COLLEGE PHYSICS

大学物理

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Compiled by LI Zengzhi Wang Ying Yang Jiumin

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·北京·

内 容 简 介

本书是作者集20年双语教学的经验编写而成的大学物理英文教材。全书共11章，包括质点和刚体力学、振动与波、热学、电磁学、光学、近代物理等内容，每章均有相当数量的例题、思考题和习题，书末附有习题答案。全书内容翔实，理论联系实际，条理清晰，图文并茂。

本书可作为非物理专业特别是生物、医学专业的大学生以及在华学习的留学生开展大学物理双语教学的教材或参考书，也可以作为有一定英语基础的社会各界人士学习物理的参考书。

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Preface

The natural science today consists of two broad and overlapping areas, the life sciences and the physical sciences. The life sciences include biology, medical science, agricultural science, and ecology, among others. The physical sciences include physics, chemistry, geology, astronomy, oceanography, and the atmospheric science. Both the physical sciences and the life sciences are grouped together under the name of natural sciences.

Physics is the study of how nature behaves—from the largest things to the smallest. In simple terms, physics is the study of matter and energy and space and time. Physics is the most basic physical science because its principles form the foundation of all the other branches of science.

This textbook is intended for a course in introductory physics for students majoring in science or engineering, especially medical or biological science. This book has two main objectives: to provide the student with a clear and logical presentation of the basic concepts and principles of physics, and to strengthen an understanding of the concepts and principles through a broad range of interesting applications to the real world. To meet these objectives, we have attempted to motivate the student through practical examples that demonstrate the role of physics in other disciplines, including engineering and medicine.

The material in this book covers fundamental topics in classical physics and provides an introduction to modern physics. The book is divided into five parts. Part 1 (Chapter 1 to 3) deals with the fundamentals of Newtonian mechanics and the physics of fluids, Part 2 (Chapter 4) covers head and thermodynamics, Part 3 (Chapters 5 to 8) addresses electricity and magnetism, Part 4 (Chapter 9) treats light and optics, Part 5 (Chapters 10 and 11) deals with relativity and modern physics. Numerous worked-out examples and an extensive collection of problems are included with each chapter. At the end of the book, there are the answers to all the problems that appeared in this book.

The study of physics is an adventure. It is challenging, sometimes frustrating, occasionally painful, and often richly rewarding and satisfying. Very often instructors are asked, "How should I study physics and prepare for examinations?" There is no simple answer to this question, but we would like to offer some suggestions that are based on our own experiences in learning and teaching over the years.

First and foremost, maintain a positive attitude toward the subject matter, keeping in mind that physics is the most fundamental of all natural sciences. Other science courses that follow will use the same physical principles, so it is important that you understand and are able to apply the various concepts and theories discussed in the text.

During class, take careful notes and ask questions about those ideas that are unclear to you. Keep in mind that few people are able to absorb the full meaning of scientific material after only one reading. Several readings of the text and your notes may be necessary.

R. P. Feynman (1918 – 1988), Nobel Laureate in Physics, once said, "you do not know anything until you have practiced." And A. Sommerfeld (1868 – 1951) told his student W. Heisenberg (1901 – 1976) that "Just do the exercises diligently. Then you will find out what you have understood and what you have not." In keep with these statements, we strongly advise that you develop the skills necessary to solve a wide range of problems. Your ability to solve problems will be one of the main tests of your knowledge of physics, and therefore you should try to solve as many problems as possible. It is good practice to try to find alternate solutions to the same problem.

Often, students fail to recognize the limitation of certain formulas or physical laws in a particular situation. It is very important that you understand and remember the assumptions that underline a particular theory or formula.

It is our sincere hope that you too will find physics an exciting and enjoyable experience and that you will profit from this experience, regardless of your chosen profession. Welcome to the exciting world of physics!

We welcome communications from teachers and readers concerning our book, and especially concerning any errors or deficiencies that appeared in this book.

Li Zengzhi

Contents

Chapter 1 Mechanics (Ⅰ)

We begin our study of physics with the subject of **mechanics**: the study of motion and its causes. This is a natural starting point, everyday experience offers abundant examples of mechanical principles, more than for any other area of physics.

