The history of electro-plating and electro-gilding is briefly as follows: In 1803, BRUGNATELLI first gilded a silver medal by suspending it in a solution of gold from the negative pole of a battery, but proceeded no further. In 1840, DE LA RIVE, of Geneva, discovered a process of gilding metals with a battery, but by his process much gold was wasted, and the work was unsatisfactory. In the same year, ELKINGTON, an Englishman, discovered the process of gilding by means of the cyanuret of gold and potassium. A few months later, RUOLZ succeeded in silvering and platinizing metals by the methods now in general use. The arts of electro-plating, electro-gilding, and electrotyping are now of general application, and afford occupation to thousands of artisans.

Give an outline of the history of electro-plating and electro-gilding.

CHAPTER X.

ELECTRO-MAGNETISM.

I.—FUNDAMENTAL PRINCIPLES.

Relation between Magnetism and Electricity.

426. IT was observed at an early period that the magnetic and electrical fluids had many analogous properties. In each case fluids of the same name repel, whilst those of an opposite name attract. It was also observed that a stroke of lightning often reversed the poles of a magnetic needle, and sometimes completely destroyed its magnetism. The two have also points of dissimilarity. Magnetic fluids are not transmitted like electrical fluids through conductors. A magnet does not, like an electrified body, return to a neutral state when brought into communication with the earth. Magnetism can only be developed in a few, whereas electricity may be developed in all bodies.

Between these analogies and dissimilarities nothing positive could be affirmed with respect to the identity of magnetism and electricity, until, in 1819, ŒRSTED made a discovery which showed that these physical agents are most intimately allied, if not identical.

(**426.**) What early observations were made on the relation of the phenomena of electricity and magnetism? What dissimilarities were noticed?

Action of an Electrical Current upon a Magnet.

427. Ersted discovered the fact that an electrical current has a directive power over the magnetic needle, tending always to direct it at right angles to its own direction.

This action may be shown by the apparatus represented in Fig. 293. If a wire be placed parallel to and pretty near a magnetic needle, and then a current of electricity be passed through it, the needle will turn around, and after a

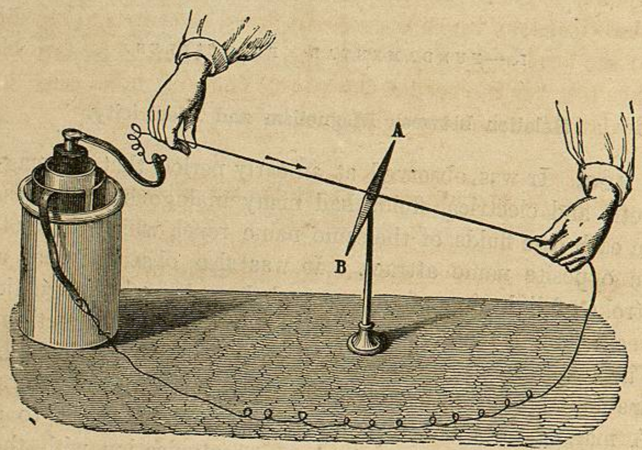

Fig. 293.

few oscillations will come to rest in a position sensibly at right angles to the current. That it does not take a position absolutely perpendicular to that of the current, is because of the directive force of the earth, which partially counteracts that of the current.

The direction towards which the austral pole, that is, the north end of the needle, will turn, depends upon the direction of the cur-

(**427.**) What discovery was made by Ersted? Explain the action of the electrical current on the needle. *Which way does the north end turn?*

rent. If that flows from south to north, and above the needle, the needle deviates towards the west; if it flows towards the south, and above the needle, the latter deviates towards the east. When the current flows below the needle, the phenomena are reversed.

Ampere's Law.

428. Ampere, to whom the discovery of the greater portion of electro-magnetic phenomena is due, gave a simple expression to the law which governs the action of a current upon a magnet. He supposes an observer lying down upon the wire along which the current flows, the current entering at the head and going out at the feet. Then, if he turn his face towards the needle, the austral pole will in all cases be deviated towards his right hand.

Action of Magnets upon Currents, and of Currents upon Currents.

429. Ampere established the following principles:

1. Magnets exercise a directive force upon currents.

To illustrate this, we bend a copper wire into a circular form, and then dip its extremities, which should be pointed with steel, into cups of mercury, one above the other, as shown in Fig. 294. These cups communicate with the two poles of a battery, by means of which a current may be generated, flowing as indicated by the arrows. Now if a bar magnet be brought near this current, the axis being in the plane of the current, we shall see the hoop turn about the steel points in the cups, and come to rest, with its plane perpendicular to the axis of the magnet. This experiment, which is due to Ampere, is the reverse of that made by Ersted.

