comet's visibility, he concluded that at the passage through perihelion in October, 1844, the comet was moving in an elliptical orbit with a period of revolution of 102050 ± 3090 years. In 1846 he made extensive calculations bearing upon the motion of the two heads of Biela's comet, the results of which will be found in No. 584 of the *Astronomische Nachrichten*. He further discussed the elements of what was called at the time "Galle's second comet," 1840 II. (*Astron. Nach.*, No. 475-6). In this paper he pointed out some anomalies in the intensity of the comet's light, similar to what has been observed from time to time in other comets.

Plantamour was placed on the list of Associates of the Royal Astronomical Society in 1844; he was a corresponding member of the Academy of Sciences of the Institute of France, and honorary member of the Academy of Turin. Few of those colleagues who were at work at the commencement of his astronomical life now remain.

ON SIR WILLIAM THOMSON'S GRADED GALVANOMETERS

TWENTY years ago the experimental sciences of electricity and magnetism were in great measure mere collections of qualitative results, and, in a less degree, of results quantatively estimated by means of units which were altogether arbitrary. These units, depending as they did on constants of instruments and conditions of experimenting which could never be made fully known to the scientific public, were a source of much perplexity and labour to every investigator, and to a great extent prevented the results which they expressed from bearing fruit to the furtherance of scientific progress. Now happily all this has been changed. The absolute system of units introduced by Gauss and Weber and rendered a practical reality in this country by the labours of the British Association Committee on Electrical Standards has changed experimental electricity and magnetism into sciences of which the very essence is the most delicate and exact measurement, and enables their results to be expressed in units which are altogether independent of the instruments, the surroundings, and the locality of the investigator.

The record of the determinations of units made by members of the Committee, for the most part by methods and instruments which they themselves invented, forms one of the most interesting and instructive books in the literature of electricity, and when the history of electrical discovery is written the story of their work will form one of its most important chapters. But besides placing on a sure foundation the system of absolute units, they conferred a hardly less important benefit on electricians by giving them a convenient nomenclature for electrical quantities. The great utility of the practical units and nomenclature, which the Committee recommended, soon became manifest to every one who had to perform electrical measurements, and has led within the last year to their adoption, with only slight alterations, by nearly all civilised nations. Although it is not yet quite twelve months since the late Congress of Electricians at Paris concluded its sittings, the recommendations which it issued have been widely adopted and appreciated by those engaged in electrical work, and have thus begun to yield excellent fruit by rendering immediately available for comparison and as a basis for further research the results of experimenters in all parts of the world. Soon even the ordinary workmen in charge of dynamo machines or employed in electrical laboratories will be able to tell the number of volts and amperes which a generator can give at a certain speed and under certain conditions, to determine the number of amperes of current required to light an incandescence lamp to its full brilliancy, or to measure the capacity of a secondary cell in coulombs per square centimetre.

But in order that the full benefit of the conclusions of the Paris Congress may be obtained it is essential in the first place that convenient instruments should be used, adapted to give directly, or by an easy reduction from their indications the number of amperes of current flowing in a particular circuit, and the number of volts of difference of potentials between any two points in that circuit. To be generally useful in practice these instruments should be easily portable, and should have a very large range of sensibility; so that, for example, the instrument, which suffices to measure the full potential produced by a large Siemens or Edison machine, may be also available for testing, if need be, the resistances of the various parts of the armature and magnets by the only satisfactory method; namely by comparing by means of a galvanometer of high resistance the difference of potential between the two ends of the unknown resistance with that between the ends of a known resistance joined up in the same electrical circuit. In like manner the ampere measurer should be one that could be introduced without sensible disturbance into a circuit of low resistance to measure either a small fraction of an ampere, or the whole current flowing through a circuit containing a large number of electric lamps. These conditions are fulfilled by two instruments recently invented and patented by Sir William Thomson and called by him Graded Galvanometers. To give a short account of these instruments is the object of the present article.

I. The Potential Galvanometer.

The galvanometer used for measuring differences of potential in electrical circuits is shown in Fig. 1 which is engraved from a photograph of the actual instrument. It consists of two essential parts, a coil and a magnetometer. The coil is made of silk covered copper or German silver wire of No. 32 B.W.G. When made of German silver wire it contains about 2,200 yards of wire wound in 7,000 turns, and has a resistance of over 6,000 ohms. It is made in the form of an anchor ring having an outside diameter of fourteen centimetres and an inside diameter of six centimetres. The diameter of section is thus four centimetres. The coil is wound within a mould of proper shape and dimensions, and is then impregnated with melted paraffin under the receiver of an air-pump. A solid compact ring is thus obtained, which does not require a wooden case; and which served round with a covering of silk ribbon looks well and is not at all liable to get out of order. The coil thus constructed is attached to one end of the horizontal wooden platform P shown in the drawing, and kept firmly in its place by a pair of wooden clamps fitted to the lower half of the coil, and screwed firmly to the end of the platform. When in position the plane of the coil is vertical, and at right angles to a V groove that runs along the middle of the platform. The centre of the coil is opposite to and about one and a half centimetres above the bottom of this groove.

