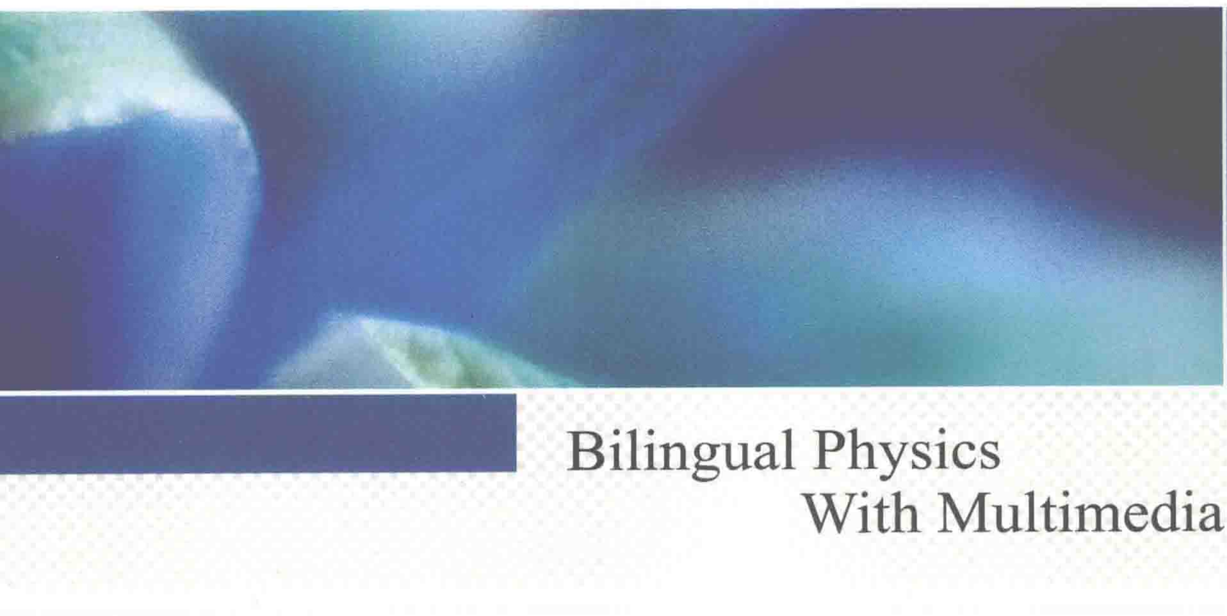
工业和信息化普通高等教育
“十二五”规划教材立项项目

高等院校通识教育“十二五”规划教材

大学物理双语导论

王辅忠 陈景莉 主编
慧娟利 闫学群 周风帆 副主编



Bilingual Physics With Multimedia

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内 容 简 介

国内外的大学物理双语教学的广度和深度不尽相同，国外大学物理英文教材的教学重点与国内大学物理双语教学重点差别也很大。本书适合30左右学时的教学和学生自学使用，内容包括大学物理学教学的基本理论和应用训练，适用于工科院校大学生在英语环境下进行物理基础知识和物理学专业术语的学习，为以后专业学习打下基础。

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前 言

英语早已经成为一种世界通用的学习、沟通和创新的重要载体。未来社会对人才的要求绝不是仅仅掌握英语或者掌握某几门学科知识的人，而是能够熟练使用英语进行学科知识交流的复合型人才。随着我国科技发展与国际接轨的步伐逐步加快，我国对这方面人才的需要更加迫切。因此，我们开始尝试进行大学物理双语教学工作。

本书是结合我校本科生特点，参考教育部物理类专业大学物理教学基本要求和英文原版教材内容体系，精心选取原版教材和参考辅助教材编制而成，内容涵盖了大学物理课程的部分基本内容，包括力学，光学，电磁学和现代物理学的基本理论和应用训练，适合学生在英语语境下进行物理学习。

《大学物理双语导论》由天津工业大学王辅忠、陈景莉、郑渝、闫学群等几位老师进行策划。王辅忠、陈景莉、慧娟利、闫学群、周风帆教师进行了编写，他们在物理系执教大学物理双语课多年，具有丰富的教学经验。

在本书编写过程中，不可避免地会有疏漏和不足之处，这些都有待于在今后的教学实践中进行改进，也希望广大的教师和同学提出宝贵意见。

编者

2014 年 6 月

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Part 1 TEXT

Chapter 1
Newton's Laws

1.1 Inertial frame and Non–inertial frame

An inertial frame of reference has a constant velocity. That is, it is moving at a constant speed in a straight line, or it is standing still.

