ELECTRO-MAGNETISM.

CHAPTER VIII.

Discovery of Electro-Magnetism by Œrsted—Discoveries of Schweigger, Arago, and Ampère—Discoveries of Sturgeon and Henry—Recapitulation of the Discoveries on Electro-Magnetism—English Telegraph Electrometers—Magnetometers—The De La Rive Ring, and other Experiments.

DISCOVERY OF ELECTRO-MAGNETISM BY ŒRSTED.

THE art of tne electric telegraph is based upon the science of electro-magnetism. The brilliant discovery of this science was made in the year 1819, by Professor Christian Œrsted, of Copenhagen.

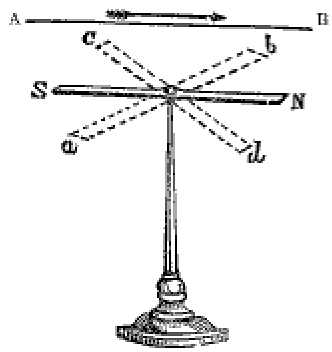
In the year 1854, I visited Copenhagen, and the first object of my curiosity was to see the laboratory of Œrsted. Through the generous attention of M. Faber, the director-general of the telegraphs of Denmark, my desire was gratified. I saw the room in which electro-magnetism was discovered, and the small compass that developed it.

Professor Œrsted was engaged in arranging some wires connected with the voltaic battery, preparatory to making some electrical experiments which he had in view. While thus adjusting the wire conductor, he had in his hand a small compass, some two and a half inches in diameter. Sometimes his hand, with the compass, was above the wires, and at other times below them. He observed the needle of the compass to move, and his attention being once directed to the development, the discovery followed as a sequence. That discovery, at the time, was made known in the following language, viz.: "When a magnetic needle is properly poised on its pivot at rest in the magnetic meridian, and a wire arranged over and parallel to the needle, in the same vertical plane, and the ends of the wire made to communicate, respectively, with the poles of a voltaic battery, the needle will be deflected."

This was the simple announcement, giving the whole of the discovery. It was enough to immortalize Œrsted.

Fig. 1 represents the discovery made by Œrsted, excepting the needle S N is poised upon an exposed pivot, instead of being enclosed in a brass compass case. If the wire charged with an electric current is placed horizontally *over* the compass needle, the pole of the needle which is nearest to the *negative* end of the battery always moves *westward:* if it be placed *under*, the same pole moves to the east. If the wire be parallel with the needle, that is, brought into the same horizontal plane in which the needle is moving, then no motion of the needle in that plane takes place, but a tendency is exhibited in it to move in a vertical circle, the pole nearest the *negative* side of the battery being depressed when the wire is to the *west* of it, and elevated when placed on the *eastern* side.

Fig. 1.



In the example given by the figure, the current is flowing on the wire north and south, from A to B. The needle S N deflects from the parallel line, and the north pole of the needle will turn to the west, and if it be below the wire, it will turn to the east to the extent, respectively, as represented by the dotted lines *a b* and *c d* in the figure.

The force exerted by the electric current on the magnetized needle diminishes in intensity in proportion as the distance between the current and the needle increases. It has been determined, as a law, that when the current is rectilinear, and the length of the wire considerable, so that in relation to that of the needle, it may be regarded as infinite, the intensity of the electro-magnetic force is *in inverse ratio to the simple distance of the thing magnetized from the current.*

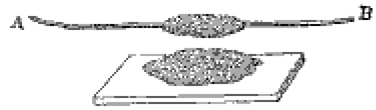
DISCOVERIES OF SCHWEIGGER, ARAGO, AND AMPERE.

Immediately after the discovery of Œrsted, which was made in 1819, and published in 1820, M. Schweigger discovered that the surrounding of a needle with many coils of wire increased the deflecting power of the voltaic current. This improvement was announced in the German "Literary Gazette," November, 1820, No. 296. Since that time the arrangement of circling the wire around a magnetized needle has been called

"Schweigger's multiplier," because it multiplied the power of the deflection. Take a small compass, about two and a half inches in diameter, and then wind around it—in the course or direction of the needle, north and south—fine insulated wire. The turns may be two or a hundred, and the principle will be the same. Transmit through the wire thus wound round the compass, and the needle will rapidly leave its north and south positions, and, if the current be strong enough, it will assume the east and west directions. Reverse the current through the wire, and the needle will immediately change its position and point in the opposite direction to that first assumed. Remove the current from the wire, and the needle will immediately take its normal, or north and south position.