On the platform P rests the magnetometer M (shown in plan in Fig. 2), which consists essentially of a system of magnets properly supported so as to be free to turn round a vertical axis, and shielded from currents of air by being enclosed in a quadrantal shaped box having a closely fitted glass cover. Each magnet is fully one centimetre in length, and is made of glass-hard steel wire of No. 18 B.W.G. Four of these magnets mounted in a frame with their poles turned in similar directions from the "needle" of the instrument. The frame carrying the magnets is made of two thin bars of aluminium placed side by side with their planes vertical and about a centimetre apart; and connected by a bridge of sheet aluminium. The ends of the magnets are fixed in holes in the vertical sides of the aluminium frame so that the four steel needles form a set of four horizontal parallel edges of a rectangular prism.

In the bridge connecting the two sides of the frame a sapphire cap is fixed, and this rests on an iridium-tipped point standing up from the bottom of the containing box. The sides of the frame are made long enough to form when brought together at one end an index about nine centimetres long of the shape shown in Fig. 2. The point of the index ranges round a scale of tangents placed round the curved edge of the bottom of the box. To prevent error from parallax the bottom of the box, with the exception of the narrow strip occupied by the scale, is covered with a mirror of silvered glass. The observer when taking a reading places his eye in such a position that the point of the index just covers its reflected image, and reads off the deflection indicated by the position of the point of the index on the scale of tangents. The scale is engraved on paper, and firmly fixed to the bottom of the box by photograper's glue; and thus any change of length due to varying amount of moisture in the atmosphere is avoided.

The magnetometer box rests on three feet and a flat spring. Two of these feet, which are in a plane perpendicular to the plane of the box and passing through the supporting point and the zero of the scale, slide in the V groove cut along the middle of the platform: the third foot rests on the plane surface on one side of this groove, the spring on the other side. By this arrangement the magnetometer is rendered perfectly steady and can be moved with perfect freedom along, but only along the platform. A small circular level carried by the box shows when the plane of the magnetometer is horizontal. This adjustment is made by means of the two screws which support the platform at the end remote from the coil.

To lift the system of magnets and index off the bearing cap when the instrument is not being used, or when it is being carried from one place to another, a small collar-piece free to move round the supporting point is raised up by a horizontal screw turned by a head outside the magnetometer box. When raised this collar-piece forms a supporting platform for the needles and securely prevents them from moving about and sustaining damage.

To increase the directive force on the needles when required, the semi-circular magnet shown in the drawing is used with the instrument. This magnet is made of the best steel, and is tempered glass-hard. It is magnetised by sending a current through a semi-circular coil containing it. When in position on the instrument it is supported on two flat pieces of brass projecting from the radial sides of the magnetometer box. The magnet terminates at one end in a cross piece of brass having on its under side at one end a small projecting brass knob. This knob fits into a hollow in one of the projecting arms of brass, while the other end of the cross piece rests simply on the plane surface of the arm. The other end of the magnet is brought to a rounded point which rests in a V notch cut round a cylindrical shoulder on a screw spindle (seen on the right-hand side of Fig. 2), which works through a nut fixed to the other projecting arm of the magnetometer box. The magnet thus rests with its magnetic axis as nearly as may be in the horizontal plane through the axis of the needle, and nearly at right angles to the line joining the centre of the needle's axis with the zero of the scale. Its axis may be placed accurately at right angles to this line by turning the screw until the needle points accurately to zero. The magnet thus mounted remains in the same position relatively to the magnetometer.

The coil is so adjusted that its centre is on a level with the magnetic axis of the needle when the magnetometer is in position. The centre of the magnetic axis, the zero of the scale, and the horizontal V groove in the platform are in the vertical plane through the centre of the coil. Hence if the magnetometer guided by its feet in the V groove be moved along the platform it will carry its magnet with it without disturbing its zero adjustment of the needle, and the magnets will in every position of the magnetometer be in the same field of force.

