ELEMENTARY LESSONS IN PHYSICS: MECHANICS (INCLUDING HYDROSTATICS) AND LIGHT

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649499472

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Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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LESSONS IN PHYSICS

MECHANICS (INCLUDING HYDROSTATICS) AND LIGHT

BY

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NEW YORK

HENRY HOLT AND COMPANY

1894

INTRODUCTION.

SOME years ago a body of educational leaders declared themselves in favor of teaching physics by means of experiments involving exact measurement and weighing by the pupils in grammar-schools. To the author of this book, well aware of the difficulty of establishing and maintaining a thorough course of quantitative experimental work in academies and high schools, the new proposition did not at first commend itself. Difficulties of various kinds, financial, mechanical, pedagogical, appeared in the way. Indeed, the author at first expressed, somewhat publicly, the opinion that grammar-school physics must be lecture-table physics, an hour or two a week devoted by the teacher to the performance and discussion of simple experiments in the presence of the pupils. He thought, and still thinks, that such a course would be not unprofitable. There are several books describing this kind of work, and their number is rapidly increasing.

But the advocates of the lecture-table method of science-teaching cannot claim for it the disciplinary advantage and the power of bringing the pupil into close quarters with physical facts and laws, that belong to a properly-conducted course of laboratory work by the pupils themselves. If such a laboratory course is readily practicable, grammar-school pupils should have it, for the grammar-

school is the popular school, the school in which the great majority of children get the last of their formal education. To what extent, then, is quantitative laboratory work in physics practicable for grammar-schools? The question is here limited to quantitative work, because the author would shrink from the task of laying out a course not mainly quantitative, which would occupy the pupils profitably without making impossible demands upon the time and patience of the teacher.

Quantitative work of a substantial and profitable character is, in the opinion of the author, practicable for grammar-school pupils in the subjects of mechanics (including hydrostatics) and light. Quantitative work in sound, heat, electricity, and magnetism demands apparatus and laboratory facilities that school-boards would at present hesitate to supply to grammar-schools, even if it were certain that pupils of fourteen years could use them to advantage.

This little book has grown out of a course of instruction given by the author, for two years in succession, to teachers conducting, or preparing to conduct, a similar course in the grammar-schools of Cambridge. A large part of the work for pupils described in this book has been actually performed by whole classes in the highest grade of all these schools during the year 1893–94. The success of this "Cambridge experiment" has been, on the whole, gratifying. A brief account of the way in which this new work has been fitted into the school program is given, in an appendix to this book, by Mr. Frederick S. Cutter, who was the first grammar-school master in Cambridge to undertake laboratory teaching in physics.

It is the firm conviction of the author that class laboratory work not accompanied by persistent, energetic, *teaching* is sure to be a failure. We are often told that the favorite method of the elder Agassiz with a new pupil was to set him to gaze in solitude at a single fish for two or

three days. Those who would make this the model for science-teaching in general forget that pure observation of numerous, minute, varied details plays a much more important part in natural history than in physics. The teacher of physics who would produce good and lasting results must see to it not merely that the laboratory work shall be carefully done, but that the proper lessons shall be drawn from it and the proper applications made. In fact, the young pupil should give as much time to the study of physics in the lecture- or recitation-room as in the laboratory proper. The *Suggestions for the Lecture-room* given in this book are sometimes very full, but in general they will have to be supplemented by hints from other books or from the teacher's own experience. One or two text-books of the high-school grade, and if possible some book of the college grade, Barker, Deschanel, or Ganot, for instance, should be at the service of the teacher.

The laboratory *Exercises* of this course cover about one third of the ground covered by the laboratory *Exercises* of Hall and Bergen's Text-book of Physics, and most of them are in close correspondence with the work in physics recommended by the Report of the famous "Committee of Ten." It is the hope of the author that the use of this book in the last year of the Grammar School, or the first year of the High School, course will remove much of the difficulty now found by some schools in condensing all of the laboratory work in physics into one year of the High School. The discontinuity thus introduced into the study of physics, a break of two or three years between the study of mechanics and optics, on the one hand, and heat, sound, and electricity and magnetism on the other, is entirely reasonable, in view of the much greater expense and experimental difficulty of laboratory work in these latter subjects.

The course is intended to run through the year and to

beginning the course rather late in the fall of 1893,

occupy the pupil two school-periods, each forty minutes long if possible, per week; one usually in the laboratory, and the other in the lecture- or recitation-room. The number of *Exercises* is only twenty-seven, much less than the number of school-weeks in the year, but some of them may prove to be too long for a single school-period, and teachers will welcome an occasional opportunity for repetition or review. The Cambridge Grammar-schools have given only one school-period per week to the laboratory work, and have, therefore, not been able to do all the *Exercises* in one year.

Although much of whatever is new in this book has originated with the author, many valuable suggestions have come to him from teachers and from makers of apparatus. Perhaps the most striking innovation of the book is a method of measuring the index of refraction of liquids by means of an extremely simple and inexpensive apparatus which yields very satisfactory results.

The book follows, as a rule, the method of leading up to the statement of laws by means of carefully-chosen experiments, rather than the opposite one of giving experiments as illustrations or proofs of laws already stated. It can hardly be said for the former method that it teaches the art of making discoveries,—that art is as difficult to teach as the art of getting rich,—but it has a tendency to keep the pupil in a more active, self-dependent state of mind than the latter method, and in particular it prevents in a large measure that state of bias, or preconception, in the performance of experiments, which is so dangerous not merely to accuracy of observation but to mental rectitude. On the other hand, the teacher using the method of this book must not allow his pupils to think that their experiments, even when most satisfactory, really *demonstrate* the rigid accuracy of any numerical law,—the law of a balanced lever, for instance. He should ask of them, "What law do your ex-

periments *indicate* as true?" and after their answer he should tell them whether their inference is or is not in accordance with the opinion held by those best qualified to judge of the matter in question.

Realizing that this book will naturally be used by teachers little accustomed to physical manipulations or the construction of physical apparatus, the author has taken especial pains in the description of laboratory operations, and has endeavored to give, in Appendix A, complete, detailed, lists of all those articles used in the laboratory exercises and the lecture-room experiments, which are not easily procurable by the teacher. A number of firms, mentioned by name in that Appendix, have undertaken to supply the apparatus described in these lists at reasonable prices. A table like those used in the Cambridge Grammar-schools is described in the same Appendix. Thus the *mechanical* difficulties of undertaking the course described in this book are reduced to a minimum.

In the Cambridge Grammar-schools the classes, whatever their size, have usually been divided into sections of sixteen or less for laboratory work, and as only one section in a school has worked in the laboratory at one time, only sixteen sets of the pupils' apparatus have been supplied to each school. These sixteen sets can now be furnished for about $80.00 or $90.00. The laboratory for a section of sixteen requires two substantial tables, which may cost $45.00 or $50.00. The teacher's list of apparatus and certain miscellaneous supplies will cost about $30.00. Much, and if necessary all, of the pupils' apparatus can be on shelves under the laboratory tables. Making no allowance for apparatus-cases, and assuming the school-building to have an available room fifteen feet by twenty, or larger, well lighted and supplied with a cold-water tap and a sink, one may estimate the cost of establishing this course fully in any grammar-school at $200.00, a considerable margin of

this estimate being intended to cover contingencies not specifically foreseen.

Whatever the merits or demerits of the course laid down in this book, its success in any particular case will depend largely upon local conditions. The author can ask for it no more favorable trial than the good-will of the school authorities and the zeal and ability of the teachers have given it at Cambridge.