Undergraduate Lecture Notes in Physics

For further volumes:
http://www.springer.com/series/8917

Undergraduate Lecture Notes in Physics (ULNP) publishes authoritative texts covering topics throughout pure and applied physics. Each title in the series is suitable as a basis for undergraduate instruction, typically containing practice problems, worked examples, chapter summaries, and suggestions for further reading.

ULNP titles must provide at least one of the following:

- An exceptionally clear and concise treatment of a standard undergraduate subject.
- A solid undergraduate-level introduction to a graduate, advanced, or non-standard subject.
- A novel perspective or an unusual approach to teaching a subject.

ULNP especially encourages new, original, and idiosyncratic approaches to physics teaching at the undergraduate level.

The purpose of ULNP is to provide intriguing, absorbing books that will continue to be the reader's preferred reference throughout their academic career.

Hafez A. Radi
John O. Rasmussen

Principles of Physics

For Scientists and Engineers

Springer

Hafez A. Radi
October University for Modern Sciences and Arts (MSA)
6th of October City
Egypt

John O. Rasmussen
University of California at Berkeley and Lawrence Berkeley Lab
Berkeley, CA
USA

Solutions to the exercises are accessible to qualified instructors at springer.com on this book's product page. Instructors may click on the link *additional information* and register to obtain their restricted access.

ISSN 2192-4791 ISSN 2192-4805 (electronic)
ISBN 978-3-642-23025-7 ISBN 978-3-642-23026-4 (eBook)
DOI 10.1007/978-3-642-23026-4
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2012947066

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

This book on Principles of Physics is intended to serve fundamental college courses in scientific curricula.

Physics is one of the most important tools to aid undergraduates, graduates, and researchers in their technical fields of study. Without it many phenomena cannot be described, studied, or understood. The topics covered here will help students interpret such phenomena, ultimately allowing them to advance in the applied aspects of their fields.

The goal of this text is to present many key concepts in a clear and concise, yet interesting way, making use of practical examples and attractively colored illustrations whenever appropriate to satisfy the needs of today's science and engineering students.

Some of the examples, proofs, and subsections in this textbook have been identified as optional and are preceded with an asterisk *. For less intensive courses these optional portions may be omitted without significantly impacting the objectives of the chapter. Additional material may also be omitted depending on the course's requirements.

The first author taught the material of this book in many universities in the Middle East for almost four decades. Depending on the university, he leveraged different international textbooks, resources, and references. These used different approaches, but were mainly written in an expansive manner delivering a plethora of topics while targeting students who wanted to dive deeply into the subject matter. In this textbook, however, the authors introduce a large subset of these topics but in a more simplified manner, with the intent of delivering these topics and their key facts to students all over the world and in particular to students in the Middle East and neighboring regions where English may not be the native language. The second author went over the entire text with the background of study and/or teaching at Caltech, UC Berkeley, and Yale.

Instructors teaching from this textbook will be able to gain online access from the publisher to the solutions manual, which provides step-by-step solutions to all exercises contained in the book. The solutions manual also contains many tips, colored illustrations, and explanations on how the solutions were derived.

Acknowledgments from Prof. Hafez A. Radi

I owe special thanks to my wife and two sons Tarek and Rami for their ongoing support and encouragement. I also owe special thanks to my colleague and friend Prof. Rasmussen for his invaluable contributions to this book, and for everything that I learned from him over the years while carrying out scientific research at Lawrence Berkeley Lab. Additionally, I would like to express my gratitude to Prof. Ali Helmy Moussa, Prof. of Physics at Ain Shams University in Egypt, for his assistance, support, and guidance over the years. I also thank all my fellow professors and colleagues who provided me with valuable feedback pertaining to many aspects of this book, especially Dr. Sana'a Ismail, from Dar El Tarbiah School, IGCSE section and Dr. Hesham Othman from the Faculty of Engineering at Cairo University. I would also like to thank Professor Mike Guidry, Professor of Physics and Astronomy at the University of Tennessee Knoxville, for his valuable recommendations. I am also grateful to the CD Odessa LLC for their Concept-Draw software suite which was used to create almost all the figures in this book. I finally extend my thanks and appreciation to Professor Nawal El-Degwi, Professor Khayri Abdel-Hamid, Professor Said Ashour, and the staff members and teaching assistants at the faculty of Engineering at MSA University, Egypt, for all their support and input.

