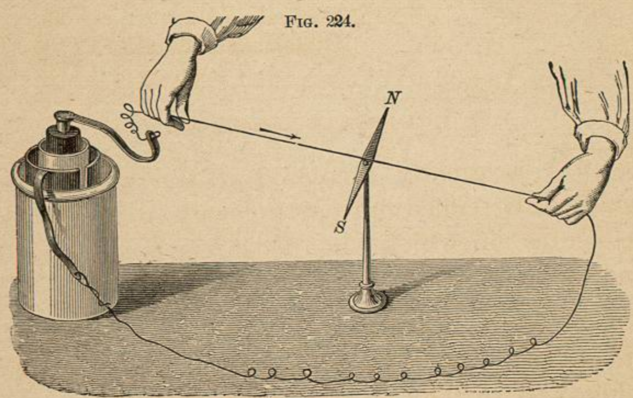
den twinge is felt, and the shock becomes painful and even dangerous, especially if the palms are moistened with salt or acid water to increase the conduction. Rabbits which had been suffocated for half an hour, have been restored by an application of a strong voltaic current.

III. TRANSFORMATIONS OF ELECTRIC ENERGY.

1. Effect of a Voltaic Current on a Magnetic Needle.—If a wire conducting an electric current be placed over a poised magnetic needle, this tends to place itself at right angles to the wire.

FIG. 224.

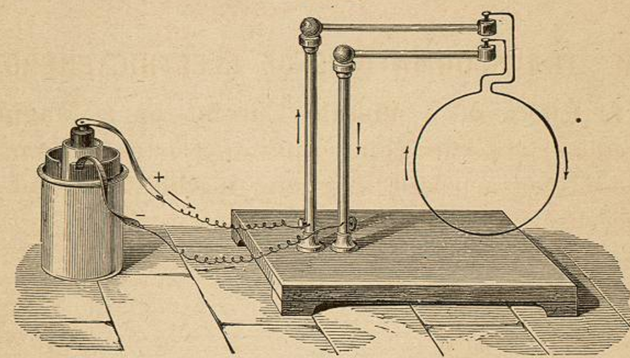


Effect of Current on Needle.

Assuming the direction of the current to be northward, the north pole of the needle will be turned toward the left. The same effect will be produced if the current pass southward under the

needle, or vertically downward on the north side of it, or vertically upward on the south side of it. By reversing these conditions, the north pole of the needle will be turned toward the right. The play of the needle becomes thus a test of the presence and direction of an electric current.* The delicacy of

FIG. 225.



Pivoted Hoop of Conducting Wire.

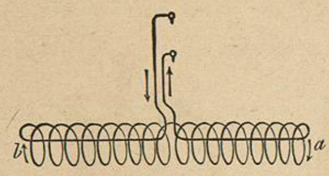
this test is greatly increased if the wire, properly insulated, be coiled into a ring with many turns, at the center of which the needle is pivoted or suspended.

2. A Wire bearing a Current acts like a Magnet.—Let a copper-wire hoop be pivoted, as shown in Fig. 225, so that its plane is in a north and south

* Ampère gave a very convenient rule for determining the direction of the current from the motion of the magnetic needle. Imagine the current to be like a stream of water, with a little swimmer in it, facing the needle and swimming along with the current. The north pole of the needle will always turn *toward his left*. The pupil should try the experiment and test it in all possible ways.

direction. On passing an electric current, it slowly turns until its plane assumes an east and west position. One side of the wire is like the north pole of a magnet and the opposite side like the south pole.

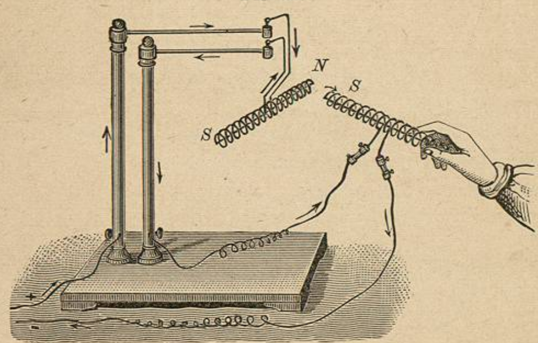
Fig. 226.