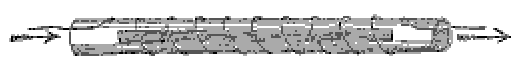
In the year 1820, M. Arago, of France, found that if the wire which connects the two extremities of a voltaic battery be plunged into fine iron filings, a considerable portion of them will be attracted, and will remain attached to the wire as long as the current continues to circulate through it; on breaking the circuit, the filings will immediately drop off. If small steel needles be laid across the wire, they will be attracted, and on removing them they will be found to be permanently magnetized.

Fig. 2.



In the year 1820, Ampère, of France, made some important experiments, and he found that two wires, through which voltaic currents were passing in the same direction, attracted, and in the opposite direction repelled, each other. Upon the theories of Ampère, Arago adopted the method of magnetizing needles. He placed in a glass tube a needle, and wound around the tube a wire composing a part of the voltaic circuit; the needle was magnetized. He also found that the polarity of the needle, as a magnet, depended upon the direction of the current around the glass tube. If a right-handed spiral, the

Fig. 3.

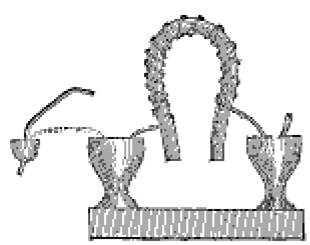


boreal pole would be formed at the end at which the current entered, that is, the positive end; if a left-handed helix, the bar acquired an austral polarity. The wire was wound around the glass tube, so that its spirals would not touch. In the glass tube was laid an ordinary sewing needle.

DISCOVERIES OF STURGEON AND HENRY.

The next grand step taken in the science of electro-magnetism was by Sturgeon in 1825. He bent a piece of iron wire in the form of a horse-shoe. He then insulated the iron wire, bent as a horse-shoe, by covering it with varnish; and having thus covered the iron to be magnetized, he wound around it a copper wire, and placed the spirals so that they would not touch, in order to prevent the current from passing from one spiral to the other without circulating around the iron.

Fig. 4.



The result was a complete success. The ends of the bent iron wire were found to be magnetic when the current was on the spiral wire; and when off, it was not magnetic. This experiment was an advance of Arago and Ampère. Fig. 4 represents the plan adopted by Sturgeon. It is an exact copy of the original drawing published in the "Annals of Philosophy," 1826.

Upon the theory advanced by Ampère, Arago coiled wire around the glass tube to magnetize the needles; Sturgeon, instead of using the glass tube to insulate the electric copper wire from the iron core to be magnetized, used varnish as an insulator. It was a non-conductor, and separated the electric wire from the iron. Besides the improvement in the idea of the insulation, he bent the wire in the form of a U, which was a very important progress from the straight bar or needle.

Professor Joseph Henry, of America, in his philosophical researches, in 1828, continued in 1829 and 1830, was led to

Fig. 5.

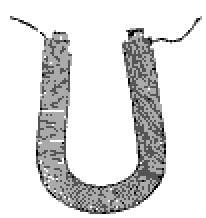
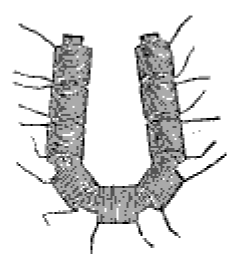


Fig. 6.



make farther advances, and he perfected the construction of the electro-magnet as now known in the science. He conceived the idea of covering or insulating the wire, instead of covering or insulating the iron to be magnetized, as had been done by others. He effected this by insulating a long wire with silk thread, and winding this around the rod of iron in close coils, as is seen in fig. 5, from one end to the other. The same principle was extended by employing a still longer insulated wire, and winding several strata of this over the first, care being taken to insure the insulation between each stratum by a covering of silk ribbon. By this arrangement the rod was surrounded by a compound helix, formed of many coils, instead of a single helix of a few coils.

