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of Schools & Colleges together with the Relevant Theory

Sir Cyril Ashford

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# PRACTICAL PHYSICS

*A Collection of Experiments  
for Upper Forms of Schools & Colleges  
together with the Relevant Theory*

BY

**SIR CYRIL ASHFORD**

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AT THE UNIVERSITY PRESS

1950

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University Printing House, Cambridge CB2 8BS, United Kingdom

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It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

[www.cambridge.org](http://www.cambridge.org)

Information on this title: [www.cambridge.org/9781107586284](http://www.cambridge.org/9781107586284)

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First published 1950

First paperback edition 2015

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

ISBN 978-1-107-58628-4 Paperback

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Sir Cyril Ashford

Frontmatter

[More information](#)

## CONTENTS

*Note.* By Mr J. L. Brereton, M.A., General Secretary to the University of Cambridge Local Examinations Syndicate *page* viii

*Preface* ix

## INTRODUCTION; THE REDUCTION OF OBSERVATIONS

(1)	Computation of a Single Constant	2
(2)	Graphical Representation; Linear Graphs	4
(3)	Distorted Graphs	10
(4)	Most Probable Value of a Single Constant	12
(5)	Most Probable Linear Equation	15

## PART I: MECHANICS

<i>Exp.</i>	1. Stretched Elastic String, I	21
	2. Stretched Elastic String, II	23
	3. Rigid Pendulum	25
	4. Simple Pendulum	27
	5. Bending of a Lath, I	30
	6. Bending of a Lath, II	33
	7. Bending of a Lath, III	34
	8. Compound Pendulum	36
	9. Resonance	41
	10. Bifilar Suspension	45
	11. Torsional Oscillations of a Suspended Bar	49
	12. Moments of Inertia	51
	13. Effects of Fluid Friction	53
	14. Measurement of Viscosity of Water	55
	15. Steady Flow through a Siphon	58
	16. Emptying a Vessel of Liquid	59
	17. Measurement of Surface Tension	62

Cambridge University Press

978-1-107-58628-4 - Practical Physics: A Collection of Experiments for Upper Forms of Schools &amp; Colleges together with the Relevant Theory

Sir Cyril Ashford

Frontmatter

[More information](#)

vi

## CONTENTS

## PART II: LIGHT

<i>Exp.</i> 18. Critical Angle	<i>page</i> 65
19. Wave Fronts	68
20. Planning for Accuracy	69
21. Newton's Lens Formula	79
22. Lens and Plane Mirror	80
23. Focal Length of a Convex Mirror	86
24. Lens Formula for a Concave Lens	88
25. Focal Length of a Concave Lens	89
26. Oblique Incidence on a Lens	92
27. Focal Lines	97
28. Focal Length of a Compound Lens, I	99
29. Focal Length of a Compound Lens, II	103
30. Principal Points of a Compound Lens	105
31. Camera Lens giving Variable Magnification	107
32. Telescopes	110
33. Thick Lenses in Contact	116

## PART III: HEAT AND ELECTRICITY

<i>Exp.</i> 34. Change of Viscosity with Temperature	119
35. Cooling Graphs	121
36. Thermal Capacity of a Vacuum Flask	123
37. Newton's Law of Cooling	124
38. Immersion Heater	126
39. Change of Resistance with Temperature	128
40. Resistance of a Coil Carrying a Current	130
41. Resistance of a Voltmeter	134
42. Resistances in Parallel	136
43. Errors due to Inadequate Voltmeter Resistance	137
44. Resistance of a Stretched Wire	143
45. E.M.F. in Galvanometer Circuit of a Wheatstone's Bridge, I	144

Cambridge University Press

978-1-107-58628-4 - Practical Physics: A Collection of Experiments for Upper Forms of Schools &amp; Colleges together with the Relevant Theory

Sir Cyril Ashford

Frontmatter

[More information](#)

## CONTENTS

vii

<i>Exp.</i> 46. E.M.F. in Galvanometer Circuit of a Wheatstone's Bridge, II	<i>page</i> 147
47. E.M.F. in Galvanometer Circuit of a Wheatstone's Bridge, III	149
48. Kirchhoff's Laws	150
49. Uniformity of a Bridge Wire	153
50. Effect of an Oblique Magnet on a Magnetometer	154
<i>Appendix A.</i> Parallax Methods with Lenses	158
B. Thick Lenses	162
C. Bending of a Beam	171
<i>Index</i>	175

Cambridge University Press

978-1-107-58628-4 - Practical Physics: A Collection of Experiments for Upper Forms of Schools & Colleges together with the Relevant Theory

Sir Cyril Ashford

Frontmatter

[More information](#)

## NOTE

The Local Examinations Syndicate was fortunate in securing Sir Cyril Ashford's help and interest after his retirement from Dartmouth in the preparation of practical physics exercises for the Higher School Certificate Examination. Most of the problems in this book were set in that examination between 1932 and 1947. They thus combine the originality and interest which they owe to their author with the merit of having been worked over by moderating examiners in the laboratory and at meetings. In their present form they have also benefited from the fact that the author was able to judge their suitability from the successful and unsuccessful solutions sent in by many examination candidates, and from the comments of their teachers. The Syndicate welcomes Sir Cyril Ashford's re-use of these practical problems as the basis of a teaching text-book which will make available in Schools and Universities the results of the author's pioneering efforts over a period of 15 years.