Pivoted Helix of Wire.

If, instead of a single hoop, we use a coil of wire (Fig. 226), the action is more prompt. By applying Ampère's rule, we easily find which end of the coil acts like a north magnetic pole. The end of a second conducting coil when brought near is attracted or repelled just as if each were a magnet (Fig. 227). We may conclude that *a current-bearing wire is in*

Fig. 227.

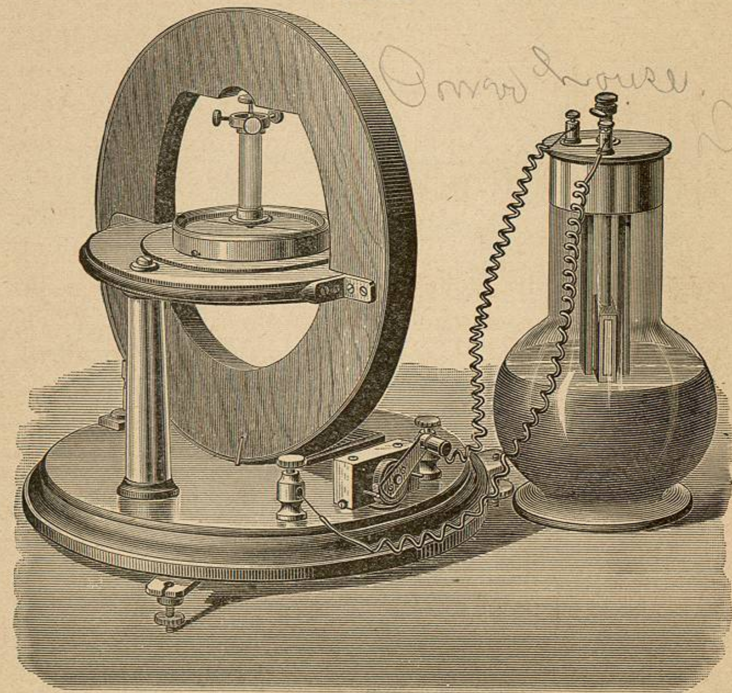


Two Helices acting like Magnets.

the midst of a magnetic field, which is due to the presence of the current. The left side of one coil being nearest the right side of the other, if the current pass in the *same* direction in both, opposite

kinds of magnetism are produced in the space between them, and hence they *attract*. If the current in one be reversed, they repel.

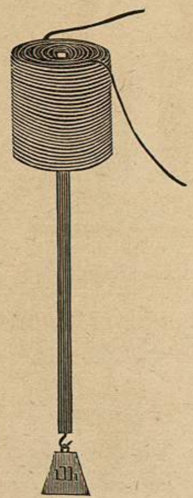
Fig. 228.



The Tangent Galvanometer.

3. The Tangent Galvanometer.—Any instrument designed to measure the strength of an electric current is called a galvanometer. Of the many varieties, the tangent galvanometer is the most important It consists of one or more coils of insulated wire wound upon a wooden hoop, at the center of which a small magnetic needle is pivoted or suspended (Fig. 228). The plane of the coils is made to coincide with that of the magnetic meridian. The earth's magnetism tends to keep the needle in this plane. The magnetic effect of a current tends to make it assume a position across this plane. Obeying both forces it assumes an oblique position, so as to make a measurable angle with the meridian. The strength of current is proportional to the tangent of this angle.

Fig. 229.



A Magnetic Mahomet's Coffin.