2. The earth, which acts like a huge magnet upon a magnetic needle, acts in the same manner upon movable cur-

(**428.**) Explain Ampere's law. (**429.**) What is Ampere's first principle? *How illustrated?* His second principle?

rents; that is, it directs them so that they are perpendicular to the magnetic meridian.

This may be shown by the apparatus of Fig. 294. If the communication with the battery be cut off, and the hoop be turned till its plane coincides with the magnetic meridian, it will remain in that

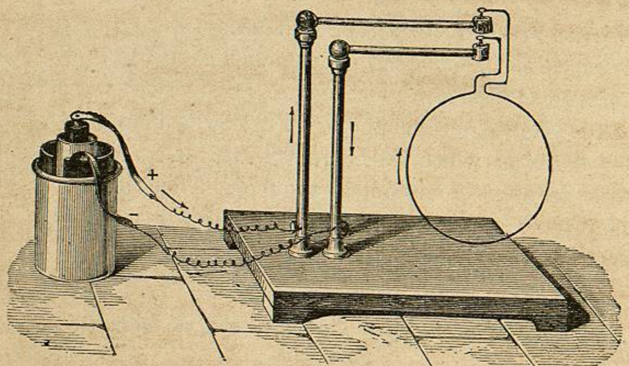

Fig. 294.

position. If now a current be passed through it, we see it turn slowly around the pivots, so as to take a position at right angles to the meridian. It will turn in such a direction that the current in the lower part of the hoop will flow from east to west.

3. Two parallel currents attract each other when they flow in the same direction, and repel each other when they flow in opposite directions.

4. If a wire be coiled into a double helix, as represented in Fig. 295, and then be suspended by its steel points in the cups of mercury (Fig. 294) it will, when a current is passed

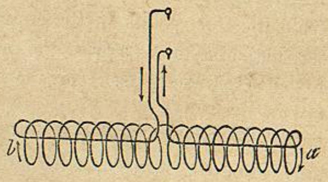

Fig. 295.

How may this be shown? His third principle? His fourth principle?

through it, arrange itself in the meridian like a magnetic needle. When the current takes the direction of the arrows, the end, *a*, becomes an austral pole, and is directed towards the north.

When thus suspended, the helix has all the properties of a magnet, and is subject to the same laws of attraction and repulsion. A helix of the kind described is called a *solenoid*.

Ampere's Theory of Magnetism.

430. From the facts explained in the last article, AMPERE deduced a theory of magnetism. He supposes magnetism to be due to currents of electricity flowing around the ultimate molecules of a magnet, always in the same direction. The currents in the interior of the magnet neutralize each other, and consequently the total effect of all the currents in a magnet, is the same as that of a set of surface currents flowing around the magnet, in such a direction, that if we place the eye at the south end of a magnet, and look in the direction of the axis, the current will flow around in the same direction, as the hands of a watch.

He supposes the directive force of the earth to be due to currents of electricity flowing around it, parallel to the magnetic equator, from east to west. These currents are produced by variations of temperature, which arise from the earth's revolution continually presenting a new portion to the direct action of the sun's rays.

If we conceive all the currents of the magnetic needle to be replaced by a single resultant about its equator, and all of the terrestrial currents to be replaced by a single equatorial current, then that portion of the latter current which lies nearest the magnet, will attract the lower part of the current on the magnet, and repel that on the upper part, thus compelling the magnet to place itself in the meridian.

What is a solenoid? (**430.**) What is AMPERE's theory of magnetism? To what did he attribute the directive power of the earth? *Explain the action of the terrestrial current upon the magnetic needle.*

AMPERE supposes that natural magnets owe their properties to the long-continued action of electrical currents. We may suppose magnetic bodies to be made up of atoms, having electrical currents flowing around them; that is, of little magnets. These, when they are arranged heterogeneously, will exhibit no magnetic properties. When they are by any action brought into positions in which their similar poles are arranged in the same direction, they become magnets.

Galvanometer. — Galvanic Multiplier.

431. A GALVANOMETER is an instrument for measuring the force of an electrical current. In its simplest form, it consists of a magnetic needle, *ab*, Fig. 296, with a conducting wire passed around it in the direction of its length.

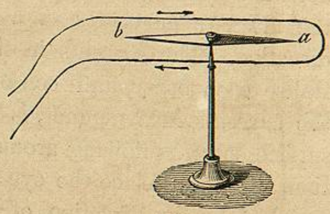

Fig. 296.