On the boxwood slip in which the V groove is cut is marked a series of positions of the front or circular edge of the magnetometer, for which the corresponding numbers of divisions of deflection for one volt difference of potentials, when the intensity of the magnetic field at the needle is one C.G.S. unit, are the terms of the geometric series . . . 8, 4, 2, 1, $\frac{1}{2}$ . . . These numbers are stamped on the boxwood slip opposite the marks indicating the corresponding positions. The number of divisions of deflection for the nearest position of the magnetometer, that at which the centre of the magnetic axis of the needle is as nearly as may be at the centre of the coil, is not generally a term of this series, but it is determined in every case, and like the others is stamped on the platform.

The instrument is used for the measurement of high potentials with the semicircular magnet in position; but for low potentials the magnet is dispensed with, and the needle left under the earth's directive force alone. The field intensity given by the magnet of each instrument is determined before the instrument is sent out, and is painted on the magnet. The intensity of the field without the magnet, at the place at which the instrument is used has if necessary to be determined. In practice it will generally be found convenient to use some position of the magnetometer which gives a convenient number of divisions of deflection per volt for the field employed. This position is determined by the user of the instrument, who marks it on the platform by drawing two vertical lines on the sides so as to prolong two white lines which are marked on the sides of the magnetometer.

The instrument as thus constructed admits of a very wide range of sensibility. By diminishing the distance of the magnetometer from the coil from the greatest to the least, the sensibility of the instrument can be increased fifty fold: and by removing the field magnet from the instrument and leaving the needle under the influence of the earth's force alone, a sensibility fifty times still greater can be given to it. For the practical purposes for which these instruments are designed the suspension of the needle by cap and point is the most convenient; but with this suspension there is always, with low directive forces, a slight error due to friction: and it is therefore not advisable to push the sensibility of the instrument further by diminishing the directive force of the earth's magnetism. An instrument of this kind, however, made for special purposes with a silk fibre suspension could be rendered more and more sensitive up to the limit of instability by so placing a magnet or magnets as, while not interfering with the uniformity of the field at the needles, to diminish more and more the earth's directive force. This method of increasing the sensibility of a galvanometer although quite commonly used by scientific electricians is not, I have reason to believe, at all well-known generally, and recourse is had, altogether unnecessarily in many cases, to troublesome astatic combinations in order to obtain sensibility.

An important feature of this instrument in connection with its use for the measurement of high potentials is the arrangement of terminals which has been adopted. In certain circumstances when the ends of the coil of a potential galvanometer are attached to terminals fitted with binding screws, it is convenient to connect the instrument with the circuit by wires attached to these screws; but in the case of a dynamo circuit giving between the terminals of the coil a potential difference of eighty or a hundred volts and upwards, this plan of connections has been found highly dangerous. If the wires are twisted together and are ordinary gutta percha covered wires there is always a liability to accidents which may cause conduction from one wire to the other, and the destruction of the wires. Again the ends of the wires are almost sure when removed from the instrument to be left dangling either in contact, or so as to be easily brought into contact inadvertently by a passer by, with the certain result if the dynamo is running, of the immediate fusing of the wires. To prevent the possibility of such an accident Sir William Thomson has used as terminals for the coil two strong strips of copper about $1\frac{1}{2}$ cms broad which stand up vertically facing one another about a centimetre apart, within a vertical cavity in the wooden block behind the coil. To prevent any current from flowing through the coil except when a reading is being taken, the small spring contact key, shown behind the coil in Fig. 1, is inserted between one of these terminals and the coil. The leads for connecting the instrument with the circuit have their ends brought together so as to terminate in two parallel strips of stout copper kept apart by a piece of wood and held in position by a good serving of strong waxed cord. The two copper strips with the piece of wood between them have their ends turned down at right angles to their length, and when connection is to be made are pushed down into

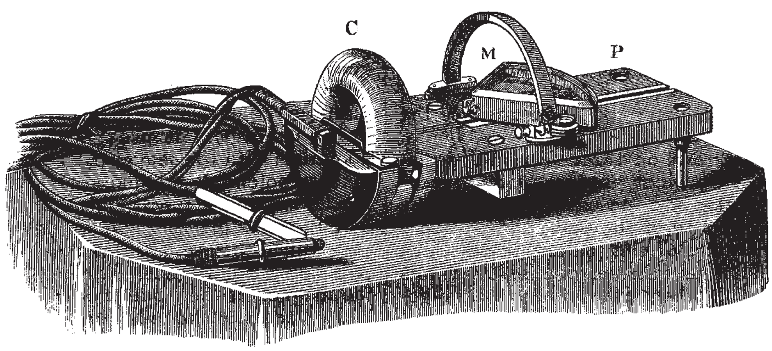

FIG. 1.

