Problems for physics students

# *Problems for physics students*

*WITH HINTS AND ANSWERS*

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# PREFACE

This book aims to provide a set of problems which will test a student's understanding of the principles which are usually taught in a tertiary level physics course. In the United Kingdom, for example, the topics covered are those typically met in an A-level physics syllabus. Most of the material is thus what is known as 'classical physics', although all A-level courses contain some 'modern physics', i.e. nuclei, atoms and photons. A few A-level syllabuses, notably the Nuffield one, also contain introductory ideas on the more advanced topics of electronics, entropy and the Schrödinger equation, and questions on these have been included. In countries which adopt a less specialized school curriculum than that found in the UK, the relevant course level is that of junior college or the early years of university.

The difficulty of the questions varies widely, from straightforward application of a single basic idea to quite complex situations involving the use of several ideas at once, some of them not immediately apparent. It is hoped that these more demanding problems will not only stretch the best of pre-university students, but prove of value to those already at university during the earlier parts of their physics courses.

In the first part (sections A–T) of the book I have tried to group problems on similar areas of physics together in one section, the separate sections being alphabetically labelled. In the later part, however, in particular in sections U, V, X and Y, a deliberate attempt has been made to include problems involving ideas from several areas. Within each section similar ideas have in general been grouped together, with those groups which in my view are the more straightforward placed earlier. The questions considered to be the most demanding have been marked with an asterisk (*). It will thus be apparent that the questions under a single letter form a generally increasingly difficult set of problems on one area of physics, and that those with the same number, but different letters, form a roughly uniform set of questions on a variety of topics. A student may therefore take advantage of this structure to meet his or her individual aims or needs.

It seems appropriate here to say a little about the choice of format for the problems posed. Consider the following question and response.

Q. A uniform solid cylinder is set spinning about its axis and is then gently placed, with its axis horizontal, on a rough horizontal table. What happens?

A. At first slipping occurs, but eventually this stops and the cylinder rolls smoothly along the table.

The answer given is, of course, correct. But is it clear that the physics principles underlying the analysis of the situation have been understood? The reply to this latter question has to be 'no'; they may have been, but it is not clear that they have. Were the original question to have asked whether the final linear speed of the cylinder depends upon its mass, its initial angular speed, its radius, the coefficient of friction or the acceleration due to gravity, or what fraction of the initial kinetic energy of the cylinder is dissipated against sliding friction, then answers of no, yes, yes, no and no, or $\frac{2}{3}$, respectively, would be clear indicators that the principles had not only been understood but also correctly applied.

I would not for a minute claim that qualitative discussions of physical problems are not important or difficult; in some cases they are the only discussions that are possible. However, for the reasons illustrated by the previous paragraph, and because it is clearly more practicable when the written word, rather than a face-to-face discussion, is the medium of interaction with the student, I have chosen to make the large majority of problems in this book quantitative. This has the additional advantage that intermediate answers can be provided in a compact form, and so enable the student to locate more readily the part of the analysis in which the reasoning has been at fault, in those cases in which the problem has not been correctly solved. Even though it is not possible in a book like the present one to provide the corresponding answers, since anything offered will inevitably be found by some to be either incomplete or misleading, the importance of descriptive physics is recognized in sections Y and Z, where a significant number of qualitative questions are posed for the student to consider.

Despite the decision to make the questions quantitative, either algebraic or numerical, the mathematical techniques involved are not difficult and should be well within the capabilities of anyone who has studied mathematics beyond O-level; nor are the techniques the main points of the questions, except in the case of the data-handling exercises of section W.

Just as important a purpose of this book as testing, is that of instruction. Not of course in the basic ideas of physics, for which standard texts and teachers are the proper agents, but in the ability to pose to one's self the kind of question which will make it clear which ideas are involved. In doing this by means of hints for the problems, a sometimes difficult balance has to be struck between being so helpful that there is nothing left to the problem, and being so oblique that the

hint is merely one more baffling aspect. I hope that in the majority of cases such a balance has been found. The same kind of considerations have applied to the intermediate answers which appear mixed in with the hints. Clearly they do not make the same kind of qualitative suggestions to the student as do the hints, but they should serve to indicate where a calculation has gone off the rails.

The hints and final answers are to be found in separate sections towards the end of the book. A letter H in square brackets at the end of a question indicates that, if needed, a hint or intermediate answer is available for that question or part-question. In some cases answers are given in the questions themselves. Separate listings have been used so as to enable a student requiring help to obtain it without 'accidentally' noticing the final answer.

In order to make the book self-contained for its own purposes, I have included the values of standard constants on the very last page of the book, an alphabetical list of symbols used in the questions, hints and answers (these I have tried to keep in accord with the recommendations of *SI Units, Signs, Symbols and Abbreviations* published by the Association for Science Education), and a list of formulae and relationships such as is used in some A-level courses in the United Kingdom.

It is a pleasure to record my sincere thanks to Heather Cuff, Belinda Powell and Sue Arnold for their patient and careful typing of a difficult text.

My thanks also go to the Cambridge University Tutorial Representatives for permission to base many of the problems on questions set in the Cambridge Colleges' Examination. The suggested answers and hints are of course my own, as they are for the original problems included, and in no way represent solutions officially approved by the Cambridge Colleges. Also my own are all errors and ambiguities, and I would be most grateful to have them brought to my attention.

Finally I wish to place on record my appreciation of the help given by the staff and advisors of the Cambridge University Press with the presentation of this book.

Cambridge, 1982 K. F. R.

*Note added at second printing*

I have taken the opportunity of a second printing to clarify some ambiguities and make some numerical values more realistic. I am most grateful to Dr J. W. Warren and Professor G. Grimvall for drawing most of these shortcomings to my attention and suggesting better alternatives.

Cambridge, 1985 K. F. R.