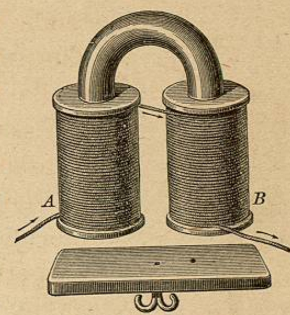
4. The Electro-magnet. — If a current be passed through a coil held vertically (Fig. 229), a rod of soft iron placed below will be drawn up into the coil, springing up as if endowed with life at the moment the current begins. It drops as soon as the circuit is broken.* Let a pair of such coils be fixed around the arms of a U-shaped rod of soft iron. This becomes a strong horseshoe magnet, whose strength comes and goes as the current is made or broken. It is therefore called an electro-magnet. Such magnets have been made strong enough to sustain a weight of several tons attached to the armature below.

5. The Electro-magnetic Telegraph depends on

* Thus is realized in science the fabulous story of Mahomet's coffin, which is said to have been suspended in mid-air.

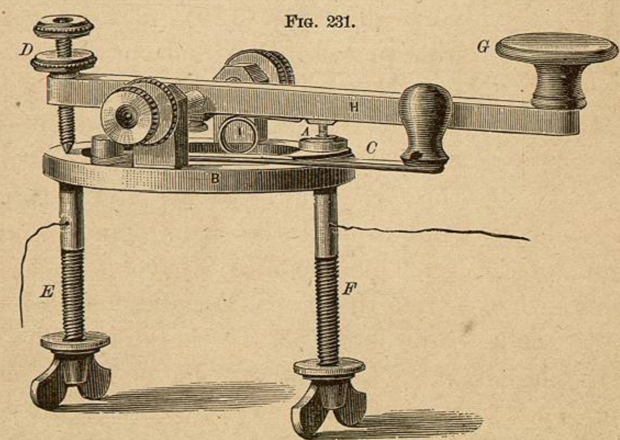
the principle of closing and breaking the circuit at one station, and thereby making and unmaking an electro-magnet at the station with which communication is held. A single wire is used to connect the two stations. The extremities of the wire extend into the ground, and the earth completes the circuit in which the battery and instruments are included. Each station has a key and a register (or sounder); the former is used for sending messages, and the latter for receiving them.

Fig. 230.



The Electro-magnet.

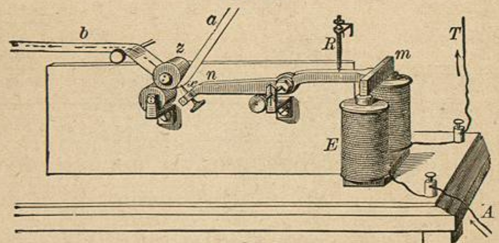
Fig. 231.



The Telegraph Key.

The key is shown in Fig. 231. *E* and *F* are screws which fasten the instrument to the table, and also hold the two ends of the wire. *F* is insulated by a ring of vulcanite where it passes through the table and the metal plate *B*. H is a lever with a finger-button *G*, a spring *I*, to keep it lifted, and a screw *D*, to regulate the distance it can move. At *A* is a break between two platinum points, which form the real ends of the wires. When *G* is depressed, the circuit is complete, and when lifted, it is broken. *C* is a *circuit-closer* that is used when the key is not in operation; the arm being pushed under *A* touches the platinum wire, and so completes the circuit. It is pushed out whenever the operator manipulates *G*. Then, by moving *G*, he can "close" or "open" the circuit at pleasure. He thus sends a message.

FIG. 232.



The Register.

The *register* contains an electro-magnet, *E* (Fig. 232). When the circuit is complete, the current, passing through the coils of wire at *E*, attracts the armature *m*. This elevates *n*, the other end of the lever *mn*, and forces the rounded point *x* firmly against the soft paper *a*. As soon as the circuit is broken, *E* ceases to be a magnet, and the spring *R* lifts the armature, drawing the point from the paper.

Clock-work attached to the rollers at *z* moves the paper along uniformly beneath the point *x*. When the circuit is completed and broken again instantly, there is a short dot made on the paper. This is called *e*; two dots, *i*; three dots, *s*; four dots, *h*. If the current is closed for a longer time, the mark becomes a dash, *t*; two dashes, *m*; a dot and a dash, *a*.