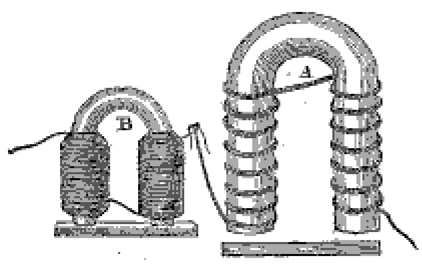
In the peculiar arrangement of the coils, Professor Henry advanced new ideas. Arago and Sturgeon wound their wires not precisely at right angles to the axis of the rod, as they should have been, to produce the effect required by the theory of Ampère, but they were placed obliquely around the rod to be magnetized; therefore, each turn tended to develop a separate magnetism not coincident with the axis of the bar. In winding the wire over itself, as done by Henry, the obliquity of the several turns compensated each other, and the resultant action was at right angles to the bar. The ends attained by Henry were of the greatest importance. The multiplied turns of the wire, and their peculiar conjunctive action in the generation of magnetic force in the iron rod, were complete in success. He found that, after a certain length of wire had been coiled upon the iron, the power diminished with a further increase of the number of turns. This was due to the increased resistance which the longer wire offered to the conduction of electricity. As an improvement, he increased the number of independent coils around the u shaped rod, as represented by fig. 6. Another was to increase the number of cells of the battery to obtain a current of greater intensity, for the purpose of overcoming the increased length of the wire, so as to produce or develop the maximum power of the iron. Fig. 6 represents the manner of coiling around the iron bar the insulated wire in several independent sections. Each of these sections was united with a Cruikshank voltaic battery. The experiment proved, that, in order to produce the greatest amount of magnetism from a battery of a single cup, a number of helices is required; but when a compound battery is used, then one long wire must be employed, making many turns around the iron core. The magnetic force generated, will be commensurate with the projectile power of the battery.

In describing the results of these experiments, Professor Henry has used the terms *intensity* and *quantity* magnets.

By the former is meant, that when a piece of soft iron, so surrounded with wire that its magnetic power could be called into operation by an *intensity* battery, the magnet was called an "*intensity* magnet;" when it was acted upon by a *quantity* battery through a number of separate coils, so that its magnetism could be fully developed, it was called a "*quantity* magnet." The terms are technical, and very appropriate.

Fig. 7 represents the Sturgeon magnet, A, and the Henry magnet, B. Around the former (A) are wound the spirals apart from each other—the iron core being insulated, and the copper wire not insulated. Around the latter, B, the wire is insulated with silk thread, and the coils are multiplied. This was the magnet invented by Henry, and which at the time astonished the scientific world. With the same battery, at least a hundred times more magnetism was produced by Henry's magnet than could have been obtained by Sturgeon's magnet. The developments were considered at the time of much importance in a scientific point of view, and they subsequently furnished the means by which magneto-electricity, the phenomena of dia-magnetism, and the magnetic effects on polarized light, were discovered. They gave rise to the various forms of electro-magnetic machines which have since distinguished the age. Upon Henry's electro-magnet are based the various electro-magnetic telegraphs.

Fig. 7.



The following may be considered as laws relative to electro-magnetism:

1st. The magnetic force developed in the iron is in proportion to the quantity and intensity of the current.

2d. The force, if the current be equal, is independent of the thickness of the wire or shape of the iron.

3d. Within certain limits, in a continuous coil wound in layers, like a spool or bobbin of silk, the external turns are as efficacious as those close to the iron.

4th. The total action of the spiral is equal to the sum of the actions of each turn.

Thus, by increasing the force of the battery so that its intensity is augmented twofold, threefold, fourfold, the force of the electro-magnet increases in the same degree. Of course this force will find its maximum in the conductibility of the metal employed in the voltaic circuit.

RECAPITULATION OF THE DISCOVERIES OF ELECTRO-MAGNETISM.

The discoveries of Henry were published to the world in 1831, and were the subject of discussion among scientific men on both continents. Since then there has not been any advance in the principles pertaining to the organization of the electro-magnet. Mechanically, it has been brought to a smaller size and made more convenient for the purposes of its use.

From the preceding it will be seen that the following are the facts relative to the progress of electro-magnetism:

1st. In the year 1819, Œrsted discovered that a magnetic needle would be deflected when situated near a wire charged with a current of voltaic electricity.

2d. In the year 1820, Schweigger discovered that the power of deflecting the needle would be increased by surrounding it with the electric wire.

3d. In the year 1820, Arago and Ampère coiled around a glass tube, and magnetized sewing needles placed in the tube.

4th. In the year 1826, Sturgeon insulated an iron wire bent like a horse-shoe, and then wound around it a copper wire. When a current of electricity was sent through the copper wire the insulated iron wire was magnetized.

5th. In the years 1828, '29, and '30, Henry wound an insulated copper wire around an uninsulated iron rod, shaped like a horse-shoe. He passed a current of electricity through the copper wire, and the bent iron rod was magnetized.

