面向21世纪课程教材
Textbook Series for 21st Century

英文版

物理学

上册

东南大学等七所工科院校 编
马文蔚 改编
林尚 译

高等教育出版社
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内容简介

本书是马文蔚等编著的《物理学》(上册)(第四版)的英文版本,由几位美籍华人物理学家翻译完成,克服了国内作者编写的英文教材使用"中国英语"的弱点,英文叙述十分纯正。本书的中文版在我国大学物理教学被广泛采用,具有非常大的影响,该书的英文版本将为我国的大学物理双语教学提供一本优秀教材。

本书可供普通高等学校工科各专业作为双语教学教材使用,也可供其他专业和社会读者参考。

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Words of the Translator

The English version of the original book PHYSICS in Chinese is as a loyal translation as possible to the best knowledge of the translator. The translator acknowledges Professor Wen-Wei Ma for critical reading of the manuscripts, and he is deeply indebted to Dr. Wei Chen for introducing him to this project.

Song Ling

August 2004

Quantities and units of mechanics and thermodynamics

Quantities		Units		Conversion relations
Names	Symbols	Names	Symbols	
Length	l, L	Meters	m	
Mass	m	Kilograms	kg	
Time	t	Seconds	s	
Velocity	v	Meters per second	$m \cdot s^{-1}$	
Acceleration	a	Meters per second squared	$m \cdot s^{-2}$	
Angle	$\theta, \alpha, \beta, \gamma$	Radian	rad	
		Degrees	(°)	$1° = (\pi/180)$ rad
Angular velocity	ω	Radians per second	$rad \cdot s^{-1}$, s^{-1}	
Angular acceleration	α	Radians per second squared	$rad \cdot s^{-2}$, s^{-2}	
Rotational speed	n	Revolutions per second	$r \cdot s^{-1}$	
		Revolutions per minute	$r \cdot min^{-1}$	$1\ r \cdot min^{-1} = 60\ r \cdot s^{-1}$
Frequency	ν	Hertz	Hz, s^{-1}	
Force	F	Newton	N	$m \cdot kg \cdot s^{-2}$
Frictional factor	μ	One	1	
Momentum	p	Kilogram meters per second	$kg \cdot m \cdot s^{-1}$	
Impulse	I	Newton seconds	$N \cdot s$	
Work	W	Joule	J	$m^2 \cdot kg \cdot s^{-2}$
Energy, heat	E, E_k, E_p, Q	Joule	J	$m^2 \cdot kg \cdot s^{-2}$
Power	P	Watts	$W(J \cdot s^{-1})$	$m^2 \cdot kg \cdot s^{-2}$
Torque	M	Newton meters	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
Moment of inertia	J	Kilogram meter squared	$kg \cdot m^2$	
Angular momentum	L	Kilogram meter squared per second	$kg \cdot m^2 \cdot s^{-1}$	
Coefficient of stiffness	k	Newton per meter	$N \cdot m^{-1}$	
Pressure	p	Pascal	Pa	
Volume	V	Cubic meters	m^3	
		Liters	L(l)	$1\ L = 10^{-3} m^3$
Thermodynamic temperature	T	Kelvin	K	
Celsius temperature	t	Celsius degrees	℃	$t = T - 273.15$ K
The quantity of matter	ν, n	Mole	mol	
Molar mass	M	Kilograms per mole	$kg \cdot mol^{-1}$	
Molecular mean free path	λ	Meters	m	
Frequency of molecular collisions	Z	Numbers per second	s^{-1}	
Viscosity	η	Kilogram per meter per second	$kg \cdot m^{-1} \cdot s^{-1}$	
Heat conductivity	κ	Watts per meter per Kelvin	$W \cdot m^{-1} \cdot K^{-1}$	
Diffusion coefficient	D	Meter squared per second	$m^2 \cdot s^{-1}$	
Specific heat	c	Joule per Kilogram per Kelvin	$J \cdot kg^{-1} \cdot K^{-1}$	
Molar heat capacity	C_m, $C_{V,m}$, $C_{p,m}$	Joule per mole per Kelvin	$J \cdot mol^{-1} \cdot K^{-1}$	
Ratio of molar heat capacities	$\gamma = C_{p,m}/C_{V,m}$			
Efficiency of heat engine	η			
Efficient of cooling	e			
Entropy	S	Joule per Kelvin	$J \cdot K^{-1}$	

