Practical Physics

Practical Physics demonstrates the purposive and critical approach that should be made to all experimental work in physics. It does not describe a systematic course of experiments, but is intended as a companion to any undergraduate course of practical work.

The text is in three parts. The first deals with the statistical treatment of data, the second with experimental methods, and the third with such essential matters as keeping efficient records, accuracy in calculations, and writing good, scientific English. The text is liberally illustrated with examples and exercises, with solutions to the latter.

The new edition includes a treatment of the χ^2 distribution, a section on atomic clocks and their applications, worked examples based on spreadsheets, and additional exercises. The examples and references have been brought up to date.

Although intended mainly for undergraduates, *Practical Physics* has proved of interest to senior school students, teachers, and research workers, not only in physics, but also in other branches of science. Previous editions have been translated into German, Dutch, Spanish, Russian, Polish, and Arabic.

GORDON SQUIRES has been a Lecturer in Physics at the University of Cambridge and a Fellow of Trinity College, Cambridge since 1956. His field of research is thermal neutron scattering and he has published many papers in leading scientific journals. He is also the author of *Introduction to the Theory of Thermal Neutron Scattering* (Dover Publications) and *Problems in Quantum Mechanics* (Cambridge University Press) as well as an article on quantum mechanics in the Encyclopaedia Britannica. Since retiring as a University Lecturer in 1991, Dr Squires has been the Curator of the Cavendish Laboratory Museum.

Practical Physics

G. L. SQUIRES

Emeritus Lecturer in Physics at the University of Cambridge and Fellow of Trinity College, Cambridge

FOURTH EDITION

CAMBRIDGE UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge CB2 2RU, UK
40 West 20th Street, New York, NY 10011–4211, USA
10 Stamford Road, Oakleigh, VIC 3166, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain
Dock House, The Waterfront, Cape Town 8001, South Africa

http://www.cambridge.org

Fourth edition published 2001

Typeset in Times 10/13.5pt System 3b2 [CE]

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

Library of Congress Cataloguing in Publication data

Squires, G. L. (Gordon Leslie)
Practical physics / G. L. Squires – 4th ed.
p. cm.
Includes bibliographical references and index.
ISBN 0 521 77045 9 – ISBN 0 521 77940 5 (pb.)
1. Physics – Experiments. 2. Physics – Methodology. I. Title.
QC33.S68 2001
530′.028–dc21 2001025559

ISBN 0 521 77045 9 hardback
ISBN 0 521 77940 5 paperback

Transferred to digital printing 2003

CONTENTS

PREFACE TO THE FOURTH EDITION

The present edition retains the basic outlook of the book, namely to demonstrate the purposive and critical approach which should be made to all experimental work in physics. But I have made a number of changes and additions in response to new experimental methods and the widespread use of computers, which I hope will add to its usefulness.

Substantial changes have been made in chapter 7, in which a selection of techniques are analysed to show the art and craft of the experimenter. I have added a section on the measurement of time and frequency, which includes an account of the caesium atomic clock and the present universal time scale. This is followed by a description of the Global Positioning System, which, based on atomic clocks, enables position on the surface of the Earth to be determined to very high precision. Timing techniques have a number of elegant and ingenious features, which, combined with the importance of their practical applications, make them instructive and interesting, both at the elementary and advanced level.

I have added an appendix on the χ^2 distribution. The goodness of fit test based on this distribution finds widespread application in the physical, biological, medical, and social sciences. Many students have had an introduction to the topic at school and have learnt to apply the formulae of the test, but I feel that valuable insight is gained from seeing a derivation of the distribution, which I have given in a not too formal manner.

Spreadsheets are now in common use, and I have included some worked examples based on them. I have taken the opportunity to add to the exercises, and have brought some of the examples, references, and definitions of units up to date.

I would like to thank Mr J. Acton, Dr C. Bergemann, Professor M. F. Collins, and Dr D. Kennedy for helpful discussions and for comments on the revised parts of the book, and Mr A. Squires both for useful comments and for providing Fig. E.2b.

G. L. SQUIRES
July 2000

PREFACE TO THE FIRST EDITION

Experimental physics has occupied some of the finest intellects in the history of man, but the fascination of the subject is not always apparent in an undergraduate course of practical work. This book is about experimental physics and it is intended for undergraduates, but it does not describe a systematic course of experiments, nor is it a handbook of experimental techniques. Instead, it sets out to demonstrate a certain outlook or approach to experimental work. It is intended as a companion to a general course of practical work. My aim is to make the student more critical of what he does and more aware of what can be done, and in this way to make the course more interesting and meaningful.

The book is in three parts. The first is on the statistical treatment of data. I have tried to give the statistical theory not as an exercise in mathematics but rather as a tool for experimental work. This is perhaps the most difficult part of the book, and the student should not worry if he does not grasp all the mathematical details at first. He should read through the chapters to get a general understanding – and then go ahead and use the results. He can always return and master the proofs at a later stage. The second part is on experimental methods. I discuss a selection of instruments, methods, and experiments with a view to showing the craft of the experimenter. The selection is arbitrary – though I have tried to illustrate the points with methods that are useful in themselves. The third part concerns such matters as keeping efficient records, getting arithmetic right, and writing good scientific English.

The examples have been kept fairly simple. Apart from the account of the measurement of the magnetic moment of the electron, the level of the material is roughly that of a first-year undergraduate course. But I think that a wider range of students – from intelligent sixth-formers to research students – could benefit from the experimental 'awareness' that the book is trying to foster.

The experiment to measure the magnetic moment of the electron is an advanced one and contains several ideas beyond those of an average first-year course. I have tried to give sufficient explanation to make it intelligible to someone in his second or third year who has had an introduction to quantum mechanics. The experiment is a rewarding one to study, but the whole account may be omitted at first reading without detriment to the understanding of the rest of the book.

I would like to thank Professor O. R. Frisch, Professor R. G. Chambers, Mr E. S. Shire, Dr J. Ashmead, Dr J. R. Waldram, Dr B. D. Josephson, and Dr

N. J. B. A. Branson for reading the first draft of the book and making valuable suggestions for its improvement. I would also like to thank Messrs R. A. Bromley, R. G. Courtney, B. C. Hamshere, H. M. C. Rowe, B. Scruton, D. R. Weaver, and M. A. G. Willson who read parts of the first draft and made many useful comments from the user's point of view. Finally, I wish to express my indebtedness to all the undergraduates who have passed through the first-year Mechanics, Heat, and Optics Class at the Cavendish Laboratory in the past ten years. They have taught me much about errors – in every sense of the word.

G. L. SQUIRES
September 1967