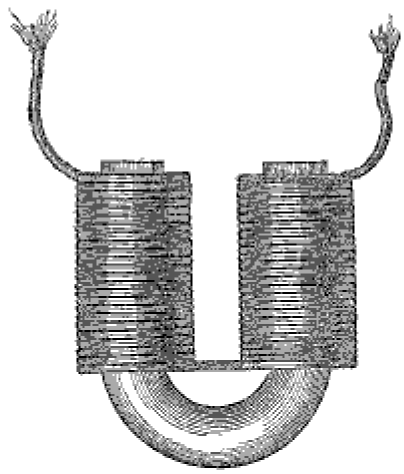
6th. In the same years Henry increased the convolutions of the insulated copper wire, and on passing a current of electricity through the copper wire, the magnetic power of the bent iron rod was greatly increased.

The above presents the true state of the science of electro-magnetism before the invention of the electro-magnetic telegraph, of either continent, as none of them can date earlier than 1832. Without the discoveries above described, made by Sturgeon and Henry, the electro-magnetic telegraph would still be in the womb of time, awaiting the allotted hour for its birth—distinguishing, for aught we know, a generation yet unborn, instead of, as it has done with singular grandeur, "the age in which we live."

Fig. 8 represents the magnet as applied in the telegraph. The wire is insulated with silk, and wound around the iron bar. Fig. 9 is another form adopted in the making of the magnet. The insulated silk wire is wound around hard rubber spools, and the U-shaped iron is moveable. One of the advantages in the use of the moveable cores consists in the facility of demagnetizing them when charged with permanent magnetism.

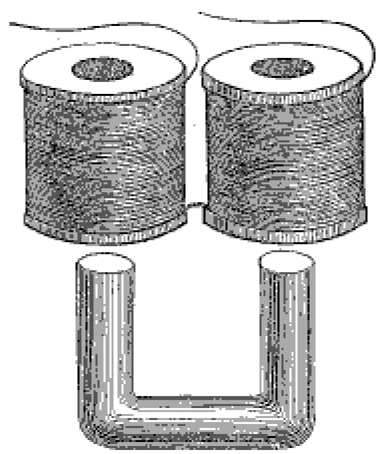
The attention of the student of telegraphing should be

Fig. 8.



directed to the proper arrangement of the wire around the cores. The wire should be well insulated, wound as regular as possible, and in the direction indicated by the preceding

Fig. 9.



figures. I once knew the working of a station to be hindered by the operator re-winding his wire, so that the magnetism could not be imparted to the iron. The arms should be wound, as represented by fig. 7.

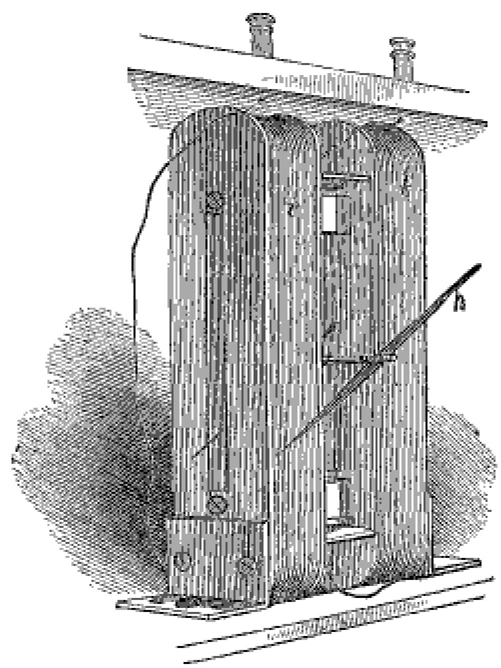
ENGLISH TELEGRAPH ELECTROMETERS.

The English electric telegraphs are organized upon the principle of Schweigger's multiplier, and so true is this, that Mr. Cooke in the invention of the first needle telegraph adopted the multiplier.

Arago used ordinary needles in his glass tubes, and they were magnetized by the coiling of the wire around the tubes, but the principle in the use of the needles in the English telegraph is precisely the original Œrsted discovery, as extended by Schweigger. The latter multiplied the coils around a magnetic needle, which was caused to move, as seen by Œrsted, whenever the wire composing the coils was charged with electricity.

Figure 10 represents a Schweigger multiplier improved by mechanism; *i k* are two coils, through the interior of which

Fig. 10.



swing a magnetized needle. When the current traverses the coils, the needle changes its position from a perpendicular to a horizontal, or to the extent influenced by the current. The exterior needle *h* may be magnetic, or it may not be. It is

Fig. 11.