A non-inertial frame of reference does not have a constant velocity. It is accelerating. There are several ways to imagine this motion:

Such an accelerating frame of reference is called a non-inertial frame because the law of inertia does not hold in it. That is, an object whose position is judged from this frame will seem to spontaneously change its velocity with no apparent non-zero net force acting upon it. This completely violates the law of inertia and Newton's laws of motion, since these laws claim that the only way an object can change its velocity is if an actual non-zero net force is applied to the object. Objects just do not start to move about here and there all on their own.

1.2 Newton's Three Laws of Motion

Newton's laws of motion are three physical laws that form the basis for classical mechanics, directly relating the forces acting on a body to the motion of the body. They were first compiled by Sir Isaac Newton in his work *Philosophiae Naturalis Principia Mathematica*, first published on July 5, 1687. Newton used them to explain and investigate the motion of many physical objects and systems.

(1) First law

There exists a set of inertial reference frames relative to which all particles with no net force acting on them will move without change in their velocity. This law is often simplified as "A body persists its state of rest or of uniform motion unless acted upon by an external unbalanced force." Newton's first law is often referred to as the law of inertia.

This we recognize as essentially Galileo's concept of inertia, and this is often termed simply the "Law of Inertia".

(2) Second law

Observed from an inertial reference frame, the net force on a particle of constant mass is proportional to the time rate of change of its linear momentum: $F = \mathrm{d}(mv)/\mathrm{d}t$. This law is often stated as, "Force equals mass times acceleration ($F = ma$)": the net force on an object is equal to the mass of the object multiplied by its acceleration.

(3) Third law

Whenever a particle A exerts a force on another particle B, B simultaneously exerts a force on A with the same magnitude in the opposite direction. The strong form of the law further postulates that these two forces act along the same line. This law is often simplified into the sentence, "To every action there is an equal and opposite reaction."

1.3 Units in Physics

The International System of Units is the international standard form of the metric system today. SI is the short name for this from the French language phrase Système International d'unités.

The metric system is a system of measuring based on the metre for length, distance or displacement, kilogram for mass, and second for time.

The metre, kilogram and second can be used in combination with each other. This will make different units of measurement to mean other amounts, such as volume, energy, pressure, and velocity.

(1) SI base units

The SI is founded on seven SI base units for seven base quantities assumed to be mutually independent, as given in Table 1.1.

Table 1.1 SI base units

Base quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

(2) SI derived units

Other quantities, called derived quantities, are defined in terms of the seven base quantities via a system of quantity equations. The SI derived units for these derived quantities are obtained from these equations and the seven SI base units. Examples of such SI derived units are given in Table 1.2.

Table 1.2 Examples of SI derived units

Derived quantity	Name	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
mass density	kilogram per cubic meter	kg/m^3

1.4 Fundamental Forces

There are 4 fundamental forces that have been identified gravitational, electromagnetic, strong, and weak in our present universe. They have rather different properties.

Gravitation and electromagnetism were recognized long before the discovery of the strong and weak forces because their effects on ordinary objects are readily observed. The gravitational force, described systematically by Isaac Newton in the 17th century, acts between all objects having mass; it causes apples to fall from trees and determines the orbits of the planets around the Sun.

The electromagnetic force, given scientific definition by James Clerk Maxwell in the 19th century, is responsible for the repulsion of like and the attraction of unlike electric charges; it also explains the chemical behavior of matter and the properties of light.

The strong and weak forces were discovered by physicists in the 20th century when they finally probed into the core of the atom.

The strong force acts between quarks, the constituents of all subatomic particles, including protons and neutrons. The residual effects of the strong force bind the protons and neutrons of the atomic nucleus together in spite of the intense repulsion of the positively charged protons for each other.

The weak force manifests itself in certain forms of radioactive decay and in the nuclear reactions that fuel the Sun and other stars. Electrons are among the elementary subatomic particles that experience the weak force but not the strong force.

Exercises

1. A rubber ball weighs 49 N. What is the acceleration of the ball if an upward force of 69 N is applied?

2. A skier has just begun descending a 30° slope. Assuming the coefficient of kinetic friction is 0.10,

(1) Draw a force diagram.

(2) Find her acceleration.

(3) Suppose, instead the snow is slushy and she moves down the hill at a constant speed. What will the coefficient of kinetic friction be?

Chapter 2

Momentum Conservation and Mechanical Energy Conservation

2.1 Momentum and Impulse

(1) Momentum

Momentum is a physics term; it refers to the quantity of motion that an object has. Momentum depends upon the variables mass and velocity. In terms of an equation, the momentum of an object is equal to the mass of the object times the velocity of the object.

$$\vec{p} = m \cdot \vec{v} \tag{2.1}$$

Where m is the mass and v is the velocity.