the cavity between the two bars to which the ends of the coil are attached. These bars are placed sufficiently near together to be forced a little apart by the contact piece, and thus give a secure spring contact. The leads are made of thin stranded copper wire, well protected by a thick woven covering of cotton, and are very flexible. They terminate in two spring clips (shown in Fig. 1) made each of a strip of stout copper held firmly against the flat side of a piece of wood, of semicircular section, by an india rubber

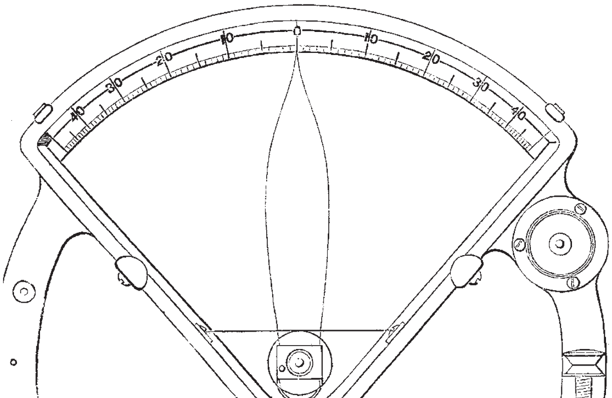

FIG. 2.

band passed round a groove in a semicircular piece of brass soldered to the copper strip, and round the back of the piece of wood. A groove carried along the piece of wood above the elastic band prevents the copper strips from turning round relatively to the wood, and thus a good and safe contact is made between the copper and anything on which it may be clipped. These clips are quite as efficient as binding screws and a great deal more convenient. They can in an instant be attached to or removed from a wire or lead of any size and in any position. For convenience in the use of the instrument the covering of one lead is coloured red, of the other blue.

II. *The Current Galvanometer.*

This instrument is shown in Fig. 3. It differs from the galvanometer above described only in the coil and arrangement of terminals. The coil is made of stout copper strip about 1·2 cm. broad and 1·5 mm. thick, wound in six turns, insulated by asbestos paper placed between. The outside diameter of the coil is about 10 cm., the inner diameter about 6 cm. It is covered like the other with silk ribbon, and attached in a similar manner to the platform P. A magnetometer exactly the same as that described above is used with the instrument, and all that has been said above with regard to the graduation of the potential galvanometer is applicable also in the present case, except that now amperes, not volts, are the subject of measurement.

This instrument is of course only suitable for the measurement of continuous currents, but owing to the small resistance of the coil, it can be left without risk of damage in a circuit with a current of upwards of 100 amperes flowing continually through it, while it is of sufficient sensibility to measure with accuracy, when the needle is acted on by the directive force of the earth alone, a current of from 1-10th to 1-100th of an ampere.

In special instruments for measuring very strong currents the coil is made of a single turn of massive copper strip, fitted with proper terminals to obviate undue heating at the contacts. With this mode of construction, an instrument can be made which shall measure with accuracy currents of from 1-10th of an ampere to 1000 amperes.

A pair of well-insulated leads several yards long, made of copper-wire cable containing 133 strands of wire of 32 mm. diameter (No. 30 B.W.G.), and therefore very flexible and of inappreciable resistance, are sent out with each instrument to be used with it. These are shown coiled on the table beside the instrument in Fig. 3.

The terminals of the instrument and the mode of including it, by means of its leads, in any circuit in which it is to be used, are worthy of a little attention. In order that the galvanometer may be used to measure the currents in different circuits, it must be introduced into or withdrawn from each circuit with as little disturbance as possible to the current in that circuit. To do this without the complications of switches or arrangements of binding screws, the very simple plan of terminals, shown in Fig. 3, has been adopted. The ends of the copper strip forming the coil are brought out horizontally behind the instrument, one above the other, with a thin piece of wood between them for insulator. On one end of the leads for attachment to these terminals is a spring clip, formed of two stout strips of copper, one attached to each lead, kept apart for a short distance along their length by a thickish piece of wood, and held in their places by a serving of waxed cord at that place. The ends of the copper strips project beyond the separating piece of wood about two or three inches, and are bent round into similar curves, with their convexities turned towards one another. They have sufficient spring to bring their convex portions into contact, but they are held together at that place by a stout india-rubber band passed round a groove in the edges of the two semicircular pieces soldered on the backs of the strips. The points, however, of the strips are a little distance apart. If, now, the clip just described be pushed over the terminals of the coil, the jaws of the clip will be separated, but before separation takes place each of them has come into contact with a terminal of the coil. Hence if the leads form part of a galvanic circuit, the current, before the galvanometer is attached, passes from one lead to the other across the jaws of the clips, and after these have been separated, through the galvanometer