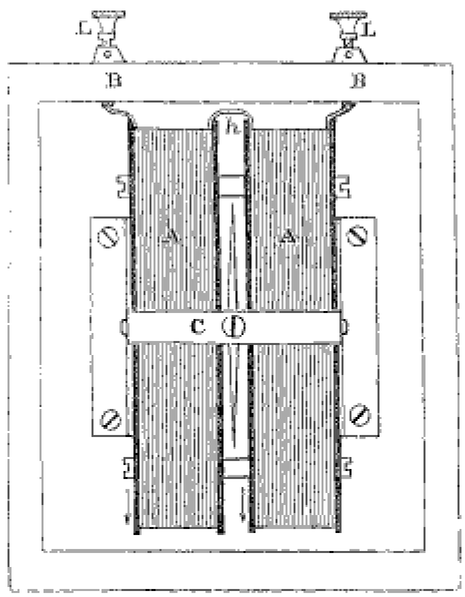
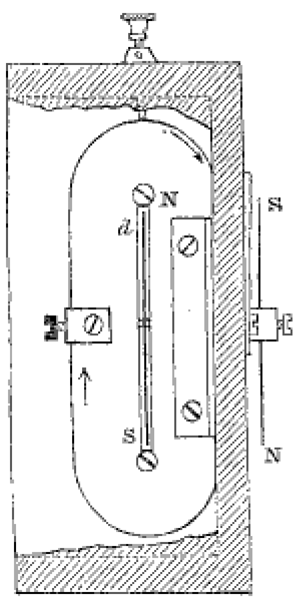


Fig. 12.

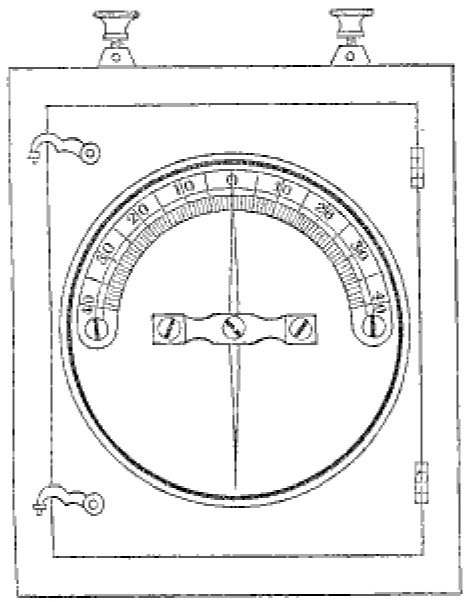


often made of light material, so as to easily swing upon the same axle with the interior needle. This instrument is called an "Electrometer."

Another view of the electrometer is represented by fig. 11, showing the coils A A and the needle suspended between them. L L are binding screws fastened to the frame B B. The line wires are fastened to L L. C is a brace band to hold the coils of fine wire A A. The arrows indicate the route of the voltaic current. Fig. 12 represents a side view of the same instrument. To the right is seen the needle and its polarity S N; in the interior is seen the other magnetic needle and its polarity N S; the arrows indicate the route of the voltaic current.

Fig. 13 represents the face of the electrometer used in nearly all the European telegraph stations. This is a small box about five inches square, with a glass cover. The index finger acts co-operative with the needle suspended between the coils, and its movement to the right or to the left indicates the quantity of the current and its polarity, whether negative or positive. It would be a useful instrument on the American lines. At this time, there is, perhaps, not one in use on any of the lines, nor has there been since the experimental line of 1844.

Fig. 13.



ELECTROMETERS GENERALLY.

Fig. 14 represents another form of an electrometer. The wire is wound around a frame not given in the figure. The needle N S rests upon a pivot on the stand C D. The battery wires are fastened at the binding posts A B, which connect with wires near C D respectively. The wire is wound upon the same principle as in the making of the magnets hereinbefore mentioned. When the electricity passes around the coil, the needle moves to the right or to the left, according to the course of the current.

Fig. 15 represents an upright electrometer. The principle of this instrument is precisely the same as the one above

Fig. 14.