TABLE OF MORSE'S SIGNS.

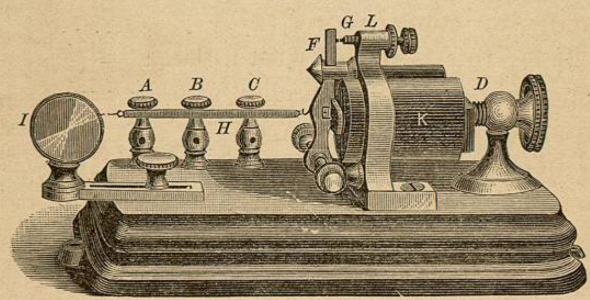
a · —	j — · — ·	s ··· ·
b — ···	k — · —	t —
c ·· ·	l ——	u ·· —
d — ··	m — —	v ··· —
e ·	n — ·	w · — —
f · — ·	o · ·	x · — ··
g — — ·	p ·····	y ·· ··
h ····	q ·· — ·	z ··· ·
i ··	r · ··	& · ···

A skillful operator becomes so accustomed to the sound that the clicking of the armature is perfectly intelligible. He uses, therefore, simply a "*sounder*," *i.e.*, a register without the paper and clock-work attachment. Indeed, the register has now gone almost entirely out of use, and every operator is required to read by sound.

RELAY.—When the stations are more than fifty or sixty miles apart, the current becomes generally too weak to work the register. By substituting the *relay* for it in the line circuit, the force of a local battery may be employed to work the sounder or register.

In Fig. 233, which represents a relay, *D* is connected with the line wire, and *C* with the ground wire; *A* is connected with the positive pole of the local battery, and *B* with the register or sounder, and thence with the negative pole of this battery. The main current passes in at *D*, traverses the fine wire of the electro-magnet, *K*, and thence passes out at *C* to the ground. The armature *E*, playing to and fro as

FIG. 233.



The Relay.

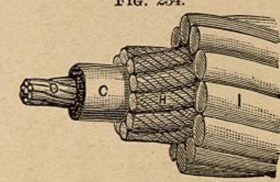
the current from the distant station passes through or is cut off, moves the lever *F*. This works on an axis at the lower end and is drawn back by the spring *H*, which is regulated by the thumb-screw *I*. As *E* is attracted, the circuit at *G* is closed; the current from *A* traverses a wire underneath, up *F*, and down *L*, and back through another wire underneath to *B*; thence to the electro-magnet of the sounder, which therefore attracts its armature.

The operator who sends the message simply completes and breaks the circuit with the *key;* the *armature* of the *relay*, at the station where the mes-

sage is received, vibrates in unison with these movements; the *register* or *sounder* repeats them with greater force; and the second operator interprets their meaning.*

6. Ocean Cables.—The Atlantic and Indian Oceans have been spanned with cables of insulated wire for the transmission of telegraphic messages. The cable must be well insulated and very strong. In the middle is a bundle of copper wires, *O* (Fig. 234); this is buried within a sheathing of gutta-percha, *C*; around this is a group of cords of tarred hemp, *H*, to protect the gutta-percha; and, to give still further protection and strength, fifteen or twenty iron wires are twisted around the whole, so as to make it a rope about an inch thick.

FIG. 234.



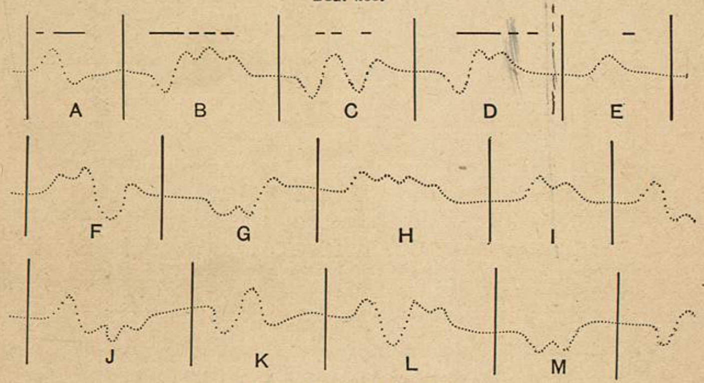
A Piece of Ocean Cable.