1.1 Statics

1.1.1 Measurement

Physics is based on measurement. Much of physics deals with measurements of physical quantities such as length, time, frequency, velocity, area, volume, mass, density, charge, temperature and energy. Many of these quantities are interrelated. For example, velocity is length divided by time. Density is mass divided by volume, and volume is a length times a second length times a third length. Most of the physical quantities are related to length, time and mass.

There are two basic types of physical quantities—fundamental quantities and derived quantities. **Fundamental quantities** are those quantities that cannot be defined in terms of other quantities. **Derived quantities**, on the other hand, are defined in terms of fundamental quantities by means of a defining relationship that is normally an equation. The present metric system, called the **International System** of Units, or SI for short, recognizes seven fundamental physical quantities. There are length (measured in meters), time (measured in seconds), mass (measured in kilograms), temperature (measured in kelvins), electric current (measured in amperes), amount of substance(measured in moles), luminous intensity (measured in candelas). We will consider five of these fundamental quantities—length, time, mass, temperature and amount of substance in the early chapters of this book.

1.1.2 Force

Force is a central concept in all of physics. When we push or pull on a body, we are said to exert a **force** on it. Forces can also be exerted by inanimate objects: a stretched spring exerts forces on the bodies to which its ends are attached; compressed air exerts a force on the walls of its container; a locomotive exerts a force on the train it is pulling or pushing. The force of gravitational attraction exerted on every physical body by the earth is called the **weight** of the body. Gravitational forces (and electrical and magnetic forces also) can act through empty space without contact. A force on an object resulting from direct contact with another object is called a **contact force**; viewed on an atomic scale, contact forces arise chiefly from electrical attraction and repulsion of the electrons and nuclei making up the atoms of material.

Force is a vector quantity. To describe a force, we need to describe the **direction** in which it acts, as well as its **magnitude** in terms of a standard unit of force. The SI unit of force is the **Newton**, abbreviated N.

Suppose we slide a box along the floor by pulling it with a string or pushing it with a stick, as in Fig. 1-1. Our point of view is that the motion of the box is caused not by the **objects** that push or pull on it, but by the **forces** these objects exert. The forces in the two cases can be represented as in Fig. 1-2; the labels indicate the magnitude and direction of the force, and the length of the arrow, to some chosen scale, also shows the magnitude.

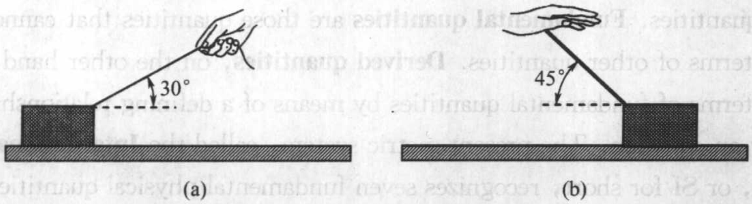

Fig. 1-1 Force may be exerted on the box by either pulling it(a), or pushing it(b).

Some vector quantities, of which force is one, are not **completely** specified by their magnitude and direction alone. The effect of a force depends also on the position of the point at which the force is applied. For example, when one pushes horizontally against a door, the effectiveness of a given force in setting the door in mo-

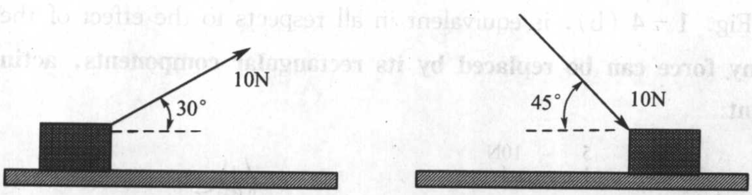

Fig. 1-2 Force diagram for the forces acting on the box in Fig. 1-1.

tion depends on the distance of the point of application from the line of the hinges, about which the door rotates. We return to this consideration in Chapter 2.

