



Textbook Series for 21st Century

# PHYSICS

Fifth Edition

Part I

AUTHOR MA WENWEI

TRANSLATORS ZHU MING / XU WENXUAN



HIGHER EDUCATION PRESS



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INTRODUCTION OF CONTENT

On the base of *Physics*( Fourth Edition ), the revision of this book is made consulting *The Basic Requirement of Teaching University Physics Course for Non – physical Major in University of Science & Engineering ( Discussion Draft )* and constituted lastly by sub – committee of physics essential lecture teaching guidance for non – physics specialty, Education Department. What in the book contains all of kernels required in the *basic requirement*, moreover, a certain amount of extension content is presented as well as for different majors. In the revision, this book keeps specialties such as logical system, well – situated profundity and extension, proper capacity, wide flexibility coming from the original vision of the book. Meanwhile, it adds more contents in following aspects: modern physics, the annotation with modern viewpoints for classic physics, and the effects to science and technology from the achievements of modern physics.

This book has two volumes. In Volume I , it contains mechanics and electromagnetic. And in Volume II , it contains oscillation and undulation, optics, theory of molecular dynamics and basic of thermodynamics, theory of relativity, quantum physics. There are books *The Applications of Physical Principle in Engineering and Technology*( Third Edition ) , *The Analysis and Solution for Exercises In Physics*( Fifth Edition ) , *Guidance for Learning Physics*( Fifth Edition ) and the multimedia *The Electronic Teaching Plan for Physics* ( Fifth Edition ) to form a complete set with this book.

This book can be the teaching material of the higher education for non – physical major in university of sciences and engineering. It can also be selected as texts by the relevant fields of social sciences and natural sciences and read by social readers at large.

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# Quantities and units of mechanics and thermodynamics

Quantities		Units	
Names	Symbols	Names	Symbols
length	$l, L$	meters	m
mass	$m$	kilograms	kg
time	$t$	seconds	s
velocity	$v$	meters per second	$\text{m} \cdot \text{s}^{-1}$
acceleration	$a$	meters per second squared	$\text{m} \cdot \text{s}^{-2}$
angle	$\theta, \alpha, \beta, \gamma$	radian	rad
		degrees	°
angular velocity	$\omega$	radians per second	$\text{rad} \cdot \text{s}^{-1}, \text{s}^{-1}$
angular acceleration	$\alpha$	radians per second squared	$\text{rad} \cdot \text{s}^{-2}, \text{s}^{-2}$
rotational speed	$n$	revolutions per second	$\text{r} \cdot \text{s}^{-1}$
		revolutions per minute	$\text{r} \cdot \text{min}^{-1}$
frequency	$\nu$	hertz	$\text{Hz}, \text{s}^{-1}$
force	$F$	newton	N
frictional factor	$\mu$	one	1
momentum	$p$	kilogram meters per second	$\text{kg} \cdot \text{m} \cdot \text{s}^{-1}$
impulse	$I$	newton seconds	$\text{N} \cdot \text{s}$
work	$W$	joule	J
energy, heat	$E, E_k, E_p, Q$	joule	J
power	$P$	watts	$\text{W}(\text{J} \cdot \text{s}^{-1})$
torque	$M$	newton meters	$\text{N} \cdot \text{m}$
moment of inertia	$J$	kilogram meter – squared	$\text{kg} \cdot \text{m}^2$
angular momentum	$L$	kilogram meter squared per second	$\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-1}$
coefficient of stiffness	$k$	newton per meter	$\text{N} \cdot \text{m}^{-1}$
charge	$q, Q$	coulomb	C
intensity of electric field	$E$	volt per meter	$\text{V} \cdot \text{m}^{-1}$
permittivity of vacuum	$\epsilon_0$	faraday per meter	$\text{F} \cdot \text{m}^{-1}$
relative permittivity	$\epsilon_r$	—	1
the flux of electric field	$\Phi_e$	volt meter	$\text{V} \cdot \text{m}$
electric potential energy	$E_p$	joule	J

(Be continued)

