PRACTICAL WORK IN GENERAL PHYSICS FOR USE IN SCHOOLS AND COLLEGES

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649419593

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Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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Trieste

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FOR USE IN SCHOOLS AND COLLEGES

Slate

BY

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Oxford

AT THE CLARENDON PRESS

1894

'Now the forces and action of bodies are circumscribed and measured either by distances of space, or by moments of time, or by concentration of quantity, or by predominance of virtue; and, unless these four things have been well and carefully weighed, we shall have sciences, fair perhaps in theory, but in practice inefficient.' *Nov. Org.* ii. Aph. xliv.

INTRODUCTION

It is perhaps too late in the day to insist upon the comparatively small value of mere book knowledge in any of the experimental sciences. To reap the full benefit from the mental discipline a scientific study offers reading must go hand in hand with individual experiment. In the case of Chemistry and Biology this is universally acknowledged, but in Physics the experiments are too generally performed by the lecturer himself, which deprives the teaching of much of its value. The cost of providing for experimental work, even in the case of large classes, need not be great. In the present volume as well as in the author's *Practical Work in Heat* an essential feature is to offer a fairly complete experimental course in the ground covered at but a trifling cost. The question of time is always a crux with the authorities who have to arrange the time table, but if a course of Practical Physics were estimated at its proper value this difficulty would be at once met.

The knowledge of physical facts is not the be-all and end-all of the study. The student must be brought up to do the experiments himself, and, unless he has learned by his own experience and observation what experimental evidence means, he will be unable to appreciate rightly the evidence on which is based the reasoning by which the general conclusions of Physical

Science are established. It would not, perhaps, be too much to say that if a student has conscientiously been through even such a course as is here offered to him, he will have derived far more benefit mentally than if he had stored his mind with a mass of facts and formulae out of books.

The advantages of a course of practical physics as a mental discipline are numerous. It teaches us the experimental method and the process of inductive reasoning which it involves, and the result of the training ought to give the student confidence in what he has seen with his own eyes and reasoned out with his own mind.

It also teaches us accurate observation. We all know the story of *Eyes and No Eyes*. Every measurement necessitates primarily a choice of a unit of the same nature as the quantity to be observed, and also the reading of a scale of such units (cf. Thermometer, Barometer, Galvanometer, &c.), and it is only by practice that a student becomes able to read the simplest scale with sufficient accuracy, as any one can testify who has had to do with beginners.

Again, the interest of the student is aroused on the subject if he has the opportunity of handling the apparatus and performing experiments in illustration of his book-work. 'Without observation and experiment,' says Desaguliers, 'our Natural Philosophy would be a science of terms and an unintelligible jargon.' It is only by individual experiments that we can infuse life into what some students are otherwise apt to look upon as the dry bones of science.

From a purely utilitarian point of view a course of practical physics is of great importance. The mere fact of reading a particular scale is in itself of no value, but the consequent sharpening of the faculties of observation is of prime importance, as the cuteness of a successful man of business depends much on his observational powers, and success in Chemistry, Astronomy, Civil and Electrical Engineering, &c. on a thorough understanding of the methods of accurate measurement.

Another advantage in a course of this kind is to teach the student to look for errors he may have committed and to adopt means to eliminate them. However precise our observations or instruments, we never get the same number if we repeat an experiment. The errors involved may be (α) **systematic errors**, over which we have no control. For instance, the temperature of the room may alter, or the currents of air may affect the balance differently and may tend to give different results; (β) **constant errors**, due to the graduation of the scale not being correct or the zero of the scale having altered: these, being due to the instrument used, can only be eliminated by comparing with a standard scale or by observing the zero error (Note 4); (γ) **accidental errors**, which may be got rid of in various ways according to the experiment we have in hand. The following means of neutralizing accidental errors may be noted.

(i) *By the method of least error*, i.e. by arranging the experiment so as to reduce possible errors to a minimum; e.g. in determining the densities of solids we take as large a piece of the solid as possible. It is evident that an error of 1 mgr. in estimating a mass of 100 grs. is only $\frac{1}{100}$th of the same error in estimating the mass of 1 gr.

(ii) *By the method of multiplication.* For instance, in finding the time of vibration of a pendulum (Experiment 44), by observing the time of twenty vibrations we only commit $\frac{1}{20}$th of the error we should have made if we observed the time of one vibration only.

(iii) *By check methods*, or by repeating an experiment after altering the conditions under which it is performed. Refer to Experiments 5, 31, 36, 44, 47, in which check methods are applied.

(iv) *By the method of averages.* If we repeat an experiment two or three times, assuming all our results to be equally trustworthy, the error probably is in excess in some, in defect in others, so that on taking the average of our results we get a value nearer the true one than either of the individual results.

A student may think that if an apparatus of greater precision were at his disposal he would be relieved of the continual tax which he feels upon his powers of observation. This is, however, not the case. The better the instrument the harder it is to do justice to it. One must learn to get the best possible results with rough instruments before one is fitted to use instruments of precision.

The student should also distinguish between real and apparent accuracy, and should not be deceived by an imposing array of decimal places, nor try to get a nearer accuracy than the instrument he uses will permit (Note 10). Thus, in Experiment 44, if an ordinary watch with a seconds hand is used, we cannot reckon the time of twenty vibrations to a greater accuracy than half a second, which gives a possible error of $\frac{1}{40}$th of a second for the time of one vibration. Now, in a pendulum of a metre in length, an increase of one centimetre in its length only involves a difference of $\frac{1}{400}$th of a second in its time of vibration, so that in measuring its length we need only measure to the nearest centimetre. If we lessened the error in measuring the time by using a stop-watch or by taking the time of a greater number of vibrations, we should have to measure the length with greater accuracy.

A word as to the conduct of the classes. Those under the author's charge average about twenty, and for the juniors one hour a week is devoted to Practical Physics. The students work in pairs, and, as the lectures are arranged so as to be in advance of the practical work, each set can, with the instructions before them, begin work at once, allowing ample time for the teacher to go round and give any further explanation or help in manipulation required. Each student has a note-book devoted specially to his practical work, and, on the completion of an experiment, if the result is satisfactory, he enters into his note-book—

(i) The enunciation of the experiment.

(ii) A neatly-drawn figure of the apparatus used.

(iii) A description in his own words of the method pursued.

(iv) Each measure made, and the results in a properly tabulated form, mere arithmetical calculations only being omitted.

This last is essential, as, unless insisted upon, a great deal of the good effect is lost.

The author begs to acknowledge his indebtedness chiefly to Harold Whiting's *Physical Measurements*, and ventures to express a hope that this book may be the means of suggesting the adoption of a most important branch of study in all schools, large and small, where science is taught.

KING EDWARD'S HIGH SCHOOL,
BIRMINGHAM,
March, 1894.