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Mastering

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Fourth Edition

Martin Harrison
Frank McKim

Founding authors: John Keighley and
Frank McKim

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Preface to the first edition

The book aims to provide a concise, easily readable treatment of all the essential principles contained in introductory physics courses. We have tried to present them with a directness and simplicity that will enable students to achieve maximum comprehension in the shortest possible time. Many diagrams have been included in the text as these are a great help in understanding physics and are especially useful in revision.

MARLBOROUGH, 1982

JOHN KEIGHLEY
FRANK MCKIM
ALAN CLARK
MARTIN HARRISON

Preface to the fourth edition

This new edition has been prompted both by changes in syllabus and in ways of assessing a student's abilities in physics. It has meant putting together a new book rather than updating the previous edition. Most of the illustrations are new, having been chosen to show how physics is important in the natural world, as well as in such fields as athletics, engineering, medicine and music. We have also included examples in the text where a grasp of physics has become increasingly important to environmentalists and politicians, as well as in other fields like motor racing and space flight.

MARLBOROUGH, 1999

MARTIN HARRISON
FRANK MCKIM

Acknowledgements

The early editions of Mastering Physics were the work of four collaborators. Dr Alan Clark wrote the final quarter of that book, and we want to pay tribute to his clarity of presentation, setting a standard for his successors to strive for.

John Keighley was the coordinator of the first three editions, and it was due to his experience of authorship, enthusiasm and attention to detail that the original text took shape.

Both men have been our teaching colleagues in the Physics Department at Marlborough College. Our thanks go to that Department and to the Music Department under Robin Nelson, some of whose Symphony Orchestra players are pictured with their wind instruments in chapter 14. They include Candida Sopwith, Hannah O'Regan, Edward Baring, Edward Cooke, Robert Greville-Heygate, Basil King, and Henry Jeens.

Our thanks are also due to the following who have kindly provided illustrations and information for our examples: Richard Austin, Rebecca Bangay at the BBC Natural History Film Library; Graham Bell; Sylvia Chaplin at the Nuffield Radio Astronomy Laboratories, Jodrell Bank; Kevin Conkey, Chris Freemantle at the Wellcome Department of Cognitive Neurology; Anne Froggatt at the Blackpool Pleasure Beach; Frank Greenaway; Charles Healey; Haydn Jones; Nick Parks at Marlborough College Outdoor Activities Department; Mark Shearman; Bruce Tulloh; California Institute of Technology; Civil Aviation Authority; Falcon Cycles Ltd; Mount Wilson and Palomar Observatories; NASA; Projects and Modules Team at

Maplin Electronics plc; Rolls-Royce plc; the Science Photo Library; the Transport Research Laboratory; and the Wellcome Department of Cognitive Neurology.

We are grateful to both the London and Northern Ireland Examination Boards for permission to reprint GCSE questions from their past papers.

Introduction

The content of this book has been determined by the GCSE physics syllabus in the United Kingdom, which is comparable with first level High School physics in some other countries. Our aim has been to describe the physical properties of materials, and the laws of physics relating to observations we can make both inside and outside the laboratory.

We have included a limited number of mathematical examples, encouraged by the thought that Michael Faraday, who has been described as the greatest experimental physicist of the nineteenth century, used no equations at all in his papers. In this book the numerical work is no more complicated than most physics courses at this level require. However, there are equations throughout the book. We hope you will find that they provide a concise summary of relationships between physical quantities, and can be simply applied.

We have tried to keep the language straightforward, explaining new technical terms where they arise in the text. Words used in a scientific sense sometimes need careful definition and understanding. For example 'power', 'energy', 'momentum', 'force', 'resistance' and 'moderator' all have non-scientific meanings. To use words like these accurately in context is to make your reasoning clear.

Many physical quantities can be given numerical values. These have meaning only if a system of units is defined for each quantity. We shall use units based on the metre of length, the kilogram of mass and the second of time. This is called an m.k.s. system of units, and it is often referred to as the SI system (Système International). Multiples and submultiples of these units are also used for convenience (see Table 1 below).