In signaling over a long cable, allowance has to be made for the great resistance of the long wire, and the slowness with which the circuit has to be operated. Instead of using a relay or sounder, it is necessary to use a delicate galvanometer as a receiver. A beam of light is reflected from a little

* The simple telegraph instrument is but one of a multitude of applications that have been made of the electro-magnet. By various ingenious devices it has become possible to send two, or even four, messages with reasonable rapidity over the same line at the same time. By one system, devised by Mr. Delany, as many as seventy-two circuits have been operated with a single instrument at the rate of two or three words per minute. The message is often printed at the moment it is received. From the Stock Exchange in New York hundreds of printed reports are thus sent at the same time to offices in various parts of the city.

mirror attached to the magnetic needle, and the swinging of the bright spot on a screen is interpreted as an alphabet. Or, a fine glass siphon tube is attached to a movable galvanometer coil which swings between the poles of an electro-magnet. Its short arm dips into a vessel of ink which is insulated and can be electrified. The long arm has its end over a strip of paper moved by clock-work. The electrifica-

FIG. 235.



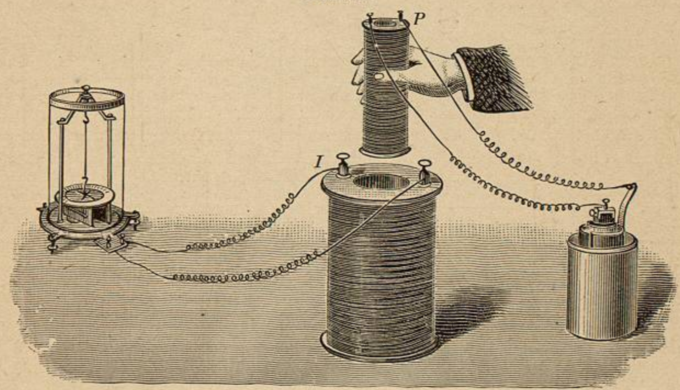
Siphon-recorder Alphabet.

tion of the ink causes it to issue in fine drops over the moving paper, and a sinuous line is recorded. This "Siphon-recorder" alphabet is partly shown in Fig. 235.

7. Current Induction.—We have seen that two magnets react upon each other when brought close together, and that current-bearing wires are magnets. If a current-bearing wire be moved swiftly past another wire forming a closed circuit but having no battery included, it renders this momentarily mag-

netic, and an evanescent current passes through it. Let the coil *P* (Fig. 236), which forms a closed circuit with the battery, be thrust into the coil *I*, which forms a closed circuit with the galvanometer. Instantly the needle turns, and then comes back to rest. Suddenly withdraw *P*. The needle turns in the opposite direction, and again comes back to rest.

FIG. 236.

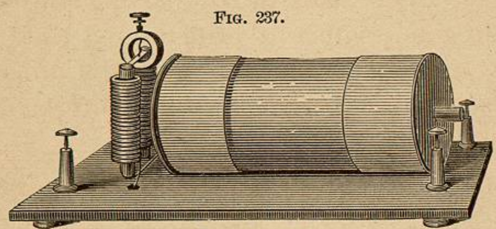


Current Induction.

P is called the primary coil; *I*, the secondary or induction coil, because currents in it are *induced* by the motion of *P*. The current in *I* is opposite in direction to that of *P* when this is thrust in, and in the same direction when *P* is withdrawn. Similar effects are obtained by making and breaking the circuit in *P*.