Quantity		Units	
Name	Symbol	Name	Symbol
electric potential	$V$	volt	V
electric potential difference	$U$	volt	V
the moment of electric dipole	$P$	coulomb meter	$C \cdot m$
capacitance	$C$	faraday	F
electric polarization	$P$	coulomb per square meter	$C \cdot m^{-2}$
electric displacement	$D$	coulomb per square meter	$C \cdot m^{-2}$
current	$I$	ampere	A
current density	$j$	ampere per square meter	$A \cdot m^{-2}$
resistance	$R$	ohm	$\Omega$
resistivity	$\rho$	ohm meter	$\Omega \cdot m$
electromotive force	$\mathcal{E}$	volt	V
magnetic induction	$B$	tesla	T
magnetic moment	$m$	ampere square meter	$A \cdot m^2$
magnetization	$M$	ampere per meter	$A \cdot m^{-1}$
permeability of vacuum	$\mu_0$	henry per meter	$H \cdot m^{-1}$
relative permeability	$\mu_r$	—	1
magnetic field intensity	$H$	ampere per meter	$A \cdot m^{-1}$
magnetic flux	$\Phi$	weber	Wb
coefficient of self – induction	$L$	henry	H
coefficient of mutual induction	$M$	henry	H
displacement current	$I_d$	ampere	A

# Greek Letters

Lower Case	Upper Case	English	Lower Case	Upper Case	English
$\alpha$	A	alpha	$\nu$	N	nu
$\beta$	B	beta	$\xi$	$\Xi$	xi
$\gamma$	$\Gamma$	gamma	$\omicron$	O	omicron
$\delta$	$\Delta$	delta	$\pi$	$\Pi$	pi
$\varepsilon$	E	epsilon	$\rho$	P	rho
$\zeta$	Z	zeta	$\sigma$	$\Sigma$	sigma
$\eta$	H	eta	$\tau$	T	tau
$\theta$	$\Theta$	theta	$\upsilon$	Y	upsilon
$\iota$	I	iota	$\varphi$ ( $\phi$ )	$\Phi$	phi
$\kappa$	K	kappa	$\chi$	X	chi
$\lambda$	$\Lambda$	lambda	$\psi$	$\Psi$	psi
$\mu$	M	mu	$\omega$	$\Omega$	omega

# The Values of Often Used Physical Quantities in Ordinary Calculations

Physical Quantity	Symbol	Value	Value in Calculation	Units
speed of light in vacuum	c	$2.997\,924\,58 \times 10^8$	$3.00 \times 10^8$	$\text{m} \cdot \text{s}^{-1}$
magnetic permeability in vacuum	$\mu_0$	$4\pi \times 10^{-7}$	$4\pi \times 10^{-7}$	$\text{N} \cdot \text{A}^{-2}$
electric permittivity in vacuum	$\epsilon_0$	$8.854\,187\,817 \times 10^{-12}$	$8.85 \times 10^{-12}$	$\text{C}^2 \cdot \text{N}^{-1} \cdot \text{m}^{-2}$
gravitational constant	G	$6.672\,42(10) \times 10^{-11}$	$6.67 \times 10^{-11}$	$\text{N} \cdot \text{m}^2 \cdot \text{kg}^{-2}$
Planck constant	h	$6.626\,069\,3(11) \times 10^{-34}$	$6.63 \times 10^{-34}$	$\text{J} \cdot \text{s}$
elementary charge	e	$1.602\,176\,53(14) \times 10^{-19}$	$1.60 \times 10^{-19}$	C
Rydberg constant	$R_\infty$	109 737 31.534	10 973 731	$\text{m}^{-1}$
electron mass	$m_e$	$9.109\,382\,6(16) \times 10^{-31}$	$9.11 \times 10^{-31}$	kg
Compton wavelength	$\lambda_C$	$2.426\,310\,238(16) \times 10^{-12}$	$2.43 \times 10^{-12}$	m
proton mass	$m_p$	$1.672\,621\,71(29) \times 10^{-27}$	$1.67 \times 10^{-27}$	kg
neutron mass	$m_n$	$1.674\,927\,28(29) \times 10^{-27}$	$1.67 \times 10^{-27}$	kg
Avogadro constant	$N_A$	$6.022\,141\,5(10) \times 10^{23}$	$6.02 \times 10^{23}$	$\text{mol}^{-1}$
molar gas constant	R	8.314 472(15)	8.31	$\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
Boltzmann constant	k	$1.380\,650\,5(24) \times 10^{-23}$	$1.38 \times 10^{-23}$	$\text{J} \cdot \text{K}^{-1}$
Stefan – Boltzmann constant	$\sigma$	$5.670\,400(40) \times 10^{-8}$	$5.67 \times 10^{-8}$	$\text{W} \cdot \text{m}^{-2} \cdot \text{K}^{-4}$
atom mass constant	kg	$1.660\,538\,86(28) \times 10^{-27}$	$1.66 \times 10^{-27}$	kg
constant of the Wien displacement law	b	$2.897\,768\,5(51) \times 10^{-3}$	$2.90 \times 10^{-3}$	$\text{m} \cdot \text{K}$
Bohr radius	$a_0$	$0.529\,177\,210\,8(18) \times 10^{-10}$	$0.529 \times 10^{-10}$	m