When a current of electricity is passed through the wire, its presence will be indicated by a motion of the needle, its force by the amount of deviation of the needle, and the direction of the current will be indicated by the direction towards which the north end of the needle deviates.

The GALVANIC MULTIPLIER is a galvanometer of great sensitiveness, but constructed on the same principles as the one already described.

It is represented in Fig. 297. It consists of a copper stand, *M*, supporting a glass cylinder, as shown in the figure. Under the cylinder is a graduated circle, beneath which is a wooden frame wound with a great number of coils of copper wire. The wire is insulated by being covered

How does AMPERE *explain the formation of natural magnets?* (**431.**) What is a Galvanometer? Describe it. *Its action.* What is a Galvanic Multiplier? Describe it in detail.

with silk. The two ends of the coil communicate with the binding screws, *m* and *n*, by means of which they may be made to communicate with the poles of a magnetic couple. A metallic frame supports a hook, from which is suspended a delicate silken cord, *s*. This cord supports two fine magnetic needles, the one, *ab*, above the graduated circle, and

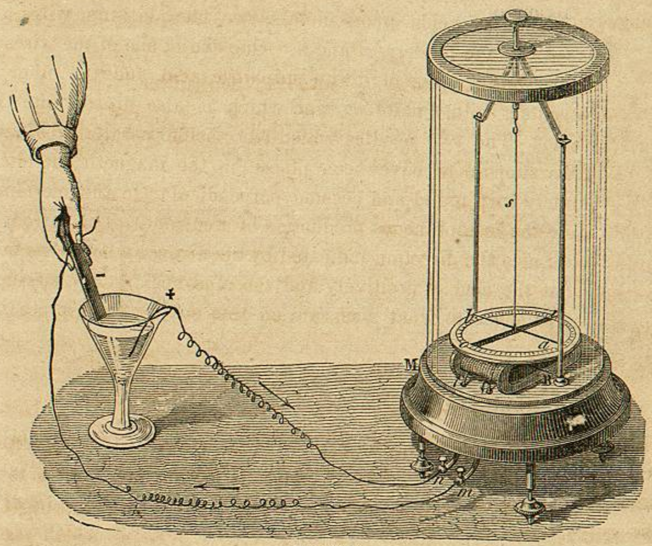

Fig. 297.

the other, *B*, within the coil, only a part of which is visible in the figure. The two needles are so united that one can not turn without the other, and their poles being placed in opposite directions, the action of the earth upon them is completely neutralized. Hence they are free to obey the least force.

Uses of the Galvanic Multiplier.

432. The Multiplier is used to indicate the feeblest currents of electricity. By means of it, BECQUEREL established

(**432.**) What is the use of the Multiplier?

the fact that a current is developed in every chemical action, in the imbibition of liquids, and in many other phenomena. By using a galvanometer with many thousands of turns of wire, the existence of electrical currents in animals and vegetables may be demonstrated.

To show the currents developed by chemical action, as, for example, the action of acids upon metals, two fine platinum wires are introduced into the binders, *m* and *n*. One end of one of the wires is then dipped into a glass of dilute sulphuric acid, and the other is held in contact with a plate of zinc which is also dipped into the dilute acid. The two needles which were before parallel to *oi*, and which we suppose to have been placed in the magnetic meridian, immediately turn round and become perpendicular to the meridian, indicating the instantaneous production of a current. The current in this case takes the direction indicated by the arrows, whence we conclude that the acid is positively and the zinc negatively electrified. This corresponds to what was said on this subject in a preceding article

Magnetizing by means of an Electrical Current.

433. If a wire be wound around a bar of iron, and a current of electricity be passed through the wire, it is at once converted into a magnet. The method of making the experiment is shown in Fig. 298.

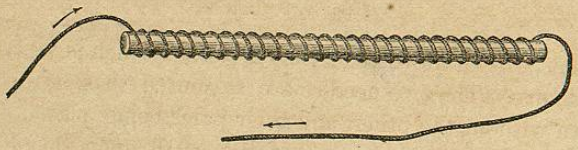

Fig. 298

If the current cease, the iron bar at once loses its magnetism. We may in like manner form a permanent magnet by using a bar of steel instead of a bar of iron.

Illustrate. (**433.**) How is an iron bar converted into a magnet by galvanism? In what way may a bar of steel be converted into a magnet?

The bar of steel may also be magnetized by passing through the wire a spark from a Leyden jar. To do this, one end of the wire is made to touch the external covering of the jar, and the other end is brought into contact with the button of the jar. The steel bar is magnetized instantaneously, thus showing the identity between the electricity of the galvanic current and that of the Leyden jar.

