctly only with a knowledge of the underlying physics. Just in the medical world, think of laser surgery, magnetic resonance imaging, instant-read thermometers, X-ray imaging, radioactive tracers, heart catheterizations, sonograms, pacemakers, microsurgery guided by optical fibers, ultrasonic dental drills, and radiation therapy.

• By studying physics, you acquire skills that are useful in other disciplines. These include thinking logically and analytically; solving problems; making simplifying assumptions; constructing mathematical models; using valid approximations; and making precise definitions.

• Society's resources are limited, so it is important to use them in beneficial ways and not squander them on scientifically impossible projects. Political leaders and the voting public are too often led astray by a lack of understanding of scientific principles. Can a nuclear power plant supply energy safely to a community? What is the truth about global climate change, the ozone hole, and the danger of radon in the home? By studying physics, you learn some of the basic scientific principles and acquire some of the intellectual skills necessary to ask probing questions and to formulate informed opinions on these important matters.

• Finally, by studying physics, we hope that you develop a sense of the beauty of the fundamental laws that describe the universe.

1.2 TALKING PHYSICS

Some of the words used in physics are familiar from everyday speech. This familiarity can be misleading, however, since the scientific definition of a word may differ considerably from its common meaning. In physics, words must be precisely defined so that anyone reading a scientific paper or listening to a science lecture understands exactly what is meant. Some of the basic defined quantities, whose names are also words used in everyday speech, include time, length, force, velocity, acceleration, mass, energy, momentum, and temperature.

In everyday language, speed and velocity are synonyms. In physics, there is an important distinction between the two. In physics, *velocity* includes the direction of motion as well as the distance traveled per unit time. When a moving object changes direction, its velocity changes even though its speed may not have changed. Confusing the scientific definition of velocity with its everyday meaning will prevent a correct understanding of some of the basic laws of physics and will lead to incorrect answers.

Mass, as used in everyday language, has several different meanings. Sometimes *mass* and weight are used interchangeably. In physics, mass and weight are not interchangeable. Mass is a measure of inertia—the tendency of an object at rest to remain at rest or, if moving, to continue moving with the same velocity. Weight, on the other hand, is a measure of the gravitational pull on an object.

There are two important reasons for the way in which we define physical quantities. First, physics is an experimental science. The results of an experiment must be stated unambiguously so that other scientists can perform similar experiments and compare their results. Quantities must be defined precisely to enable experimental measurements to be uniform no matter where they are made. Second, physics is a mathematical science. We use mathematics to quantify the relationships among physical quantities. These relationships can be expressed mathematically only if the quantities being investigated have precise definitions.

1.3 PHYSICS FOR MEDICINE AND BIOLOGY

1.3.1 Physics in Life Science

Hardly can any activities of research including medicine and biology advance without the use of modern physical principles and techniques (Figure 1.1). The physical laws governing the behavior of molecules, atoms, and atomic nuclei are the basis for chemistry and biochemistry. Physiology offers many examples of physical processes and principles: diffusion within cells, the regulation of body temperature, the motion of fluids in the circulatory system, and electrical signals in nerve fibers are just a few. Perhaps the most obvious impact of physics on biology and medicine is at the level of instrumentation. The modern hospital is equipped with laboratories in which the most sophisticated physical techniques are used.

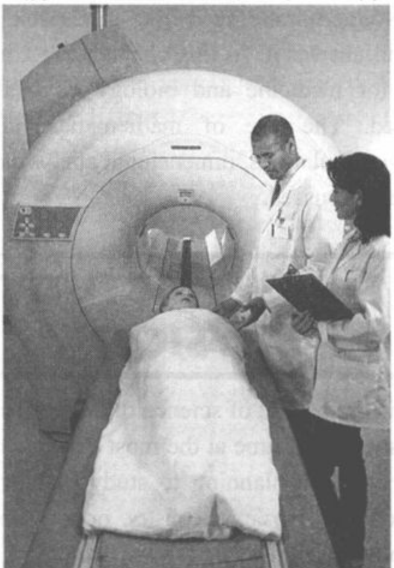

Figure 1.1 MRI provides a detailed image of the internal structures of the patient's body.