All the values of the physical constants listed in this table are taken from the 2002 recommended values of the Committee on Data for Science and Technology (CODATA) with three significant figures.



# Preface

Physics is a science to research the basic structure, the basic modus of motion as well as law of interaction of matters. It is a subject formed in the process that human has been exploring nature. In the first, physics was developed from the research to the law of the motion in mechanics; later on, it researched to the law of thermo phenomenon, the law of electromagnetic phenomenon, optical phenomenon as well as radiation. Until the end of 19th century, physics had formed already a whole system itself, called classical physics. In the first thirty years of 20th century, physics experienced a great revolution that brought the naissance of theory of relativity and quantum mechanics. Modern physics was founded herefrom.

Physics is the basic of nature sciences. In the progress of exploring the matter structure and basic law of motion, each important discovery and breakthrough brought the development of new fields and new direction, even the foundation of new branch of the subject, the cross subject and the subject of new technology. In the past 100 years, a mass of subject separated out from physics, such as mechanics, calorifics, optics, and acoustics. Thereinto, laser, radio, microelectronics, atomic energy are already the independent subjects now. Although physics is an age – old foundational subject—the knowledge learned in the time of university are almost all discoveries found one or two hundred years before, even three or four hundred years before—it has important and inseparable relationship with the life of human being and the development of science and technology today and even in the further. ‘Shenzhou’ airship roaming in the airspace, drilling petroleum underground, exploring the cosmic arcanum in immense out space, making the micro – electronic chips in computer, all these depends on the foundational effect of physics. Even on the field that seems to be looked having no relation with physics in the past, such as economy, finance, stock and police, some people are making research by physical way now and achieved the success getting on people’s recognition. In 2000, 20 greatest items of engineering in 20th century were chosen by American Academy of Engineering, most technologies adopted thereinto get relation directly or indirectly with discoveries on the field of physics in the past 300 years. These 20 items engineering are listed firstly with electrization, automobile, airplane, tap water system, micro – electronics, radio and TV, next with mechanization of farming, computer, telephone, air – conditioning and refrigerator, highway, satellite, internet, photography, then with home electric devices, medical technology, petroleum and petrochemistry, laser and fiber, nuclear technology, high performance material. The year of 2005 is ‘International Physics Year’ named by UN. This was the first time to name an international year with the name of a single subject in UN history.

The 1st edition of this book was published in 1977. When, the slogan of students in the university was ‘learning math, physics and chemistry well, unafraid going anywhere!’ Then, excellent students mostly chose the major of math or physics to have their high education. Now, going with the social development, young people’s interest and ideal are more pluralistic. Going with this, the education mode has been changed greatly. Therefore, under the new environment, the purpose of authors and teachers is to explore how to be a good initiator for this university physics course to satisfy the

demand of scientific accomplishment to people with high abilities in 21st century. In one side, it should deliberate with modern view to traditional contents of physics teaching; in another side, it should use well all kinds of modern technical education way, and combine every kind of teaching resource across – the – broad like liberal form, carton, graph, picture and video, and then interrelate and arrange all of them conformably into books, disks or on internet. Each way has its own work and to be charge of its own purpose, then to let the student achieving the magic learning effect. Just due to this, the plan of content and visage of this book has changed enormously comparing with the 1st edition. From the simplex papery book, it develops into a package consisting of main book in paper, assistant book in paper, electronic book and internet teaching materials.