The Values of Often Used Physical Quantities in Ordinary Calculations

Physical quantity	Symbol	Value*	Units
Speed of light in vacuum	c	3.00×10^{8}	$m\cdot s^{-1}$
Magnetic permeability in vacuum	μ_0	$4\pi\times10^{-7}$	$N\cdot A^{-2}$
Electric permittivity in vacuum	ϵ_0	8.85×10^{-12}	$C^2\cdot N^{-1}\cdot m^{-2}$
Gravitational constant	G	6.67×10^{-11}	$N\cdot m^2\cdot kg^{-2}$
Planck constant	h	6.63×10^{-34}	$J\cdot s$
Elementary charge	e	1.60×10^{-19}	C
Rydberg constant	R_∞	10 973 731	m^{-1}
Electron mass	m_e	9.11×10^{-31}	kg
Compton wavelength	λ_C	2.43×10^{-12}	m
Proton mass	m_p	1.67×10^{-27}	kg
Neutron mass	m_n	1.67×10^{-27}	kg
Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
Molar gas constant	R	8.31	$J\cdot mol^{-1}\cdot K^{-1}$
Boltzmann constant	k	1.38×10^{-23}	$J\cdot K^{-1}$
Stefan – Boltzmann constant	σ	5.67×10^{-8}	$W\cdot m^{-2}\cdot K^{-4}$
Constant of the Wien displacement law	b	2.90×10^{-3}	$m\cdot K$
Standard gravitational acceleration	g	9.81	$m\cdot s^{-2}$

* All the values of the physical constants listed in this table are taken from the recommended values of the committee of the international scientific data (CODATA) with three significant figures.

Greek Letters

Lower case	Upper case	English	Lower case	Upper case	English
α	A	Alpha	ν	N	Nu
β	B	Beta	ξ	Ξ	Xi
γ	Γ	Gamma	o	O	Omicron
δ	Δ	Delta	π	Π	Pi
ϵ	E	Epsilon	ρ	P	Rho
ζ	Z	Zeta	σ	Σ	Sigma
η	H	Eta	τ	T	Tau
θ	Θ	Theta	υ	Υ	Upsilon
ι	I	Iota	ϕ	Φ	Phi
κ	K	Kappa	χ	X	Chi
λ	Λ	Lambda	ψ	Ψ	Psi
μ	M	Mu	ω	Ω	Omega

Contents

Chapter 1

The Kinematics of Mass Points

Physics is a fundamental science that studies the basic laws of the most universal and elementary forms of motions including those of mechanical, thermal, electromagnetic, atomic, nuclear, and microscopic particles. Mechanical movements, with the elementary forms of translation and rotation, are the simplest and most ubiquitous. During translation, the time variation of the position of an object can be represented by that of any single point of it, since all points of the object move identically and the relative positions of the points remain unchanged. Therefore the translation of an object can usually be reduced to the motion of a single dimensionless mass point. In mechanics, the relevant study is called the kinematics of mass points.

The contents of this chapter are: position vector, displacement, velocity and acceleration, the equation of motion of mass points, tangential and normal accelerations, and relative motions.

1 – 1

The description of the movements of mass points

1. Reference frames and mass points

i . *Reference frames*

All objects in nature are in constant motion, nothing stands still absolutely. Other objects must be chosen for reference when observing the variation of the position of an object. The description of the motion depends on the reference objects chosen, that is to say, the motion looks differently with respect to different reference objects, this is called the relativity of the description of motion.

