A SWINGING ARM GALVANOMETER.

BY GEORGE S. MOLER, A. B., B. M. E., CORNELL UNIVERSITY.

The objects sought in the construction of this galvanometer were applicability to a great range of currents, accuracy of indication and portability. In passing from the measurement of large to that of small currents, no change in the apparatus is necessary, and still throughout a wide range great sensitiveness is maintained.

These ends are attained by making use of the fact that the influence of a current on the magnetic needle varies with change of distance and with the angle which the plane of the coil makes

Fig. 1.

with the horizon. The principles of the sliding coil galvanometer and of Obach's cosine galvanometer are thus combined. A movable arm is hinged to the base of the galvanometer, Fig. 1,

and carries the coil, which is attached to its outer end. The length of the arm is such that in the vertical plane the needle will be in the axis of the coil. By means of screw clamps, the hinges are made to produce friction enough to hold the arm in any required position.

When the coil is brought up into the vertical plane, it is very near the needle and a small current will produce a deflection. In this position, which is that of maximum sensitiveness—(since the distance is a minimum and the angle which the coil makes with the horizontal plane is 90°)— $\frac{1}{100}$ th of an ampere produces a deflection of about 8 mm.

As the arm is carried down toward the horizontal position, greater and greater currents must be employed to produce the same effect. The position of the coil can be read upon a graduated quadrant which passes through it, there being a pointer attached to the coil and extending inward to the graduations.

The arm consists of two parallel bars of copper, terminating in the two hinges. These are insulated from each other, and from them two flexible conductors are carried to the extremity of the base; after that they are twisted together for a distance of about one meter, and end in a block to which two large binding-posts are attached.

The coil is made of a copper rod 8.5 mm. thick, and its outside diameter is 76.5 mm. The radius of the graduated quadrant is 343 mm. and it is divided into twentieths of an inch. The radius of the lamp-scale is 381 mm. The scale forms the arc of a circle, having the galvanometer mirror for the centre. Its length is 500 mm., and it is composed of paper rendered semi-transparent by being treated with castor oil.

The needle is shown in Fig. 2. It is a bell-shaped magnet carrying a mirror, which can be rotated slightly upon the suspension rod for the sake of adjustment.

The needle is suspended by means of a fine silk fibre, and is prevented from making a complete revolution by means of a stop. Its motions are dampened in the usual manner by the action of a surrounding cylinder of copper.

The rays of light from a small gas lamp, shown in Fig. 1, after passing through a lens, are reflected from the mirror and then fall upon the scale. When the plane of the swinging coil is in the magnetic meridian, and no current is flowing, the spot of light will fall at the centre of the scale. The lamp and scale are

attached rigidly to the body of the instrument for the sake of rigidity, and to avoid the necessity of repeated calibrations. In the lamp-case is a small circular opening having a fine vertical cross-hair of platinum, and the lens is so placed that the image of the cross-hair is sharply defined upon the scale. All parts of the scale being equally distant from the mirror, as shown in Fig. 1, the definition of this image is equally good for all deflections.

The swinging-arm galvanometer is especially designed to be used with the method of constant deflections. By carrying the coil up from the horizontal position, the spot of light will be de-

Fig. 2.

flected more and more, until the image of the cross-hair is made to coincide with the chosen mark upon the scale; the position of the coil is then to be read and the current found by reference to a calibration curve or chart. In the measurement of feeble currents the chosen point on the lamp-scale may be near the position of no deflection, while for stronger currents it may be further

away. Several deflection points may be thus chosen and a calibration by means of some standard instrument can be made for each; then, to insure greater accuracy in the determination of a current, several of these points may be used, and the means of currents indicated by them may be taken, giving to each its proper weight.

The instrument may also be used by taking different fixed positions for the coil and reading the deflections of the spot of light, calibrating for each of these positions as before. These two methods may also be combined by moving the coil until the spot of light is approximately in coincidence with a selected deflection point, observing its distance from the same and applying to the current value, by means of the previously determined figure of merit, the proper correction. In this way changes in a slightly fluctuating current can be followed and measured by moving the coil.

In order to indicate heavy currents to an audience in a lecture-room, it is only necessary to remove the lamp-stand and scale and to make use of the stronger light of the magic lantern, the image of a slit in the field of the lantern, after reflection from the galvanometer mirror, being thrown upon a wall or screen. A position of the coil can then instantly be found which will produce suitable deflections for any given current, from a fraction of one ampère up to that which the coil and connections can be made to convey without destruction from heating.

Fig. 3.

In the curve, Fig. 3, and the accompanying table are given the

results of a calibration of a galvanometer of the pattern just described, which has just been constructed in the Department of Physics in Cornell University.

The deflection selected was 10 cm., and the measurements, which extended from three ampères to 60 ampères, by no means covered the possible range of the instrument. The movement of the coil indeed covered only 200 of the 400 scale divisions into which the reading quadrant is divided.

The calibrations were made in the magnetic observatory of the University, in which locality the average value of the earth's horizontal intensity is .1713. The currents were measured upon the great tangent galvanometer. Simultaneous readings were made upon that instrument and upon the swinging-arm galvanometer.

The readings of the great galvanometer, reduced to ampères, with the corresponding positions of the swinging coil for a deflection of 10 cm. are given in the following table:

CALIBRATION OF THE SWINGING-ARM GALVANOMETER BETWEEN 5 AMPERS AND 60 AMPERES CONSTANT DEFLECTION=10 CM.

Current in ampères (large gal- vanometer).	Quadrant readings (swinging-arm galvanom- eter).	Current in ampères (large gal- vanometer).	Quadrant readings (swinging-arm galvanom- eter).
5.21	79.0	19.48	138.0
5.24	79.5	24.42	151.0
5.84	82.0	24.48	151.5
8.04	95.8	32.00	167.0
10.35	106.0	33.44	168.5
10.39	107.0	33.99	171.0
10.86	110.0	38.50	179.5
11.53	110.0	42.79	185.0
13.25	119.0	43.90	187.0
13.92	119.5	46.14	191.0
15.25	125.0	53.56	202.0
19.39	137.5	59.39	208.0

From these values, with the readings of the new galvanometer as abscissæ and currents in ampères as ordinates, the curve shown in Fig. 3 has been constructed.

From this curve the currents for intermediate positions of the coil may be determined and the degree of accuracy of which the instrument is capable may be estimated.

The Chairman read the communication from the Secretary of the Electric Club, which had been presented at the annual meeting on the previous day, inviting members of the Institute to visit the house of the Electric Club.

THE CHAIRMAN:—I have another announcement to make in regard to Mr. Tesla's motor. I believe that this motor—Mr. Tesla can correct me if I am not right—is the first good alternating current motor that has been put before the public anywhere—is that not so, Mr. Tesla? And he says that the system can be seen in practical operation at 89 Liberty street, second floor, and he invites you all to come and see it. (Applause.)

The next meeting of the Institute will take place on June 12th, and Mr. F. J. Sprague will read a paper on "The Engineering Problems of Electric Railway Work," and I hope that all will be present so as to lend the scientific atmosphere that is needed for papers of this class, to the occasion. (This meeting was subsequently postponed to June 19th.)

The general meeting then adjourned.