II. — ELECTRO-MAGNETIC TELEGRAPHS. — THE ELECTRO-MOTOR.

The Electro-Magnet.

434. An Electro-Magnet is a magnet obtained by the use of electricity.

Electro-magnets are generally made of soft iron, bent in the form of a horse-shoe, as shown in Fig. 299. Upon each branch is wound a great number of coils of wire, insulated by being covered with silk. The wire is coiled in different directions upon the two branches, and its extremities are then connected with the poles of a battery.

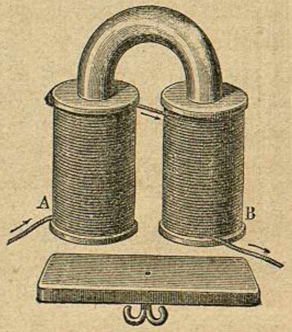

Fig. 299.

In this way magnets may be constructed of immense power, so powerful, in fact, as to support the weight of ten or twelve persons. Fig. 300 represents the method of arranging the details of a magnet which is intended to exhibit a great *sustaining power*.

The plate in contact with the two poles is called an *armature*.

When the instrument is of soft iron, it is magnetized instantaneously by the passage of a current of electricity through the wire, and

In what other way may it be done? What inference is drawn from this fact? (**434.**) What is an Electro-Magnet? How are they constructed? What is an armature?

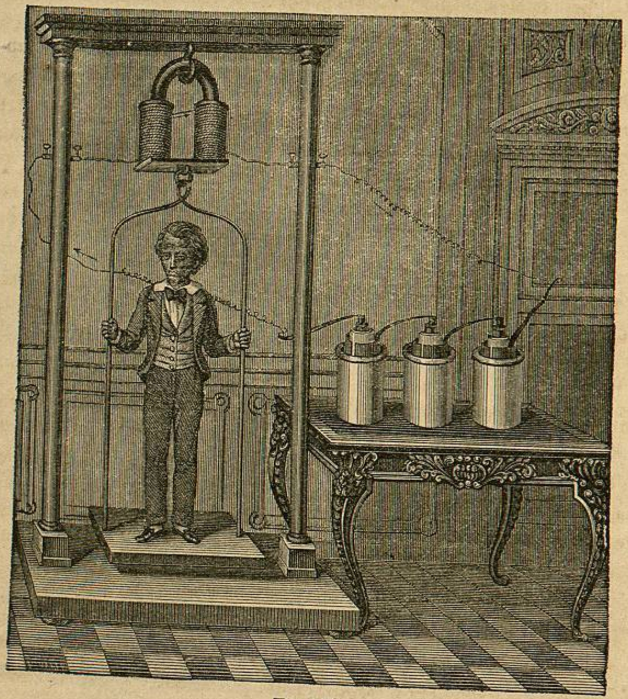

Fig. 300.

as instantaneously loses its magnetism when the current is stopped, or *broken*. This property has been utilized in the electro-magnetic telegraph.

The Electrical Telegraph.

435. An ELECTRICAL TELEGRAPH is an apparatus for transmitting intelligence to a distance by means of electrical currents.

In 1820, AMPERE proposed to transmit signals by passing currents over magnetic needles, making use of as many wires and needles as

What is the principal use of the electro-magnet? (435.) What is an Electrical Telegraph? *Give an outline of the history of magnetic telegraphs.*

there are letters. In 1837, STEINHEIL, of Munich, actually constructed such a telegraph.

In 1831, Prof. HENRY, now of the Smithsonian Institute, published the results of his researches on the subject of electro-magnetism, and in subsequent years, exhibited experiments illustrative of their application to the transmission of power to a distance, for the purpose of producing telegraphic effects.

In 1837, Prof. MORSE invented a machine for recording signals upon paper, and in 1844, the first working line of telegraph for practical purposes was built from Washington to Baltimore.

Many modifications of the telegraphic apparatus have been made since its first invention. Three principal varieties are now in use, all of which are based upon a common principle, which is very simple.

At the station from which a telegram is dispatched, is an electrical battery, and at the one where it is to be received, is an electro-magnet. The two are connected by a wire running between the stations. When the current is transmitted through the wire, the iron becomes magnetized and attracts an armature of soft iron, which in turn imparts motion to other pieces, by means of which the signals are imparted. When the current ceases, the iron loses its magnetism, and a spring forces the armature back to its primitive position. By successively breaking and restoring the current, the telegram is transmitted.