This book has two volumes. Volume I is revised by Prof. Ma Wenwei; Chapter 9, 10 and Information Entropy, Plasma & Thermonuclear reaction, Scanning Microscope and Nanometer Material are edited and revised by Prof. Zhou Yuqing; Chapter 11 is revised by Prof. Xie Xishun; and Chapter 12 to 15 are revised by Prof. Ma Wenwei.

## ► Words To Teachers

In the new century, career of higher education in our country is developing rapidly. Therefore, the ideal and content of university physics should fit the new circumstances of education reform. Sub – committee of physics essential lecture teaching guidance for non – physics specialty, Education Department revises *The Basic Requirement of Teaching University Physics Course for Non – physical Major in University of Science & Engineering ( Discussion Draft )* in time, and divides the teaching content of university physics into two parts of the kernel and the extension contents. The Fifth edition of this book is revised just under the direction of the idea and spirit of the new ‘basic requirement’.

## The Features of Fifth Edition

### The Idea Directing the Revision

For ascertaining the idea directing the revision of *Physics*(Fifth Edition), we held the Proseminar of Teaching Materials of University Physics and Proseminar of Superior Course Construction especially in Dalian city and Nanjing city. Teachers attending meetings discussed widely to draw on wisdom of masses. Finally, all recognizes that *Physics*(Fifth Edition) should keep its original features on the base of referring to the new ‘basic requirement’, and pay attention to be harmonic and conformable with the reform of physics course in high school. According to the thinking above, we ascertained that the content of *Physics*(Fifth Edition) should cover all kernel requirements in the ‘basic requirement’. Meanwhile, select certain amount of extension contents to meet the demand to this course from different majors. It is as same as the fourth edition in difficulty, but exercise difficulty is easier a little bit. Moreover, add some optional exercises to examine student’s physical concepts.

### The Changing of Chapters and Sections

According to the basic requirement of teaching, and considering of reader’s foundation of physics in the middle school, contents in some chapters and sections has been adjusted as making the revision:

1. Chapter 20 in original book changes to chapter 15 now. Cancel five chapters of Gravitation force field, Constant current, Magnetic medium in magnetic field, Electromagnetic oscillation & Electromagnetic wave as well as Physics & New technology. However, contents such as the condition for

constant current, concepts of electromotive force and magnetic medium go into the chapter of constant magnetic field. The content of liquid crystal is behind the part of wave optics, contents of Plasma & Thermonuclear reaction, Scanning Microscope and Nanometer Material go into Chapter of Quantum of physics. The purpose is to let these subjects of new technology constructing a whole integer with the basic content of the chapter so that students can understand easily and extend their ken. Meanwhile, cancel some contents that is with too more technology and difficult to understand.

2. Add a number of optional learning items, such as the Newtonian proposition of the universal gravitational force, symmetry and conservative law, brief introduction of information entropy, simple introduction of non – linear system, geometrical optics.

3. Cancel sections of the mass point motion with acceleration as a constant vector, boundary condition of static electric field, piezoelectric effect, ferroelectric body, electret, the principle of magnetoelectric galvanometer, Nicol prism, interference of polarized light, ideal gas experimental law. In addition, cancel Wien displacement law derived by Planck Equation as well as Stefan – Boltzmann law.

For reader's convenience to learn extension contents, all of the extension content in the book is mark with symbol ' \* ' in title, and printed with small size word. These extension contents can enlarge reader's ken, have profound understanding to the basic theory and essential method. It also redounds readers to understand how the physical theory established, and helps readers to know the relationship between the physical theory and the development of new technology. All extension contents makes the whole system of their own. It is able to select for teaching, or guide students learning themselves. Ignoring them does affect the system and continuity of the book.

Under the situation that increases the book price, it adopts the two – color printing for the book so that pictures and graphs herein are clearer. This enhances the expression of the book and upgrades reading effect.