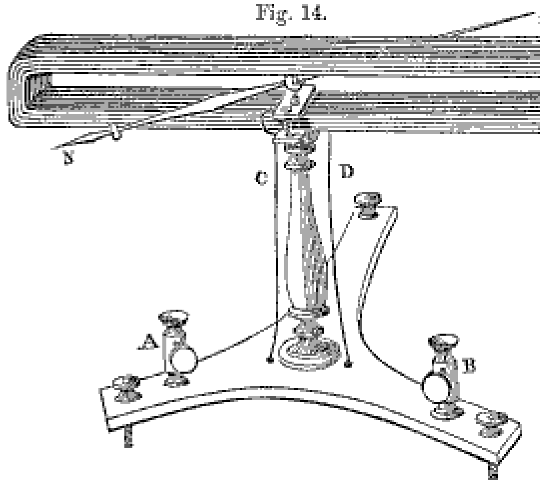
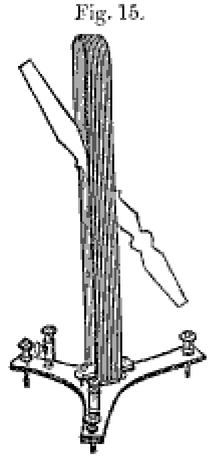


Fig. 15.



described. It is nearer the simple multiplier devised by Schweigger.

Fig. 16 represents the compass form electrometer. The coil of wire is made to surround an ordinary pocket compass, and the strength of the electric current is measured by the deflection of the needle. The circle is divided into divisions as minute as may be required for the purposes of its use. It is a very convenient instrument, and will be useful in the practice of telegraphing.

Fig. 17 represents the most delicate form of electrometer. It is capable of being influenced by the slightest presence of electricity. On the base are placed two coils of wire, as represented by fig. 10, between which is suspended a delicate magnetic needle, with its mate or index needle above a dial plate. The needle is suspended by a cocoon thread from the top. Over the whole is placed a glass cover. If there is any electricity in the coils, the index needle will exhibit it and the quantity.

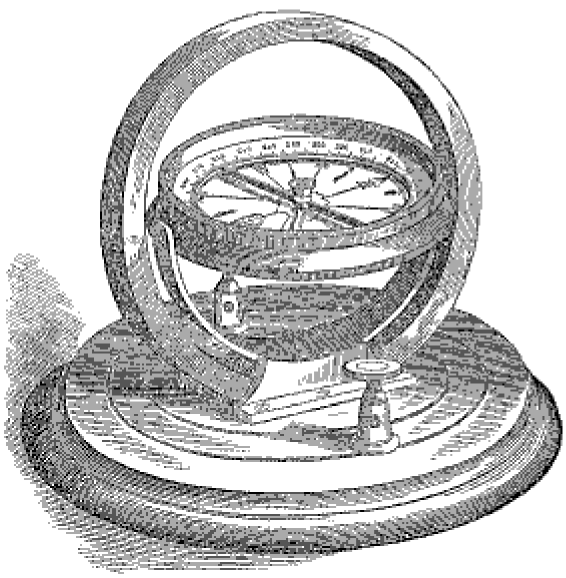
MAGNETOMETERS.

Various contrivances have been made to measure the magnetic force of electro-magnets. Fig. 18 is one gotten up by

Mr. Charles T. Chester, of New-York, as an attachment to the electro-magnet used on the Morse telegraph. The ends of the coils are seen below; the measurement scale is seen above. The armature of the magnet is connected with the index finger, and the slightest magnetic influence will be exhibited.

Fig. 19 represents Hearder's magnetometer. A B is a strong base of wood, about four feet long and one foot wide, to which are attached four levelling screws; D D are two strong iron uprights, firmly screwed into the base and connected at the top by a stout iron cross piece, E, having a hole in the centre, through which passes the screw, F, of the strong double sus-

Fig. 16.



pension hook G. Two iron nuts, H H, serve to fix the suspension hook at any height. I I is a light and delicate, but strong steel yard, being graduated on one side to correspond with the distance between the knife-edge K and M; these are respectively one and two inches apart. Different weights may be employed; on the arm N is a rest to support the long arm of the lever, and it is capable of being adjusted to any height by a tightening screw in the hollow socket O. The different parts of the scale are marked by letters, each of which will be readily understood by the reader. The magnet, U U, is wound with the conducting or electric wire; this arrangement will give the strength of the magnetic force. It can be made upon any

Fig. 17.