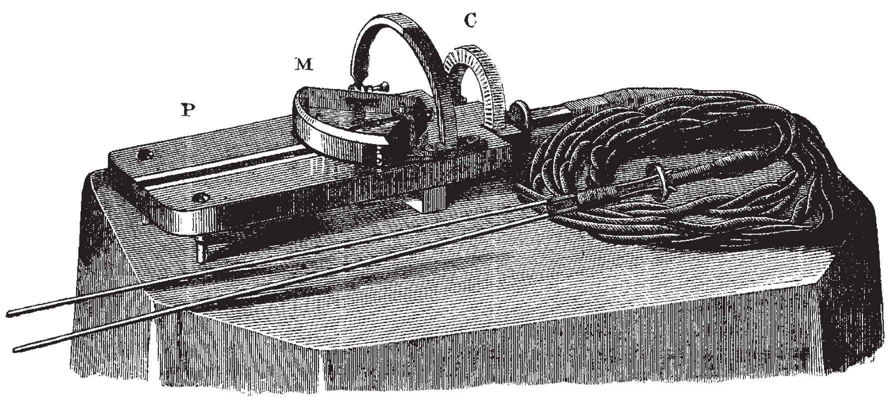

FIG. 3.

coil; and it is plain that no cessation of the current, and in practical cases only an infinitesimal disturbance can be caused by introducing the galvanometer. Sparks are thus altogether avoided, and the galvanometer is included in the circuit by a single simple and sure operation. When the leads are withdrawn from the coil-terminals the action is simply the reverse, the jaws of the clip have come together at their convexities before the terminals of the coil have lost contact with them.

In practice two stout wires which have one pair of ends attached to one of these spring clips are included in each circuit, the current in which is to be measured by the galvanometer. The instrument is placed with its leads attached to its terminals in a convenient position, so that the free end of the leads may reach easily the spring clips of all the circuits. The terminals at that end are similar to those of the galvanometer. They can therefore be pushed in between the jaws of each clip to allow the current to be read off, and withdrawn without disturbing the current in the circuit. The leads are shown attached at one end by their spring clip to the galvanometer, and at the other end to a spring clip supposed included by means of the two straight pieces of wire in a galvanic circuit.

This arrangement is exceedingly useful for a great number of purposes, as for example for measuring the currents charging secondary cells, or flowing through the various parts of an electric lighting circuit, or for measuring the whole current sent into the circuit by the dynamo or generator.

ANDREW GRAY

NOTES

THE German Association began its proceedings on Monday at Eisenach, when Prof. Haeckel delivered a lecture on the interpretation of nature by Darwin, Goethe, and Lamarck. The attendance at the meeting amounted to about 1000.

THE autumn meeting of the Iron and Steel Institute was opened on Tuesday at Vienna in the great hall of the Vienna Ingenieur und Architekten Verein. In the absence of the president, Mr. Josiah Smith, the vice-president of the Institute, Mr. I. Lowthian Bell, took the chair. The British and other foreign guests were then welcomed, in the name of the Government, by Baron Possinger, the Governor of the province of Lower Austria, and in the name of the city by the burgomaster. Mr. Bernhard Samuelson, M.P., of Banbury, was chosen president of the Institute for the next two years. The place of next year's Congress it was decided should be London. The Congress next proceeded with the reading of the papers set down for the day. After this work was concluded, the Members were conveyed by steamer down the Danube to inspect the works which have been commenced by the Vienna Corporation for improving the navigation of the river. Thence the guests were taken to Nussdorf, and proceeded to the top of the Kahlenberg, a hill in the vicinity. The first day was wound up by a banquet, at which the guests were entertained by the municipal authorities of Vienna. The present is the fourth meeting which the Institute has held upon the Continent, it having met at Liège in 1873, at Paris in 1878, and at Dusseldorf in 1880. The number of guests from abroad is nearly three hundred. They include not only Members of the English Institute, but visitors from America, Germany, France, Belgium, Spain, and Russia. The business portion of this autumn's Congress is expected to occupy three days, but fully a week will be spent in excursions and other festivities, and in visits to the chief ironworks and mines of Austria and Hungary.

M. BARTHELEMY ST. HILAIRE has completed the translation of Aristotle's "History of Animals," which will be published shortly by Baillière, and will extend to four volumes 8vo,