Physics for the IB Diploma

Fifth edition

K. A. Tsokos

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore,
São Paulo, Delhi, Dubai, Tokyo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

www.cambridge.org
Information on this title: www.cambridge.org/9780521708203

First published by K. A. Tsokos 1998
Second edition 1999
Third edition 2001
Fourth edition published by Cambridge University Press 2005
Fifth edition 2008
5th printing with corrections 2009

Printed in the United Kingdom by Latimer Trend

A catalogue record for this publication is available from the British Library

ISBN 978-0-521-70820-3 Paperback

ACKNOWLEDGEMENTS
We are grateful to the following for permission to reproduce photographs:
76, 526(*t*), 644 Science Photo Library; 89 Harold Edgerton/Science Photo Library; 255,
Bettmann/CORBIS; 256 Reuters; 276 Sheila Terry/Science Photo Library; 315 Richard Megna/Science
Photo Library; 400 (Francis Simon), 403 (Segre Collection), 526(*b*), 725 (Physics Today Collection)
American Institute of Physics/Science Photo Library; 464(*l*) Robert Gendler/Science Photo Library; 464(*r*)
John Walsh/Science Photo Library; 492, 535c Anglo-Australian Observatory/David Malin Images; 535a, b
NOAO/Science Photo Library; 733 Stanford Linear Accelerator Center/Science Photo Library; 737a CERN
PHOTO/ Frédéric Pitchal/Sygma/CORBIS; 737b David Parker/Science Photo Library; 741 Goronwy Tudor
Jones/University of Birmingham/Science Photo Library; 742 CERN/Science Photo Library; 747 Klaus
Guldbranden/Science Photo Library

Contents

HL Option H – Special and general relativity

HL Option I – Biomedical physics

HL Option J – Particle physics

For Alexios and Alkeos

Preface

Physics is a fundamental science, and those who study it will gain an understanding of the basic laws that govern everything from the very small subatomic to the very large cosmic scale. The study of physics provides us with an unparalleled power of analysis that is useful in the study of the other sciences, engineering and mathematics, as well as in daily life.

This fifth edition of *Physics for the IB Diploma* follows the previous edition, but contains material for the new syllabus that will be examined for the first time in May 2009. It covers the entire International Baccalaureate (IB) syllabus, including all options at both standard level (SL) and higher level (HL). It includes a chapter on the role of physics in the theory of knowledge (TOK), along with many discussion questions for TOK. Each chapter opens with a list of objectives, which include the important formulae that will be covered in that chapter. The questions at the end of each chapter have been increased, and there are answers at the end of the book for all those involving calculation (and for some others too).

Part I of the book covers the core material and the additional higher level (AHL) material. The title and running heads of each chapter clearly indicate whether the chapter is part of the core or AHL. Part II covers the optional subjects. There are now four options that are available to SL students only (Option A, Sight and wave phenomena; Option B, Quantum physics; Option C, Digital technology; and Option D, Relativity and particle physics). The material for these is the same as the corresponding AHL material, and so these four SL options are neither repeated nor presented separately (except for one chapter, Option A1, The eye and sight, which is not part of the AHL core). Three options (Option E, Astrophysics; Option F, Communications; and Option G, Electromagnetic waves) are available to both SL and HL students. Finally, there are three options (Option H, Special and general relativity; Option I, Biomedical physics; and Option J, Particle physics) that are available to HL students only.

The division of this book into chapters and sections usually follows quite closely the syllabus published by the International Baccalaureate Organization (IBO). This does not mean, however, that this particular order should be followed in teaching. Within reason, the sections are fairly independent of each other, and so alternative teaching sequences may be used. It must also be stressed that this book is not an official guide to the IB syllabus, nor is this book connected with the IBO in any way.

The book contains many example questions and answers that are meant to make the student more comfortable with solving problems. Some are more involved than others. There are also questions at the end of each chapter, which the student should attempt to answer to test his or her understanding. Even though the IB does not require calculus for physics, I have used calculus, on occasion, in the text and in the questions for the benefit of those students taking both physics and mathematics at higher level. They can apply what they are learning in mathematics in a concrete and well-defined context. However, calculus is not essential for following the book. It is assumed that a student starting a physics course at this level knows the basics of trigonometry and is comfortable with simple algebraic manipulations.

In many questions and examples I have not resisted the temptation to use 10 m s^{-2} as the numerical value of the acceleration due to gravity. I have also followed the conventions of symbols used by the IBO in their *Physics Data Booklet*, with one major exception. The *Data Booklet* uses the symbol *s* for displacement. Almost universally, the symbol *s* is reserved for distance, and so *s* stands for distance in this book, not displacement. Also, I have chosen to call initial velocities, speeds, etc. by v_0 rather than the IBO's *u*.

I wish to thank my wife, Ellie Tragakes, for her great help and support. I am indebted to fellow teacher Wim Reimert for his careful reading of the book and his extensive comments that have improved the book – I thank him sincerely. I would like to thank Geoff Amor, who has edited the new material for the fifth edition, implemented my changes, and made many suggestions for its improvement.

K. A. Tsokos
Athens
May 2007

A note to the reader

The main text of each chapter contains a number of different features, which are clearly identified by the use of headings or by other typographical means, as outlined below.

Learning outcomes/objectives

These are provided as bullet lists at the beginning of each chapter, and indicate what you will have learned or be able to do when you have finished studying the chapter.

Important results, laws, definitions and significant formulae

Particularly important material, such as important results, laws, definitions and significant formulae, appear in a shaded box.

Example questions

These occur in nearly all of the chapters. They are indicated by the heading 'Example question(s)' and all have a full answer. It is a good idea to attempt to solve these problems before reading the answers. There are over 500 such example questions in this book.

Material for higher level students

This material is highlighted in a shaded box that is labelled 'HL only'.

Material that is outside the IB syllabus

Some material is included that is outside the IB syllabus and will not be examined in the IB exams. It is included here for two reasons. The first is that I believe that it clarifies syllabus material and in some cases it does so in essential ways. The second is that it gives the interested student a more rounded view of the subject that is not bounded by the rigid syllabus content. Such material is highlighted in a shaded box that is labelled 'Supplementary material'. There is also a small amount of other similar material with different labels.

Questions

Each chapter ends with a set of numbered questions. Answers to all those that involve calculation are given at the end of the book. Answers are also provided for some other questions where it is useful for students to be able to check their answers.