A MANUAL OF PHYSICAL MEASUREMENTS

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PREFACE TO FOURTH EDITION

This manual is an outline of the laboratory experiments given in the courses in general Physics at the University of Minnesota. The laboratory work, in these courses, supplements the lectures and recitations.

The experiments given in a junior course of one quarter in electrical measurements are also included in the section on electricity.

It is taken for granted that the student has acquired a general knowledge of a subject before it is considered in the laboratory and no attempt is made in the manual at completeness in subject-matter or in explanations. The work is done under the guidance of an instructor who furnishes any additional information necessary.

The student should feel that acceptable results depend upon his own ability to properly adjust the apparatus, and he alone should plan and execute the details of the experiments, subject of course to the criticism of the instructor.

We here wish to thank Professors L. W. McKeehan, John T. Tate and L. F. Miller for valuable suggestions, criticisms, and assistance during the preparation of this manual.

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INTRODUCTION

Work in the Physical Laboratory brings the student into first-hand touch with physical principles and physical apparatus, and the impressions produced through the senses furnish a solid foundation for further study.

The close attention to every detail and the exercise of deliberate judgment which are required in every experiment if a worthy result is to be obtained, tend to produce a habit of accuracy which is of inestimable value. This training is obtained only when every effort is made to get the very best result that the time allowed for the experiment and the apparatus employed will permit.

Before observations on any experiment are begun, the theory of the experiment should be mastered as well as the functions of the various parts of the apparatus which is to be used. Without such study, necessary observations may be omitted or taken in the wrong way, and apparatus whose value depends upon its accuracy may be injured permanently because of a lack of knowledge of its delicate parts. Furthermore it is important to determine the degree of accuracy of every result which is obtained.

Errors.—For various reasons it is impossible to obtain the absolute value of an unknown quantity. Any measurement is affected, to a greater or less extent, by errors which may be classified under the two heads: *constant* and *accidental*.

As examples of *constant* errors may be mentioned the following:

Physical errors, or errors which arise out of physical sources, e.g., change of length of a steel tape with temperature; instrumental errors, such as faulty construction or adjustment of apparatus; personal errors, or the personal equation; blunders. Constant errors can often be eliminated or corrected for.

Under *accidental* errors are grouped those which remain after the constant errors have been taken into account. It is not possible to determine the magnitude of the accidental error. The best that can be done is to determine the probable limits within which the true result lies.

A number of rules and methods for finding these limits have been developed in the Theory of Least Squares.

The rigid application of these rules in the elementary laboratory is hardly justifiable. However some simple method for determining the first figure in the result affected by the accidental error is necessary, and, therefore, the mastery of the following is required.

Error in a Single Reading.—Instruments should be read to a fraction of their smallest division and hence the last figure in the reading is an estimated quantity, the accuracy of which depends upon the experience of the observer and the size of the smallest division. Estimate fractions in tenths, and record decimally. In general the estimation is liable to be correct to within one of the estimated parts. The quantity so estimated must be included in the result as the last *significant* figure and one of the estimated parts may be taken as the probable limit of error in the reading. For example, if in the reading 2.56 the last figure was obtained by estimating, the reading is liable to contain an error as large as 0.01. This fact may be expressed by writing the result 2.56 ± 1 meaning that the true value probably lies between $2.56 + .01$ and $2.56 - .01$.

Error in an Average.—If several readings of the same quantity are taken they will differ among themselves