Physics by Example contains two hundred problems from a wide range of key topics, along with detailed, step-by-step solutions. Applying the knowledge gained from lectures and textbooks to actual problem-solving is not always straightforward, but by guiding the reader through carefully chosen examples, this book will help to develop skill in manipulating physical concepts.

The book deals with the following areas: dimensions, errors and statistical analysis; classical mechanics and dynamics; gravitation and orbits; special relativity; quantum, atomic and nuclear physics; oscillations and waves; optics; electromagnetism; electric circuits; thermodynamics. Throughout, exercises are cross-referenced to emphasise the relationships between the different topics covered. There is also a section listing physical constants and other useful data, including a summary of some important mathematical results.

In discussing the key factors and most suitable methods of approach for given problems, this book imparts many useful insights, and will be invaluable to anyone taking first- or second-year undergraduate courses in physics.

Physics by Example

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200 Problems and Solutions

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For Christine

Contents

Preface

This is a book about physics, consisting of two hundred problems with solutions worked out in detail. My experience in teaching physics at university level has led me to believe that many first-year undergraduates find physics interesting but hard. With perhaps one or two exceptions the concepts are straightforward enough to be grasped, and students often enjoy learning these concepts, many of which are beautiful or at least intellectually satisfying. However, students often find that translating their understanding of the ideas of physics into problem-solving can be difficult. I believe the best way to learn how to solve problems is by example, hence this book. The level of difficulty of the problems (in some cases it would be more accurate to say the level of sophistication of the solutions) is intended to be roughly that of the first year of a physics course at a British university, and the range of topics treated is correspondingly intended to reflect typical first-year syllabuses. In order to ensure that this is so, I have drawn most of these problems from recent first-year examination papers at several British universities. However, I hope that it will find some use both below and above this level. Its intention is to help students to make the transition from school physics to university physics, so it assumes a background in physics and mathematics appropriate to such a level.

This is not a textbook in the normal sense of the word. Although I hope you will learn some physics from it, a book of this kind will inevitably have a number of defects. The first is that it is far too short to contain all the physics you are likely to meet even in a single year at university. I have deliberately kept it short to encourage you to work your way through all of it. However, even a much larger book of this kind, containing many more problems, would not be an adequate substitute for a textbook or a course of lectures. Lectures and textbooks communicate ideas, but this book is intended to develop skill in manipulating those ideas. I hope it will thus supplement, rather than duplicate, the function of a textbook. For these reasons I have largely avoided including problems that require little more than duplicating standard derivations, except where the results are of direct relevance to other problems or where I believe them to illustrate important ideas.

The arrangement of the text is roughly by subject area – dimensions,

errors and statistical analysis; classical mechanics and dynamics; gravitation and orbits; special relativity; quantum, atomic and nuclear physics; oscillations and waves; optics; electromagnetism; electric circuits; thermodynamics – but some spillage from one area to another is inevitable. Perhaps it is also desirable, in that it might encourage students to realise that in 'real life' problems cannot always be neatly categorised. Within each section I have tried to group problems by topics, and also to try to put easier ones before more difficult ones and to try to introduce results in earlier problems for use in later problems. It has not always been possible to meet all these criteria simultaneously, and I have therefore cross-referenced the problems, and also provided an index. Generally speaking, the index does not contain entries for items whose location should be obvious from the structure of the book, nor does it contain entries for familiar and widely applicable topics such as the conservation of energy. There is also a section listing physical constants and other useful data, which also contains a compendium of mathematical results. This is not intended to be comprehensive, but to serve as a ready reference for the techniques necessary in solving the problems. Supplementary material, not strictly required in the solution of the problems, is enclosed by brackets [ ]. Marginal arrowheads ▶ show the positions of the answers.

The coverage of the book is not intended to be comprehensive. It does not purport to provide model solutions to every problem the student will meet, nor to cover every topic. However, I would be grateful to learn of any glaring omissions that readers may feel I have made.

Although I have tried to eliminate errors from the book, since I know they will be embarrassing, I expect that a few will remain. I should be very grateful if readers would inform me of any errors that they may discover.

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Cambridge

Acknowledgements

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Most of the problems in this book are not original, and I am grateful to the Universities of Birmingham, Cambridge, Nottingham and Oxford for granting me permission to use their material. Specifically, I acknowledge the University of Birmingham for problems 2, 11, 13, 14, 16, 19, 23, 24, 34, 39, 46, 50, 54, 58, 73, 82, 87, 101, 102, 112, 114, 125, 128, 139, 143, 152, 153, 154, 175, 187 and 190, the University of Nottingham for problems 6, 8, 9, 20, 25, 27, 30, 35, 42, 53, 66, 72, 78, 79, 81, 84, 85, 88, 89, 90, 94, 95, 97, 100, 103, 106, 116, 118, 120, 126, 127, 131, 136, 142, 144, 145, 147, 172, 173, 174, 194, 195, 197, 198 and 200, the University of Oxford for problems 21, 40, 69, 77, 83, 115, 117, 129, 140, 150, 157, 163, 164, 165, 169, 171, 177, 178, 192, 196 and 199, and the University of Cambridge for the remainder, excluding problems 3, 15, 37, 38, 41, 109, 110 and 111 for which I accept responsibility. Except in those few cases where problems have been devised especially for this book, the copyright in these problems remains the property of the universities supplying the problems. In many cases I have modified the problems, and I accept full responsibility for any inconsistencies or ambiguities which may have resulted from such modification.