The chosen object as a reference of the motion is called a *reference frame*, as mentioned in the last paragraph different reference frames present different descriptions of the motion of an object. As a consequence, the reference frame must be specified when talking about the motion of an object. Even though arbitrary choices exist when selecting a reference frame, the earth is usually chosen as the reference frame when studying the objects moving on the earth.

ii. *Mass points*

Objects are of different sizes and shapes as well as different ways of motion. Examples are: in the solar system the planets both rotate about their own axes and revolve around the sun; a moving bullet spins about itself other than flying ahead; a diatomic molecule exhibits overall translation and rotation in addition to having its atoms vibrating about each other. All of these show that the motions of various objects can be complicated, and the sizes, shapes, and masses of them can also be quite different. Below is a list of the order of magnitude of the masses and lengths of some objects:

Mass m in kilograms(m/kg)	Length l in meters (l/m)
Electron 10^{-30}	Nuclear radius of a proton 10^{-15}
Proton 10^{-27}	Atomic radius (distance between an electron and the nucleus) 10^{-10}
Hemoglobin 10^{-22}	Scale of a virus 10^{-7}
Flu virus 10^{-19}	Scale of an Ameba worm 10^{-4}
Ameba worm 10^{-8}	Human height 10^{0}
Rain drop 10^{-6}	Height of the Zhumulangma Summit 10^{4}
Human 10^{2}	Radius of the Earth 10^{7}
Saturn5 Rocket 10^{6}	Radius of the Sun 10^{9}
The Pyramid 10^{10}	Radius of the Solar System 10^{13}
The Earth 10^{24}	Distance between the Earth and its nearest fixed star 10^{16}
The Sun 10^{30}	Scale of the Milky Way 10^{21}
The Milky Way 10^{41}	

When we study the motion of an object, *if we may ignore its size and shape, or we may take into account its translational motion only, we may therefore regard the ob-*

ject as a single point with a mass, such a *point* is usually called a *mass point.*

A mass point is a physical model of scientific abstraction, treating an object as a mass point is conditional and relative, not unconditional and absolute. We must make specific analysis for specific cases. For example, when studying the Earth revolving around the Sun we may treat the Earth as a mass point, since the average distance between the Earth and the Sun is about 10^4 times the radius of the Earth thus the motion of all points of the Earth relative to the Sun can be thought of as equivalent. However, when studying the motion of objects on the Earth, the Earth itself can not be treated as a mass point.

We should point out that the research approach of abstracting an object as a mass point is of great significance both in theory and in practice. If the object under our study can not be regarded as a mass point, we may consider it as composed of many mass points. Understanding the motion of these mass points would lead to the knowledge of the motion of the object. Therefore, the studying of the motion of mass points is the basis of studying the motion of objects.

All the chapters on mechanics of this book, except the chapter on rigid bodies, treat objects as mass points.

2. Position vector, equation of motion and displacement

ⅰ. *Position vector*

As we have pointed out, a reference frame must be chosen when describing the motion of an object. After the reference frame is selected, a coordinate system must be constructed on it to quantitatively describe the position variation of the mass point. There are coordinate systems such as Cartesian, polar, and natural coordinate systems. ①In the Cartesian coordinate system of Fig. 1 - 1, at time t the position of mass point P in the coordinate system is represented by the position vector $\boldsymbol{r}(t)$. The position vector is a line segment with a direction, its starting point is the origin O of the coordinate system and its ending point coincides with the position of mass point P at time t. We see in Fig. 1 - 1 that the projections of the position vector r on the Ox, Oy, and Oz axes(i. e., the coordinates of the mass point) are x, y, and z, respectively. Accordingly, the position of mass point P in the $Oxyz$ Cartesian coordinate system can be represented by either the position vector $\boldsymbol{r}$ or the coordinates x, y, and

① Planar polar and natural coordinate systems are introduced in Section 1 - 3 of this chapter.