## ► Word to Learners

Welcome going with *Physics*(Fifth Edition) into the classroom of university physics!

Maybe, by the book content, you can find that you learned in the middle school contents like mechanics, calorifics, optics and electromagnetics. For some contents hereinto such as the Newtonian law, you have done numerous exercises already in the middle school. However, in the university, you are going to learn these knowledge with completely new math tools——calculus and vector, and your cognition to this physical world is going to be more objective and profound, and makes great progress than the time in middle school. Therefore, although these contents are not unknown to you, still hope you to learn hardly like a beginner. Sometime, it is necessary to give up some viewpoints formed in the time of middle school. In this way, what exhibited in front of you will be a complete new world of physics!

Opening this book, you may find many equations in the book. Please note, the method of which you learn these equations of physics should be different from those you learnt in the mathematical book! First, there are rich and profound physical meaning behind these equations. Some of them describes a physical phenomenon and physical process, some of them discovers what meaning of physics and physical graph, therefore, you should spend more times and beat your own brain to think of what is ' behind ' these equations, but only keep these equations self in mind. Second,

although there are many equations in the book, it is not that each one has the same importance. The kernel, also the profound equation is not too many. You should put your main vigor on understanding the physical meaning of these equations, but spend too many time for details of derivation so to learn the profound theory and the method that support the building of physics indeed. This is also the first step of the process what people says usually to make book ‘from thickness to thinness, and from thinness to thickness again’. Third, Physics is never only the equation in your book or the force analysis graph you drawn for your home exercise, it is closely bound up and made nearly relationship with your living. Even out of the classroom, hope you to think of which of every kind of matter used in your living and the phenomenon met operates the profound principle of physics; and else, among what you learnt in your major, which makes relationship with basic of physical knowledge. This is the second step of which is the effectual reading usually mentioned by people. In this way, you are going to find that physics is rather interesting, very useful; and you self who learn physics well is larruping!

### ► Other Items in the Teaching Package

As a sub –subject of ‘the construction plan of teaching materials for one hundred superior courses in higher education’, at the beginning of the book revision, we considered of the edition and R&D of the teaching reference and each kind of digital teaching resource. These teaching references match the main textbook compactly, and support each other. And they help teachers and students to use the textbook well;

#### 1. *Internet Course of University Physics V2.0*

This edition succeeds and develops the characters and advantages of edition V1.0, exert the advanced internet technology and make aborative work for numerous of topic carton, fine original material, graphic carton and video information; The advanced teaching plan such as teacher frame, learning guide, self examination are adopted for exerting teacher’s effect completely. Introduce cases of application of physical principle in engineering & technology, and introduce chiefly the principle, the structure and the use of instruments for physical experiments. This embodies the character of physics course of the engineering university. Recommend and introduce the last development and progress of physics subject, as well as the important website of physics for the purpose to exert characters of internet, such as exploitability, advancement, shareable.

#### 2. *Physics( Fifth Edition) Electric Teaching Plan*

In this teaching plan, the division of chapter and section corresponds to the textbook completely, includes all contents taught necessarily and all examples in the book, and the description and derivation to the principle and law of physics are same as the main textbook. Numerous of fine and ingenious Flash carton and pictures represent vividly and visually the physical image and dynamic process of physics. The teaching plan supports teacher’s individuation of teaching. It is able to do the secondary exploitation, and exert advantages of multimedia teaching. It changes the teaching method before, and break the traditional teaching mode to let teaching physics course more directly and vividly. It can be the reference software for teaching and self – learning.

#### 3. The database of original material for university physics

The database of original material has two parts as ‘basic original material’ and ‘extension original material’. ‘Basic original material’ is designed and made according to the content of *Physics( Fifth*

Edition) and *Tutorial of Physics*( Second Edition ), covers 95% original material of the textbook , and collocates with the textbook for using. ‘Extension original material’ is made according to the demand of the modernization of teaching content, as well as the content related to modern science and physical foundation of new technology. The purpose is to develop and extend student's ken, to enhance the theoretical guidance to the practice, and to bring up student's ability and their spirit of innovation. Therefore, this database of original material is suitable for every kind of textbook teaching in technological university, so has wide applicability.