A knowledge of physics helps in the intelligent use of everything from light microscopes and centrifuges to electron microscopes, computers. lasers, Computed Tomography, ultrasound scanners, electronic techniques, and elaborate radiation detection systems used in nuclear medicine. Therefore it may be concluded that physics is related to medicine and biological science mainly in two respects:

(1) The knowledge of physics is indispensable to the understanding of life phenomena.

(2) The means and techniques provided by physics have opened up many new approached to the research of medicine and medical practice.

A few remarks about how one studies physics may be helpful. More than any other science, physics is a logical and deductive discipline. In any subfield of physics, there are just a few fundamental concepts or laws derived from experimental measurements.

Once one has mastered these basic ideas, the applications are usually straightforward conceptually, even though the details may sometimes become complicated. Consequently, it is important to focus one's attention on the basic principles and to avoid memorizing a mass of facts and formulas.

1.3.2 Biomedical Applications

- Bone density and osteoporosis (Example 1.1)
- Number of cells in the human body (Example 1.3)
- Surface area of alveoli in the lung (Example 1.8)
- Density of body fat (Problem 1-9)
- Mass dependence of metabolic rate (Problem 1-3)
- Blood flow rates (Problems 1-10, 1-17)
- Recording for a patient's temperature (Problem 1-16)

1.4 THE USE OF MATHEMATICS

1.4.1 Mathematics Base

A working knowledge of algebra, trigonometry, and geometry is essential to the study of introductory physics. Some of the more important mathematical tools are used in physics textbook. If you know that your mathematics background is shaky, you might want to test your mastery by doing some problems from a math textbook.

Mathematical equations are shortcuts for expressing concisely in symbols relationships that are cumbersome to describe in words. Algebraic symbols in the equations stand for quantities that consist of numbers and units. The number represents a measurement and the measurement is made in terms of some standard; the unit indicates what standard is used. In physics, a number to specify a quantity is useless unless we know the unit attached to the number. When buying silk to make a sari, do we need a length of 5 millimeters, 5 meters, or 5 kilometers? Is the term paper due in 3 minutes, 3 days, or 3 weeks? Systems of units are discussed in Section 1.6.

There are not enough letters in the alphabet to assign a unique letter to each quantity. The same letter V can represent volume in one context and voltage in another. Avoid attempting to solve problems by picking equations that seem to have the correct letters. A skilled problem-solver understands specifically what quantity each symbol in a particular equation represents, can specify correct units for each quantity, and understands the situations to which the equation applies.

1.4.2 Ratios and Proportions

In the language of physics, the word **factor** is used frequently, often in a rather idiosyncratic way. If the power emitted by a radio transmitter has doubled, we might say that the power has "increased by a factor of 2". If the concentration of sodium ions in the bloodstream is half of what it was previously, we might say that the concentration has "decreased by a factor of 2," or, in a blatantly inconsistent way, someone else might say that it has "decreased by a factor of 1/2." The factor is the number by which a quantity is multiplied or divided when it is changed from one value to another. In other words, the factor is really a ratio. In the case of the radio transmitter, if P_0 represents the initial power and P represents the power after new equipment is installed, we write

$$\frac{P}{P_0}=2$$

It is also common to talk about "increasing 5%" or "decreasing 20%. " If a quantity increases n%, that is the same as saying that it is multiplied by a factor of $1+(n/100)$. If a quantity decreases n%, then it is multiplied by a factor of $1-(n/100)$. For example, an increase of 5% means something is 1.05 times its original value, and a decrease of 4% means it is 0.96 times the original value.

Physicists talk about increasing "by some factor" because it often simplifies a problem to think in terms of proportions. When we say that A is proportional to B (written $A \propto B$), we mean that if B increases by some factor, then A must increase by the same factor. In other words, the ratio of two values of B is equal to the ratio of the corresponding values of A, expressed as

$$\frac{B_2}{B_1}=\frac{A_2}{A_1}$$

For instance, the circumference of a circle equals 2π times the radius: $C = 2\pi r$. Therefore $C \propto r$. If the radius doubles, the circumference also doubles. The area of a circle is proportional to the square of the radius ($A = \pi r^2$, so $A \propto r^2$). The area must increase by the same factor as the radius squared, so if the radius doubles, the area increases by a factor of $2^2 = 4$.