

EXPERIMENTAL  
SCIENCE

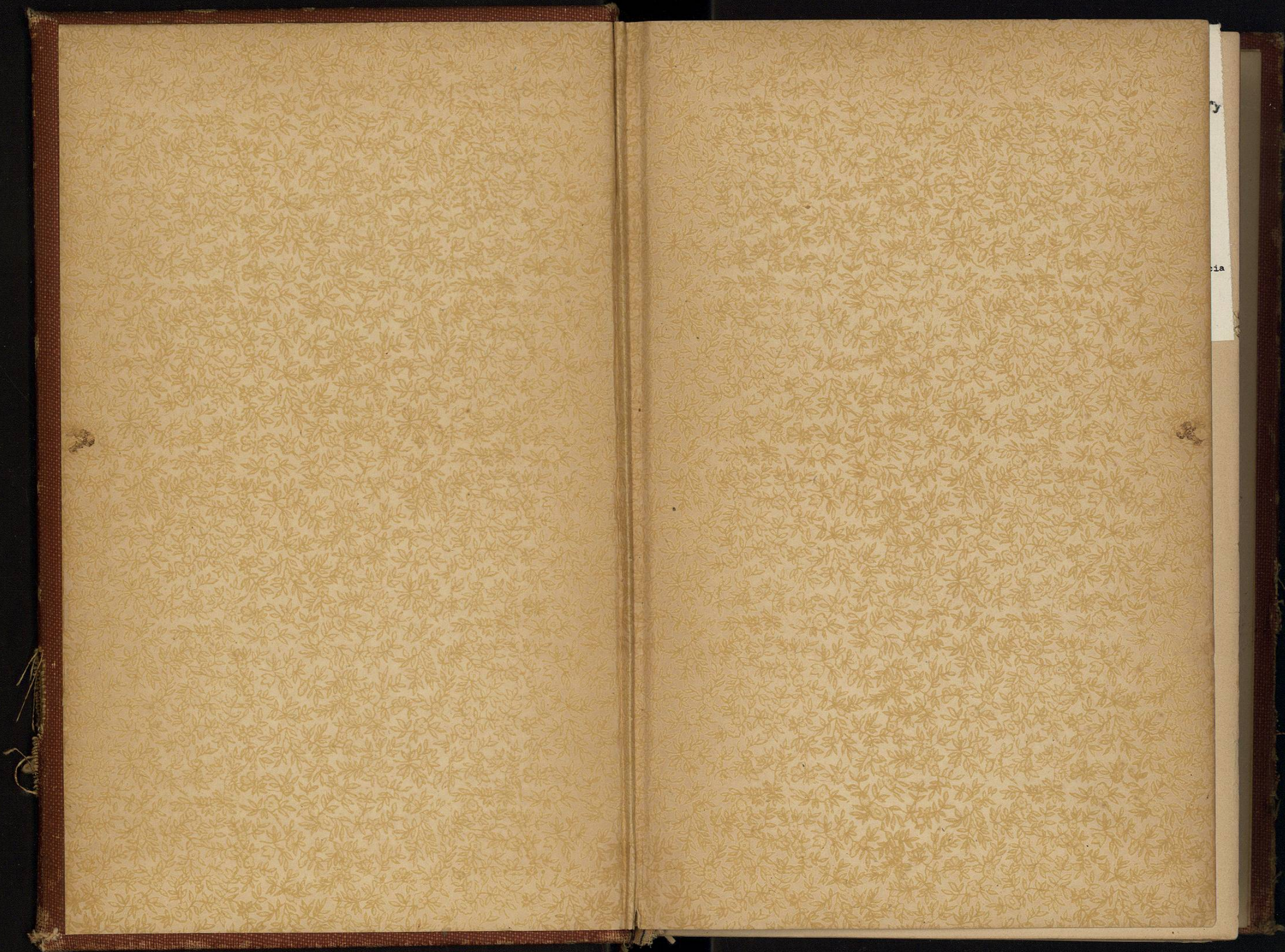
---

HOPKINS

VOL. I.

QC21  
H67  
1906

MILLEN & CO.



No. Accesoión

000145

Fecha de pedido

No. de pedido

Procedencia

No. de ejs.

Fecha de recibido

Obs.

Autor George M. Hopkins

Título  
Experimental science elementary  
practical and experimental physics

Lugar  
New York

Editor  
Munn

Año  
1906

Vols.

Serie

Edición

Precio

Costo

Dependencia

clasif.

# PHYSICS

BY  
GEORGE M. HOPKINS

VOL. I.

TWENTY-FIFTH EDITION

(Revised and Enlarged)

NEW YORK:  
MUNN & CO.

1906



BIBLIOTECA

000145

Deal  
H67  
1904

COPYRIGHT 1889  
BY  
MUNN & CO.

COPYRIGHT 1893  
BY  
MUNN & CO.

COPYRIGHT 1898  
BY  
MUNN & CO.

COPYRIGHT 1902  
BY  
MUNN & CO.

COPYRIGHTED 1902 BY MUNN & CO.

ENTERED AT STATIONERS' HALL,  
LONDON, ENGLAND.

ALL RIGHTS RESERVED.

Macgowan & Slipper, Printers, 30 Beekman St., New York.

## PREFACE.

---

THE design of this work is to afford to the student, the artisan, the mechanic, and in fact all who are interested in science, whether young or advanced in years, a ready means of acquiring a general knowledge of physics by the experimental method. One of its principal purposes is, also, to furnish to the teacher suggestions in experimentation, which will be helpful in making classroom work interesting and attractive, rather than dry and monotonous.

Most of the apparatus here illustrated and described may be constructed and used by any one having ordinary mechanical skill. Simple and easily made devices have been chosen for physical demonstration.