#### 4. *The Application of Physical Principles in Engineering and Technology*( Third Edition)

In teaching of physics, it is necessary indeed to contact the practice correctly. It is an important profound principle to teaching. However, in many years, this issue has not been solved rightly, sometimes, it even opposes having a stable base to practice contacting, so we went on the wrong way. In this book, it made some rewarding experiment in this aspect. The book asked for the contribution many times all of the country. Do the best for both of having the background of engineering application and matching the teaching. And the purpose is to let readers extending his ken, understand the basic principle profoundly, realize the practicality of physics indeed, and take the profound effect of physics to the foreland of the engineering and technology field. In *Physics*( Fifth Edition ), there are more than thirty places as the footnote of which sets up the relationship between the taught profound knowledge of physics with the special topic in this book. This is convenient for interested reader's further learning. The book starts off the engineering practice, keeps away from the technical detail, abstract the issue in practice to the physical mode and analyze with physical principles, and submits the solution finally. Therefore, it benefits to training student's ability for analysis and solving practical problems, as well as to student's enhancing their interest to learning and curious desire.

#### 5. The analysis and solution for exercises in *Physics*( Fifth Edition)

This book makes the analysis and solution to all exercises in the textbook. The guide – idea of this book is to emphasize the analysis and predigest the solution. In the book, by the way of analyzing exercises before making solutions, it tries the best to let students having further recognition to relative physical rules. To combine with the introduction and operation of methods and skills for solution, it can develop student's thought – way for solution, and make the physical meaning more clearly by the discussion to the calculation result. It tries to do the best for making the solution process to be compendious and concise, and lets students complete the detail calculation themselves.

#### 6. Guidance for learning *Physics*( Fifth Edition)

This book keeps the main textbook. All chapters and sections, as well as the order of them is same as the main textbook. Each chapter consists of five parts as ‘basic demand’, ‘thought – way and relationship’, ‘the guidance for learning’, ‘discussion to difficult point’ and ‘self – test exercise’. In the ‘basic demand’, it points out briefly the content mastered necessarily and operated expertly in each chapter; in ‘thought – way and relationship’, its emphasis is to describe the inter – relationship between each chapter and related chapters; ‘The guidance for learning’ is the main part of the book, it expounds synoptically and synthetically the key content in each chapter, and points out the emphasis as understanding the key content; ‘discussion to difficult points’ makes more detail analysis to brief difficult points in the chapter; the writing of ‘self – test exercise’ carries out the principle of ‘less but extractive’, however, it covers wide field, and its content keeps around ‘basic demand’ to select a few of issues contacting the practice. In answer of self – test exercises is

enclosed at the end of the book.

#### 7. Series video of university physics topics

As the supplement and extending to the extension part of 'basic requirement of teaching', this series can play to combine with teaching in class, as well as on the internet and after school. The brief topics of the series are laser, semiconductor, superconductor, liquid crystal, scanning tunnel microscope, optical fiber and fiber communication, fractal and plasma.

#### 8. Physics course website

We open the course website for this course. As long as visiting <http://phy.cncourse.com>, and making login with the accounts and password on the learning card enclosed to the book, readers can get free from the relative teaching resource and have teacher's tutorship.

### Acknowledgements

In preparing the Fifth edition of this textbook, we had invaluable ideas of many teachers who has been use this textbook for a long time. We wish to express our sincere appreciation to them here. We wish to acknowledge Prof. Xu Xudu (chief reviewer, Northwest Polytechnical University) and Prof. Tang Yujun (Donghua University) and express our sincere appreciation for their perusing the manuscript, their cogent criticisms, and suggestions. We wish to acknowledge Prof. Yin Shi, Prof. Shen Caikang, Prof. Bao Gang and Prof. Wei Na and express our sincere appreciation for that they added some exercises to this book.

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Fourth edition

Authors: Ma Wenwei, Xie Xishun, Tan Shumei (Southeast University)

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Second edition

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First edition

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Due to authors' limitation, there are still few of improper places, welcome your invaluable ideas.

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