In one form of the telegraph, the electro-magnet causes a needle to move over a sort of dial, around which are printed the letters of the alphabet. The letters before which the needle stops, is the one to be transmitted. This machine requires as many signals as there are letters in the message. This is the *dial telegraph.*

In another form of the telegraph, there are two electro-magnets, which set in motion two movable arms placed at the extremities of a horizontal black line on a white dial-plate. The relative positions of the hands with reference to the fixed line, serve as conventional signals, nearly in the same way as was customary in the old-fashioned telegraph. This is the *signal telegraph.*

How many kinds are in common use? Explain their general principle. What is the dial telegraph? The signal telegraph?

The dial telegraph is used in France on the lines of railways. The signal telegraph was used in France for ordinary purposes until it was replaced by MORSE's registering apparatus.

Morse's Registering Telegraph.

436. In MORSE's telegraph, the telegram is permanently registered upon paper by means of a conventional alphabet.

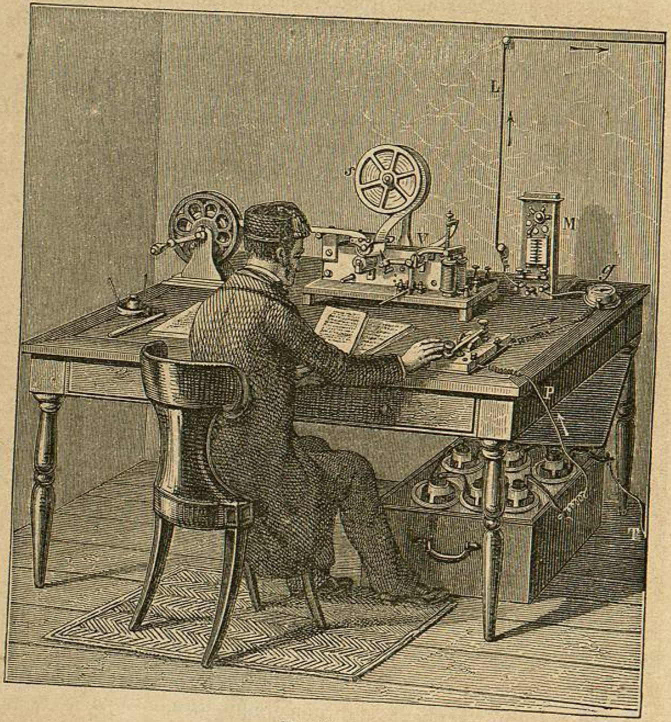

Fig. 301.

Fig. 301 represents the method of dispatching a telegram, and Fig. 302 represents the method of receiving it. At

Where were these used? (**436.**) Describe MORSE's registering telegraph.

each station the apparatus is identical, but it is double; that is, composed of two pieces, the *manipulator* and *receiver*. These pieces are shown more in detail in Figs. 303 and 304. In order to explain the working of this telegraph, let us commence with Fig. 301.

Under the table is shown the battery which furnishes the electrical current. The current is conducted by the wire, *P*, into the manipulator, which will be described hereafter.

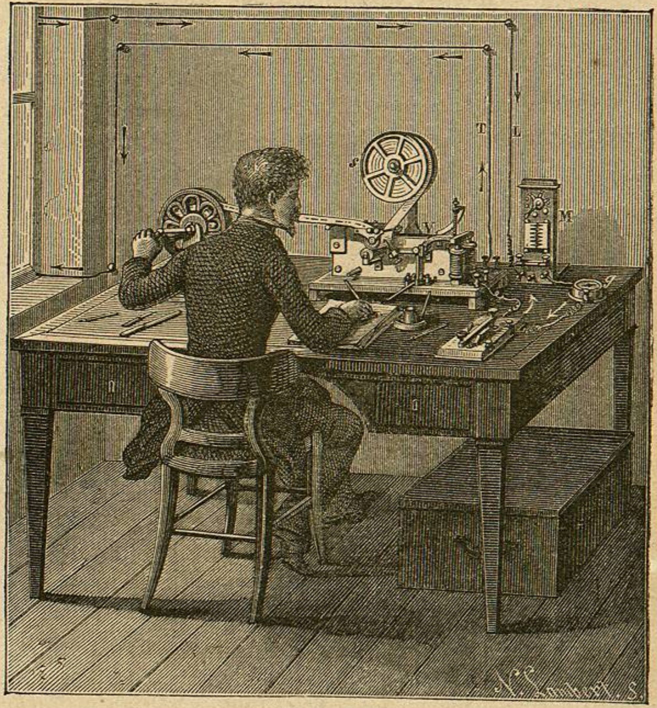

Fig. 302.

From thence it goes into a galvanometer, *g*, which indicates by a needle the passage of the current; it next passes

Explain the method of working this telegraph.