J. L. BRERETON

SYNDICATE BUILDINGS  
CAMBRIDGE

*February 1949*



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Frontmatter

[More information](#)

## PREFACE

In the early stages of his science course a boy lacks reasoning power and first-hand acquaintance with the properties and behaviour of materials, so that he cannot fully comprehend a logically connected course of lecture-demonstrations. During those stages, laboratory work should therefore, so far as is practicable, go hand-in-hand with the lectures. By the time the boy enters what is commonly called the post-certificate stage the conditions have changed; he can then follow lectures and demonstrations without having previously handled the apparatus himself, and consciousness of the true relation between theory and practice in an inductive science is beginning to dawn on him. The need for individual experimentation is certainly not lessened at this stage, but its main purpose becomes for the time being the verification of theory which has been, or can be, developed by deductive logic from earlier, more fundamental, experiments, and the practical testing of hypotheses, sprung perhaps from his own, perhaps from a more mature, scientific intuition.

The emphasis should now be laid on the best way of using his available instrumental equipment to establish or reject a particular theoretical result, and on the extent to which his experiments do establish it. Laboratory technique and manipulative skill in general, the setting up of apparatus and the precautions for accuracy of observation in a particular case, and the reduction of those observations, all enter into this procedure. New powers of a general kind, applicable to any particular problem, have to be developed, so that there is no longer any strong reason for close relation between lecture and laboratory work; indeed, laboratory work may almost be kept in a separate compartment, to be developed concurrently with his growing body of theoretical knowledge, whereby each may be ready to come to the assistance of the other as need arises. Hence the exercises forming a laboratory text-book for this stage need not have any logical sequence and are therefore capable of being taken in any order (which is a great convenience in a school laboratory with its necessarily limited equipment), nor do they need to cover the whole of the lecture course.

There is already available a considerable body of traditional experiments designed to illustrate the lectures appropriate to this

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Sir Cyril Ashford

Frontmatter

[More information](#)

stage; to propose new ones calls for justification. Many of those included in this book, which is primarily designed for the last year of the school course, are intentionally concerned with theory which the schoolboy is unlikely to have studied, and the verification of such theory by experiment is a procedure in line with the foregoing arguments. In others the results to be tested can be deduced from theoretical work with which he is more or less familiar, but the general lay-out of the experiments and the methods of reducing the observations in such a way as to check the theory effectively may be unfamiliar to him. In every case the aim has been to present the problem as one in Practical Physics, with the laboratory functioning at least as the Court of Appeal rather than as a place where lectures can be revised at leisure, and preferably as a real laboratory where a boy can try out hypotheses and determine physical or instrumental constants, free from authoritarian influences.

The outlines of relevant theory with which experiments are prefaced in many text-books are often worded in such a way as to convey the impression that that theory settles the matter by its own authority, and that the boy succeeds in his experiments only in so far as his results agree with it; that he is to do the experiment for the sake of practice in experimenting, and that it is his manipulative skill, not the theory, which is being put to the test. It is in the belief that this is to deny Physics its true status as an inductive science that a vigorous attempt has been made here to banish any such impression from the boy's mind and to make him realise that teachers and text-books alike 'abide our question'.

Most of these exercises are based on questions set during the last 15 years in the Higher School Certificate papers of the Cambridge University Local Examinations Syndicate, and grateful acknowledgment is made to the Syndics for their permission to use them in this form. The exercises have of course been radically transformed and amplified to fit them to form part of a teaching course, and care has been taken to increase rather than diminish the extent to which their original design was influenced by the foregoing considerations. The use of examination questions as a basis for a teaching course has the merit that the problems set for solution in a practical examination must be so designed that they can be carried through in every one of a wide variety of laboratories, some at any rate possessed of a very slender sequence, all the experiments in

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Frontmatter

[More information](#)

## PREFACE

xi

exception, require no apparatus that does not already exist in every laboratory where the book is likely to be used. This puts into effect another general principle which the author believes to be of considerable importance, that a student should learn to rely on his own powers rather than on elaborate equipment; in C. V. Boys's words, not 'to bow down to the brazen image that the instrument maker has set up', but to make the very best use of what is to hand, however simple it may be.

In some of these practical problems the boy cannot be expected to know, to have been taught, or even to have access to books or publications containing the relevant theory. Notes on this theory have therefore been appended to individual exercises.

It is by no means essential, though it is desirable, for him to master the substance of these notes; they may in some cases be too advanced for him, but it will do him good to see how much of them he can follow at the stage he has reached in his theoretical work, and to realise that he can safely and properly explore by experiment ground which is beyond his present range of theory. From that point of view there is really no need for him even to glance at these notes, but they are at hand in case he is moved to do so. Their presence may be rather intimidating to a student unless he understands that this is their purpose, and that for him the actual experiment is the all-important matter; it is hoped that this will be made plain by the teacher and that he may not himself be misled into overrating the difficulty of the course. The fact that most of the experiments have been carried out under examination conditions by hundreds of VIth Form boys, with a measure of success represented by normal distribution curves, should dispose of such misapprehensions.

An Introduction has been provided in which a number of practical points in the reduction of observations is set forth. Teachers usually prefer that their pupils should follow local customs in the setting-up of apparatus and the choice of precautions for accuracy; they would be unlikely to welcome outside interference in these matters. On the other hand, the art of reducing observations may almost be said to be one and indivisible; it would take too long for a demonstrator to teach it separately to each pupil, but it is of such practical importance that the demonstrator may well wish to be able to refer the student to some treatise on the subject; such treatises are not usually to be found in elementary text-books; it therefore seemed

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Sir Cyril Ashford

Frontmatter

[More information](#)

---

xii

PREFACE

desirable to attempt to meet the need here, even in this restricted form. It will be seen that graphical methods, with emphasis on linear equations, have been given the preponderance that is now common in teaching laboratories.

In the Introduction, appendices and some of the notes on theory a few unpublished pieces of theoretical work have been included; the author can only express the hope that they will withstand criticism and plead that he has at least offered his critics facilities for testing their truth by designing experiments for that purpose, in accordance with the principles set out in this preface.