ART. XL.—*On a New Method for Reading Deflections of Galvanometers*; by C. B. RICE.

A METHOD of reading deflections of galvanometer needles and analogous apparatus has been recently devised in this laboratory by Professor C. S. Hastings, which, since it proves to have considerable value, he has given me the opportunity to describe.

There are two types of sensitive galvanometers in general use, namely, those in which the deflections of the suspended system are determined by the motion of an image of a luminous source on a scale, and those in which the deflections are measured by telescope and scale after the method first introduced by Gauss and Weber. The Thomson galvanometers are the familiar examples of the first, and the Wiedemann of the second.

Each of these has certain inconveniences. That of Thomson, although an exceedingly sensitive galvanometer, requires a darkened room and a lamp, with somewhat inaccurate determination of the angle of deflection. It is also rather too delicate to put into the care of the untrained student. Wiedemann's is much better suited for ordinary laboratory work. Here less sensitiveness is compensated by much greater precision of angle measure, while its construction renders it safe to put the instrument into comparatively unskillful hands. A much wider range of sensitiveness and of damping is readily secured in this form than in Thomson's. It has, however, the inconvenience of requiring the rather expensive accessory of a telescope and scale and also of demanding a large amount of space in its employment. These disadvantages are not of such great moment in most cases, perhaps, to forbid its use, and in our laboratory we found such instruments, well constructed of metal throughout, thoroughly satisfactory until continuous disturbances of magnetic field in the region were brought about by the construction of an electric road. Experience showed that the sensitiveness was thus reduced to about one-tenth its former value. D'Arsonval galvanometers of course eliminated this difficulty, but they too have their inconveniences and limitations.

If the linear dimensions of a Wiedemann's galvanometer were sufficiently reduced, say n -fold, the sensitiveness would be increased, while the accuracy of determination of duration would be decreased in the same ratio, since the apertures of the optical apparatus are thus reduced. If this were carried far enough, the aperture of the telescope would be reduced to that of the pupil of the eye and might be dispensed with

without loss. On the other hand, the disturbances of the field being no greater than before would now have n -fold less effect. Hence, in an irregularly variable field such an instrument would be n -times as accurate. In practice the gain is really much greater than this because of the much reduced period of the needle. These disturbances must be regarded as perfectly irregular in the larger instrument, but may here be treated as sudden occasional changes separated by periods of quiescence. A galvanometer constructed on this theory, as developed by Professor Hastings, has been tried with very satisfactory results.

The magnet is a circular steel disk of 1^{cm} diameter polished on both sides for convenience, serving as a mirror, hung between two coils of wire with a silk suspension of about 5^{cm} . The coils are of number 36 wire with an outside diameter of 2.5^{cm} and have a resistance each of six ohms. The brass covers which fit over the coils are provided with openings closed by glass so that there is a clear view of both faces of the magnet, while air currents are excluded. A small aperture of 1.4^{mm} diameter in the center of the steel mirror permits a view of objects beyond, which lie sufficiently near the axis of the instrument. Facing the coil and the magnet within, but at a trifle higher level, is placed a small lens at a distance adjustable from 5 to 7^{cm} from the magnet. On the opposite side, at a similar adjustable distance from the mirror, is fixed a fine

point, preferably of some dark material with a white background. Directly under the lens is a small scale. The image of this scale as formed by the mirror is seen superimposed upon the image of the fixed point as seen through the aperture in the mirror, and any change in the angular position of the mirror causes a relative shifting of these two images, which, under proper adjustment, are in the same plane and are, therefore, perfectly free from errors of parallax. The use of the lens serves the double purpose of reducing the linear dimensions of the apparatus and of giving such precision to the ocular accommodation that the edges of the hole in the magnet as well as the fixed image of the scale due to the glass windows are so far out of focus as to be quite invisible. When the lens, point and small scale are once adjusted the instrument is ready for use at any time with no further attention. If the support be moderately level no leveling screws are necessary.

With this galvanometer a potential of $\frac{1}{100,000}$ of a volt is readily detected by repeated closing of the circuit—a sensitiveness which is more than sufficient for a large part of the elementary work of the laboratory.

The simplicity and cheapness of this type of galvanometer make it very desirable, while its lack of delicacy is of considerable moment where the care of it falls upon the novice.

There seems to be no reason why this method for reading deflections should not be used with all other galvanometers as a substitute for the telescope and long scale. The angular measures are read with great accuracy and with much greater precision than with the lamp and scale of Thomson's method. The small scale used in this connection should be divided into half millimeters, for the reading is made with clearness to tenths of such an interval.

The instrument figured is one of those constructed at this laboratory and must be looked upon simply as an example of a convenient, moderately sensitive, but widely useful form. The two coils are separated by a copper ring about 3^{mm} in thickness which produces a certain damping, although the galvanometer serves very well for ballistic use. Notwithstanding the moderate damping, the actual time required to secure a succession of readings is certainly not greater than is found necessary in using a Wiedemann aperiodic galvanometer, because the period is so greatly reduced. In an astatic system with long period more effective damping would doubtless be desirable, but in such a case there would be no difficulty in employing Thomson's ingenious air damping.

It is obvious that a needle constructed of small steel magnets cemented to silvered glass, the silver being removed from a small portion, might replace, and in some cases advantageously, our steel mirror.

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