So the following are all equal amounts of energy: 1 000 000 J, 10^6 J, 1 MJ, and 1000 kJ.

We do not list all the experiments you might find in a typical course book. However, there are accounts of experiments which help to illustrate physical phenomena. As you

Table 1 Some common prefixes with their meanings and abbreviations

prefix	meaning	symbol	
giga-	$\times 10^9$	G	The universe may be older than 10 gigayears
mega-	$\times 10^6$	M	A power station may deliver 500 megawatts
kilo-	$\times 10^3$	k	A mile is about 1.6 kilometres, i.e. 1.6×1000 m
centi-	$\times 10^{-2}$	c	A wine bottle holds about 75 centilitres, or (75/100) li
milli-	$\times 10^{-3}$	m	This page is about 0.1 millimetre thick, or (0.1/1000) m
micro-	$\times 10^{-6}$	μ	A soap film may be a few micrometres thick

read through a chapter you may find a self test question in the text, together with an answer you should be able to obtain. The previous part of the text should be reinforced by your answering the question. Further questions based on the text occur at the ends of chapters, and answers to some of these may be found at Appendix D. In Appendix C you will find some revision questions which have been asked in GCSE examinations in the UK.

This book could be used for revision of the subject. However, for those who use it to accompany their coursework, some hints on planning and carrying out a practical physics project may also be helpful. We use the rest of this introduction to consider how you might plan, carry out and write up a record of your work.

Experimental project work

Several physics courses devote some time to an assessed practical project. Typical subjects for study might be:

1 the time it takes a simple pendulum to swing forwards and backwards again
2 the greatest friction force which occurs when you try to pull a wooden block along a flat surface. (This is the force you must apply to get the block to slide)
3 the energy transferred to solids or liquids from a current in an electric heating element
4 the rate of loss of heat from a can of hot water surrounded by a layer of lagging.

Whatever the assignment may be, it will be helpful to have an outline of the stages of planning, conducting experiments, analysing results and concluding your report. The following outline shows the steps which should be recorded in the write-up of your work.

Practical assignment outline

1 Planning
2 Conducting experiments
3 Analysing results and concluding

1 **Planning** (you keep a record of each of these steps)
  a **Identify** and make a list of the possible **variables**. These are the things you could change in order to investigate their effect on the phenomenon you are given to study. With a pendulum study you might choose its length and the mass of the bob as variables, or you might think of others.
  b Devise experiments **adjusting one variable at a time**.
  c Make a list of the apparatus you will use.
  d Show how the apparatus is to be set up for each test.

e Decide how you will obtain the readings in each test.
f Show how you will record your readings.
g Predict what you expect your results to show.

2 **Conducting experiments** (to obtain and record readings **with units**)
a Set up the apparatus and try some simple tests.
b See if you can obtain repeatable readings.
c Conduct each of the planned tests and **record readings clearly**.
(Repeated readings may lead to reliable average results).

3 **Analysing results and concluding your write-up**
a Plot graphs and complete calculations.
b Use results to assess the effect of each variable.
c Express your findings in conclusions, which express general trends and/or more precise mathematical relationships.
d Now have a look at 1 g above and compare your findings with your predictions.
e Say what improvements you could make to the experiments.

A practical scientist records numerical data to an appropriate number of significant figures, and you can be marked down for giving answers to calculations to more figures than your data can justify. A good rule of thumb is not to use more than three sig. figs, and be ready to round up your answers to two sig. figs unless you have very accurate instruments and very repeatable results. So, for **3.86 mm** you write **3.9 mm** (2 sig. figs), but for **3.84 mm** you write **3.8 mm** (2 sig. figs).

On completion of your project you should check that your name is on each page. The front page should carry a title, e.g. **'The swings of a pendulum. Pete Jones. Set P.'** Check that your graphs are properly plotted on squared paper with the axes clearly ruled, numbered, and labelled. The graphs also need headings, e.g. **'Graph of time for ten swings of a pendulum plotted against the pendulum's length'**. Number the pages in order, and clip or staple them together. Anyone who reads your report should then be able to grasp what it was you studied, how you set about it, what you found out and how reliable you think your results are.