With scarcely an exception the experiments described were performed at the time of writing, to insure fullness of detail, and to avoid inaccuracies. The reader can therefore be assured that by following the instructions, success will be certain.

Mathematics has been almost entirely excluded. The few problems presented are capable of arithmetical solution. The importance of mathematical knowledge in all branches of science is fully recognized, but the majority of students have little taste for the intricacies of numbers. Faraday was an illustrious example of a scientific man without great mathematical proclivities.

The late Clerk Maxwell, one of the most eminent mathematicians and electricians of the present century, said: "A few experiments performed by himself will give the student a more intelligent interest in the subject, and will give him a more lively faith in the exactness and uniformity of nature, and in the inaccuracy and uncertainty of our observations, than any reading of books, or even witnessing elaborate experiments performed by professed men of science."

A large proportion of the material of this work consists of original articles published from time to time in the *Scientific American*. These have been revised or rewritten, with copious additions of text and engravings. Very few of the conventional illustrations of the text books have been used. Most of the engravings are now for the first time given in book illustration.

The leading principles of physics are here illustrated by simple and inexpensive experiments. The endeavor has been to make the explanations of both apparatus and experiment plain and easily understood.

If what is here written shall induce any who are now indifferent to the subject to begin the study of physics experimentally, so as to gain even a faint conception of the marvelous perfection of the physical world, or if anything in these pages proves helpful to those who instruct, or who seek scientific information, the end sought by the writer will have been gained.

GEORGE M. HOPKINS.

NEW YORK, January, 1890.

## PREFACE TO EDITION OF 1898.

THE seventeenth edition of *Experimental Science* contained an appendix including much new matter, but, in the four years which have elapsed since the publication of this edition, several startling physical discoveries have been made, among which are the X-Ray and its phenomena, Wireless Telegraphy, the Liquefaction of Air, and Acetylene Gas. These have been included in the present edition. Besides these, a number of additional experiments are given, some of which are new and original. The book has been considerably enlarged by the additions, and it has been revised so that it is in accord with recent ideas of the subjects treated.

The new matter added will prove acceptable to such as seek information on the more recent scientific discoveries.

GEORGE M. HOPKINS.

September 7, 1898.

PREFACE TO THE TWENTY-FIFTH EDITION

IN order to broaden the scope of this work, the author has relaxed the rather rigid rule heretofore adhered to, which called for the trial by himself of every piece of apparatus described in its pages, and has now availed himself of the experience of others. He is therefore able to present to the readers of the twenty-fifth edition, a full explanation of the Polyphase Generator, Induction Motors, and Rotary Transformers, also to give accurate information regarding the construction of modern direct current motors for 110 volts pressure.

A full description of Edison's New Storage Battery is introduced, also some interesting experiments by Prof. John Trowbridge, and some Electrical Measuring Apparatus by N. Monroe Hopkins. Wireless telegraphy is brought up to date, and other recent discoveries are noticed.

The new edition, owing to the great amount of new matter, is published in two volumes. It presents the more recent developments in modern science, and gives information which assists the reader in comprehending the great scientific questions of the day.

GEORGE M. HOPKINS.

New York, June, 1902.

CONTENTS.

CHAPTER I.—PROPERTIES OF BODIES.

PAGES

Extension and Impenetrability—Cotton and Alcohol Experiments—Solution of Sugar in Water—Reduction of Volume of Alcohol and Water Mixture—Mixture of Sulphuric Acid and Water—Divisibility—Example of Extreme Divisibility—Porosity—Physical and Sensible Pores—Porosity of Wood—Mercurial Shower—Porosity in Nature—Porosity in the Arts—Compressibility—Pneumatic Syringe—Elasticity—Gases and Liquids Perfectly Elastic—Elasticity of Flexure—Elasticity of Torsion—Experiment showing the Elasticity of Glass..... 1 to 7

CHAPTER II.—REST, MOTION, AND FORCE.

When a Body is at Rest—All Bodies continually changing Position—Absolute Rest Possible—Inertia—Force—Matter Incapable of changing from Rest to Motion, or the Reverse—Equalizing Effect of Fly Wheels—Persistent Rotation due to Inertia—Action of Projectiles, Hammers, Drop Presses and the Hydraulic Ram, due to Inertia—Inertia Locomotive—Friction due to Roughnesses—The Effect of a Lubricant—Sliding Friction—Rolling Friction—Roller and Ball Bearings—Centrifugal Force—Centrifugal Railway—Normal Path of a Moving Body a Straight Line—Spiral Railway—Effect of Centrifugal Force on Air—Choral Top—Effect of Centrifugal Force on Liquids—The Glass Top—Effect of Centrifugal Force on Liquids of Different Densities contained in the Same Vessel—A Scientific Top—Persistence in maintaining Plane of Rotation—Gyroscopic Action—Examples of Centrifugal Action—Oblate Spheroid—Centrifugal Hero's Fountain... 8 to 18

CHAPTER III.—THE GYROSCOPE.

Toy Gyroscope—A Large Gyroscope—Gyroscope with Friction Driving Gear—Pneumatic Gyroscopes—Electrical Gyroscope—Steam Gyroscope—Gyroscopes for showing the Rotation of the Earth—Equatorially Mounted Electrical Indicator—Bursting of Fly Wheels by Gyroscopic Action—Flexible Fly Wheel..... 19 to 37

CHAPTER IV.—FALLING BODIES—INCLINED PLANE—THE PENDULUM.

In a Vacuum All Bodies fall with Equal Rapidity—Effect of Resistance on Falling Bodies—Water Hammer—Swiftest Descent Apparatus