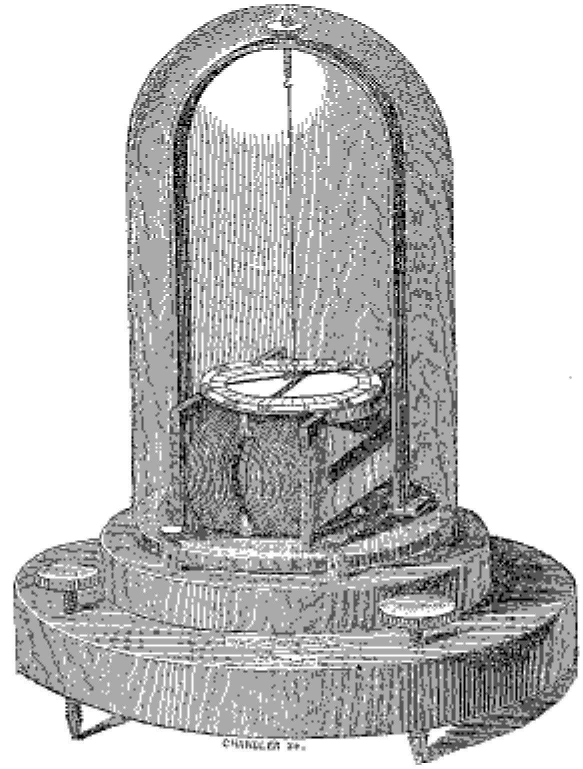
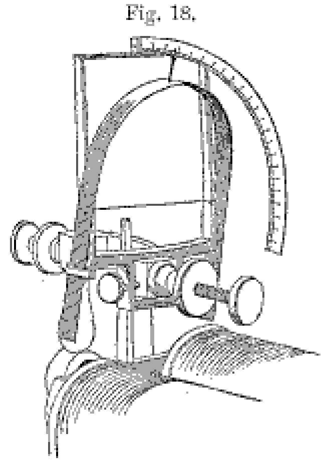
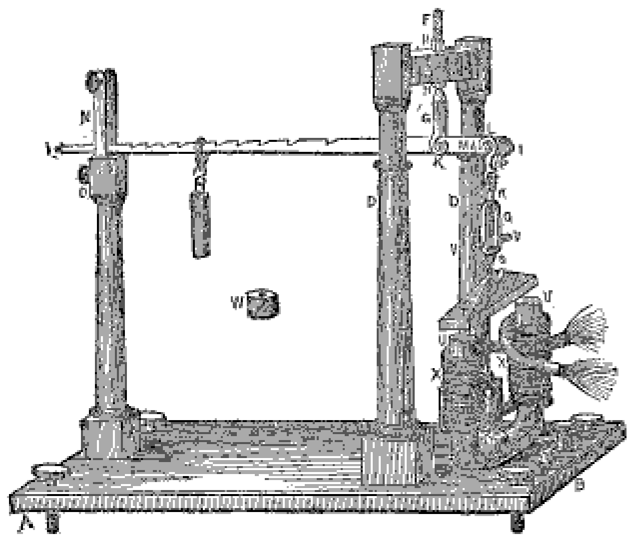


Fig. 18.



required scale, and its application in testing the strength of the magnets for telegraphic purposes might subserve a good end.

Fig. 19.

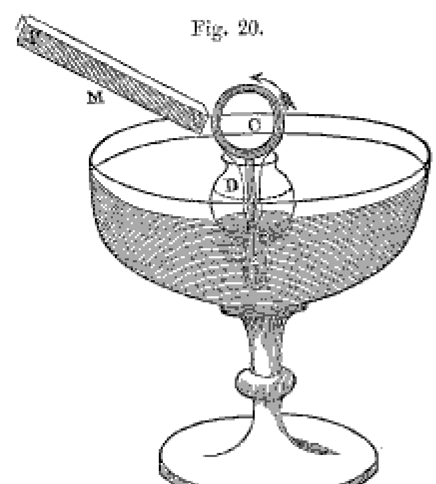


Before concluding this chapter, I desire to notice a few experiments, having in view the further illustration of the relative forces, electricity and magnetism

DE-LA-RIVE RING AND OTHER EXPERIMENTS.

Fig. 20 represents the De-la-Rive ring. S N is a permanent

Fig. 20.



magnet; c is a coil of wire fastened to zinc and copper pieces, which are placed in a vessel of acid. An electric current is generated, and traverses the coil c, as indicated by the arrow. The vessel D, with the coil c, floats in a bowl of water. When the magnet M is placed near the bowl, the ring c will be repelled or attracted, according to the polarity of the magnet directed toward the ring—the electric coil moves from or to the more powerful permanent magnet.