Momentum is a vector. The direction of the momentum vector is the same as the direction of the velocity of the object. The standard metric unit of momentum is the kg·m/s.

(2) Impulse

Impulse is the product of the average force F_{avg} and the time interval Δt during which the force acts:

$$impulse = F_{avg}\Delta t \tag{2.2}$$

Impulse is a vector. The direction of the impulse vector is the same as the direction of the average force F_{avg}. The standard metric unit of impulse is N·s.

(3) Impulse-momentum Theorem.

The Impulse-Momentum Theorem is as following: When a net force acts on an object, the impulse of the net force is equal to the change in momentum of the object.

$$F\Delta t = mv_f - m_0 v_0 \tag{2.3}$$

2.2 The Law of Momentum Conservation

The law of momentum conservation can be stated as follows. The total linear momentum, of an isolated system, remains constant (is conserved):

Initial momentum = final momentum

2.3 The Law of Mechanical Energy Conservation

(1) Mechanical Energy

Mechanical energy is the energy which is possessed by an object due to its motion or due to its position. Mechanical energy can be either kinetic energy (energy of motion) or potential energy (stored energy of position). Objects have mechanical energy if they are in motion and/or if they are at some position relative to a zero potential energy position.

Change in mechanical energy resulting from application of external force(s) is equal to the work done by the force(s).

(2) Conservative and Non-Conservative Forces

It is not always true that the work done by an external force is stored as some form of potential energy. This is only true if the force is conservative.

The work a conservative force does on an object in moving it from A to B is path independent - it depends only on the end points of the motion. Examples: the force of gravity and the spring force are conservative forces. For a non-conservative force, the work done in going from A to B depends on the path taken. Examples: friction and air resistance.

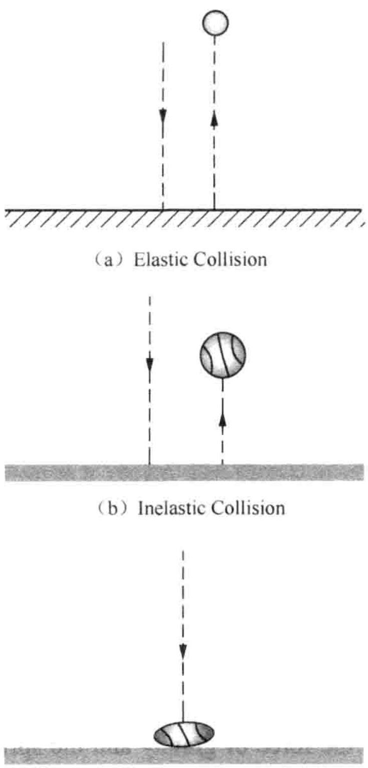
(3) The Law of Mechanical Energy Conservation

Mechanical energy is the kinetic energy plus all of the kinds of potential energy that are present. In the absence of non-conservative forces, mechanical energy is conserved. Example: if gravitational and spring forces are present.

Notice that while the total amount of energy is conserved, the distribution of energy may change. For example, there may be more kinetic energy in the initial state and more potential energy in the final state (or the other way around).

2.4 Elastic and Inelastic Collisions

Collisions involve forces (there is a change in velocity). Collisions can be elastic, meaning they conserve energy and momentum, inelastic, meaning they conserve momentum but not energy, or totally inelastic (or plastic), meaning they conserve momentum and the two objects stick together, as shown in Figure 2.1.



(a) Elastic Collision

(b) Inelastic Collision

(c) Completely inelastic Collision

Elastic Collision – the kinetic energy before and after the collision is equal.

Inelastic Collision – the kinetic energy before and after the collision is not Equal.

If the objects stick together whilst colliding the collision is said to be completely inelastic.

Figure 2.1 Elastic, inelastic and completely inelastic collisions.

Exercises

1. A 4.50kg exercise ball traveling at 3.75 m/s strikes a 2.25kg exercise ball sitting on the gym floor in a perfectly elastic head-on collision. What are the velocities of the two balls after the collision?

2. An explosion breaks an object into two pieces. One piece has a mass 2.5 times the other. If 8500 J of energy are released during the explosion, how much kinetic energy did each piece acquire?

3. A pool ball (Ball A) traveling at 5.00 m/s strikes a second pool ball (Ball B) sitting on the table in a perfectly elastic collision. If Ball A moves off at a 23.0 angle from its original path, find the velocity of each ball (magnitude and direction).