Now consider the following physical problem. Two forces, represented by the vectors $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$ in Fig. 1-3, are applied simultaneously at the same point A of a body. Is it possible to produce the same effect by applying a single force at A, and if so, what should be its magnitude and direction? The question can be answered only by experiment; investigation shows that a single force, represented in magnitude, direction, and line of action by the vector sum $\boldsymbol{R}$ of the original forces, is in all respects equivalent to them. This single force is called the resultant of the original forces. Hence the mathematical process of **vector addition** of two force vectors corresponds to the physical operation of finding the resultant of two forces, simultaneously applied at a given point.

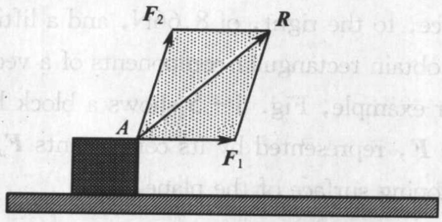

Fig. 1-3 A force represented by the vector $\boldsymbol{R}$, equal to the vector sum of $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$, produces the same effect as the forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$ acting simultaneously.

The fact that forces can be combined by vector addition is of the utmost importance, as we shall see in the following sections. Furthermore, this fact also permits a force to be represented by means of **components**. In Fig. 1-4 (a), force $\boldsymbol{F}$ is exerted on a body at point O. The rectangular components of $\boldsymbol{F}$ in the directions ox and oy are $\boldsymbol{F}_x = F_x\boldsymbol{i}$ and $\boldsymbol{F}_y = F_y\boldsymbol{j}$ ($\boldsymbol{i}$ and $\boldsymbol{j}$ are the unit vectors along ox and oy, respectively), and it is found that simultaneous application of the forces $\boldsymbol{F}_x$ and

F_y as in Fig. 1 − 4 (b), is equivalent in all respects to the effect of the original force. **Any force can be replaced by its rectangular components, acting at the same point.**

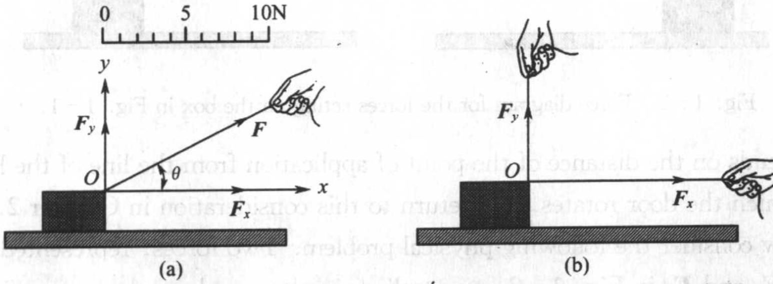

Fig. 1 − 4 The inclined force $\boldsymbol{F}$ may be replaced by its rectangular components $\boldsymbol{F}_x$ and $\boldsymbol{F}_y$.

As a numerical example, let

$$F = 10.0\text{N}, \theta = 30°$$

Then

$$F_x = F\cos\theta = (10.0\text{N}) \times 0.866 = 8.66\text{N}$$

$$F_y = F\sin\theta = (10.0\text{N}) \times 0.500 = 5.00\text{N}$$

and the effect of the original 10.0N force is equivalent to the simultaneous application of a horizontal force, to the right, of 8.66N, and a lifting force of 5.00N.

The axes used to obtain rectangular components of a vector need not be vertical and horizontal. For example, Fig. 1 − 5 shows a block being pulled up an inclined plane by a force $\boldsymbol{F}$, represented by its components $\boldsymbol{F}_x$ and $\boldsymbol{F}_y$, parallel and perpendicular to the sloping surface of the plane.

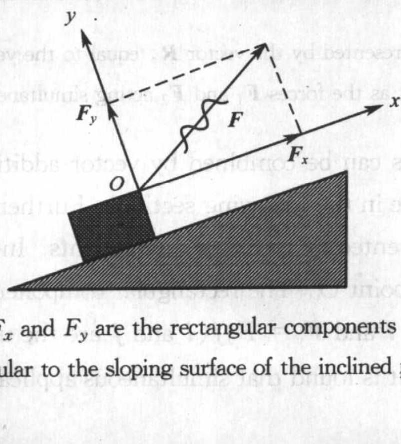

Fig. 1 − 5 F_x and F_y are the rectangular components of $\boldsymbol{F}$, parallel and perpendicular to the sloping surface of the inclined plane.