Fig. 21 represents a spiral wire suspended. The lower end is connected with a mercury cup. A current of electricity is made to traverse the spiral. In fig. 22 a permanent magnet is placed in the spiral. The moment the magnet is thus placed,

Fig. 21.

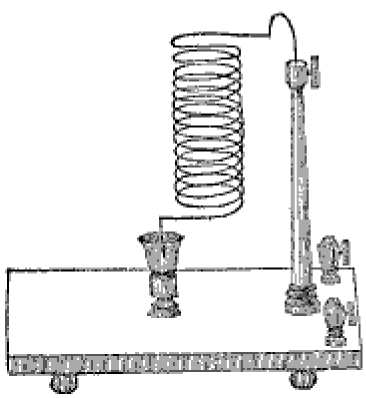
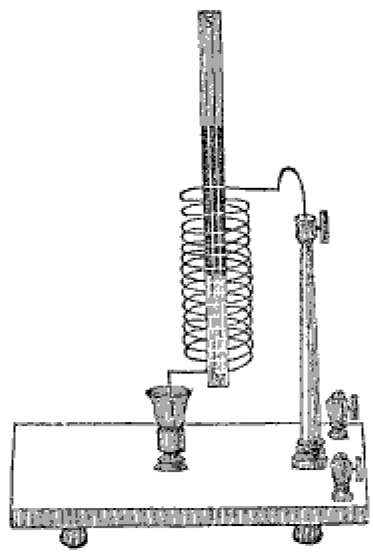


Fig. 22.

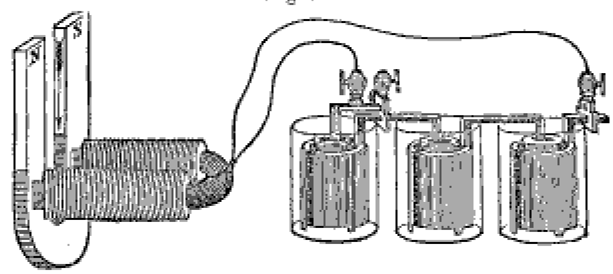


the spiral wire will move up and down, opening and closing the circuit in the mercury cup. If the battery is strong, a blue flame will be made when the wires come in contact with the mercury.

Fig. 23 represents the mode of communicating permanent magnetism to a steel bar by an electro-magnet. N S is a steel bar, which is drawn from the bend to the extremities across the poles of the electro-magnet in such a way, that both halves of the bar may pass at the same time over the poles to which they are applied.

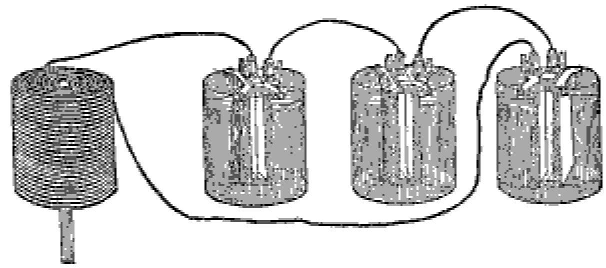
Fig. 24 represents the principle of axial magnetism, invented by Professor Charles G. Page, of America. For the purpose of explaining the principle, the following will suffice. The coil consists of a number of layers of wire, and has a small central opening. An iron bar passed within it becomes strongly magnetic. When the coil is in a vertical position, the iron bar is sustained within it in consequence of the force with which it is

Fig. 23.



drawn toward the middle of the coil. With a large battery, a considerable weight may be suspended from the bar without any visible support The action of the coil is the same, except in the amount, as that of a single circular turn of wire. At any two points of the circle, diametrically opposite, the direc-

Fig. 24.



tions of the current are also opposite. The resultant of the forces exerted by all the points, tends to bring the centre of the magnetized bar within the circle. The action of all the circles ot which the helix is composed draws the bar into it, until its middle lies within the middle of the helix, in which position only can the forces neutralize each other. This is termed an "axial magnet."

The axial magnet performs an important part in the House telegraph, the particular construction of which I have fully described elsewhere in this work. The American apparatus is the only telegraph employing this species of magnetic action.

It has subserved the purposes of its introduction, and acts in beautiful harmony with other parts of that most wonderful and beautiful combination of mechanism.

It is due to the memory of the lamented Alfred Vail, to acknowledge that he rendered great service in the discovery of the phenomena of axial magnetism. He instituted a series of experiments, and promulgated many of them to the world.