Hafez A. Radi
hafez.radi@gmail.com

Acknowledgments from Prof. John O. Rasmussen

I would like to thank Prof. Radi for the opportunity to join him as coauthor. I am grateful to the many teachers, students, and colleagues from whom I learned various aspects of the fascinating world of the physical sciences, notably the late Drs. Linus Pauling, Isadore Perlman, Stanley Thompson, Glenn Seaborg, Earl Hyde, Hilding Slätis, Aage Bohr, Gaja Alaga, and Hans-Järg Mang. There are many others, still living, too numerous to list here. I would also like to extend my special thanks to my wife for her support and encouragement.

John O. Rasmussen
oxras@berkeley.edu

Contents

Fundamental Physical Constants

Quantity	Symbol	Approximate value
Speed of light in vacuum	c	3.00×10^8 m/s
Avogadro's number	N_A	$6.02 \times 10^{23}\,\text{mol}^{-1} = 6.02 \times 10^{26}\,\text{kmol}^{-1}$
Gas constant	R	$8.314\,\text{J/mol}\cdot\text{K} = 8\,314\text{J/kmol}\cdot\text{K}$
Boltzmann's constant	k	1.38×10^{-23} J/K
Gravitational constant	G	$6.67 \times 10^{-11}\,\text{N}\cdot\text{m}^2/\text{kg}^2$
Planck's constant	h	$6.63 \times 10^{-34}\,\text{J}\cdot\text{s}$
Permittivity of free space	ϵ_0	$8.85 \times 10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2$
Permeability of free space	$\mu_0 = 1/(c^2\epsilon_0)$	$4\pi \times 10^{-7}\,\text{T}\cdot\text{m/A}$
Atomic mass unit	1u	$1.6605 \times 10^{-27}\,\text{kg} = 931.49\,\text{MeV}/c^2$
Electron charge	$-e$	-1.60×10^{-19} C
Electron rest mass	m_e	$9.11 \times 10^{-31}\,\text{kg} = 0.000549\,\text{u} = 0.511\,\text{MeV}/c^2$
Proton rest mass	m_p	$1.6726 \times 10^{-27}\,\text{kg} = 1.00728\,\text{u} = 938.27\,\text{MeV}/c^2$
Neutron rest mass	m_n	$1.6749 \times 10^{-27}\text{kg} = 1.008665\,\text{u} = 939.57\,\text{MeV}/c^2$

Other useful constants

Acceleration due to gravity at the Earth's surface (av.)	$g = 9.8\,\mathrm{m/s^2}$
Absolute zero (0 K)	$-273.15\,°\mathrm{C}$
Joule equivalent (1 kcal)	4, 186 J
Speed of sound in air (20 °C)	343 m/s
Density of air (dry)	$1.29\,\mathrm{kg/m^3}$
Standard atmosphere	1.01×10^5 Pa
Electric breakdown strength	3×10^6 V/m
Earth: Mass Radius (av.)	5.98×10^{24} kg 6.38×10^3 km
Moon: Mass Radius (av.)	7.35×10^{22} kg 1.74×10^3 km
Sun: Mass Radius (av.)	1.99×10^{30} kg 6.96×10^5 km
Earth–Moon distance (av.)	3.84×10^5 km
Earth–Sun distance (av.)	1.5×10^8 km

The greek alphabet

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

Some SI base units and derived units

Quantity	Unit name	Unit symbol	In terms of base units
Mass	kilogram	kg	Base SI units
Length	meter	m	
Time	second	s	
Electric current	ampere	A	
Force	newton	N	$kg{\cdot}m/s^2$
Energy and work	joule	J	$kg{\cdot}m^2/s^2$
Power	watt	W	$kg{\cdot}m^2/s^3$
Pressure	pascal	Pa	$kg/(m{\cdot}s^2)$
Frequency	hertz	Hz	s^{-1}
Electric charge	coulomb	C	$A{\cdot}s$
Electric potential	volt	V	$kg{\cdot}m^2/(A{\cdot}s^3)$
Electric resistance	ohm	Ω	$kg{\cdot}m^2/(A^2{\cdot}s^3)$
Capacitance	farad	F	$A^2{\cdot}s^4/(kg{\cdot}m^2)$
Magnetic field	tesla	T	$kg/(A{\cdot}s^2)$
Magnetic flux	weber	Wb	$kg{\cdot}m^2/(A{\cdot}s^2)$
Inductance	henry	H	$kg{\cdot}m^2/(s^2{\cdot}A^2)$

SI multipliers

yotta	Y	10^{24}
zeta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}