8. Ruhmkorff's Induction Coil is provided with an automatic circuit-breaker, consisting of an electro-magnet whose current passes through a spring to which the armature is attached. When there is no current this spring touches a "contact point" which forms part of a circuit. On dipping the zinc into the acid of the battery, the current excites the electro-magnet. This attracts the armature, and thus removes the spring from the contact point. The circuit is hence broken, and the spring draws back the armature, making contact again. The vibration of the

Fig. 237.



Induction Coil.

armature thus produces rapid repetitions and reversals of the current in the secondary coil. The primary coil contains a bundle of iron wires, which become magnetic and react upon the coil, causing its magnetism, and therefore its induced current, to become stronger. The insulated wire of the secondary coil is long and fine, sometimes a hundred miles or more in length. The electro-motive force of the secondary current is enormously greater than that of the primary.* Connected with the poles of the battery is a

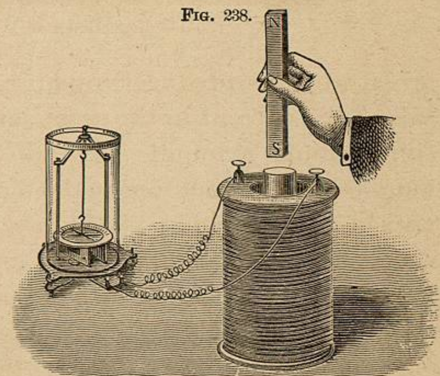
* The largest induction coil ever constructed was made for Mr. Spottiswoode, an English physicist. Its secondary coil contained 280 miles of wire, wound in 340,000 turns, and its resistance exceeded 100,000 ohms. When worked with a Grove battery of 30 cells, it gave a spark 42 inches long, or considerably more than a yard in length. Coils containing 50 miles of wire are not uncommon; they yield sparks a foot or more in length. A

condenser, which still further heightens the effect of the coil.

The induction coil is used for many purposes requiring high electro-motive force, and is usually more reliable than any machine generating electricity by friction. Beautiful effects are obtained by passing sparks from it through Geissler tubes. These are made of glass, and contain rarefied gases or vapors. The spark when passing through rarefied hydrogen assumes a brilliant red tint; through nitrogen, a gorgeous purple. With the proper degree of rarefaction it becomes stratified into bands across the tube.

9. Magneto-Induction.—To produce alternating currents in a secondary coil it is sufficient merely to move a magnet in its neighborhood. Let one pole of the magnet, *NS* (Fig. 238), be waved over an end of the coil. The currents induced will be manifested in the swinging of the galvanometer

Fig. 238.



Magneto-electric Currents.

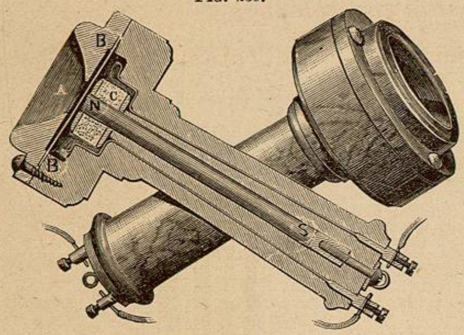
Leyden jar interposed in the secondary circuit of such a coil is charged and discharged so rapidly as to make almost a continuous sound.

The action of the condenser is not easily explained in a few words to the elementary student. Consult Thompson's "Lessons in Electricity and Magnetism," pp. 363-365.

needle. This effect is intensified by putting a rod of soft iron within the coil and bringing the magnet pole alternately toward and away from it.

10. The Telephone* is an instrument for utilizing magneto-electric currents and reproducing speech by their aid. Within a handle of vulcanite is a permanent magnet (Fig. 239), around one pole, *N*, of which is an insulated coil, *C*, connected with the binding posts at the other end. A thin disk of soft iron, *BB*, is fixed across near the encircled magnet pole, and a mouth-piece, *A*, serves to direct the sound of the voice against the disk, which is thus made to vibrate. Disturbances are produced in the strength of the magnet, and corresponding currents traverse the wire. Passing through the coil of the

Fig. 239.



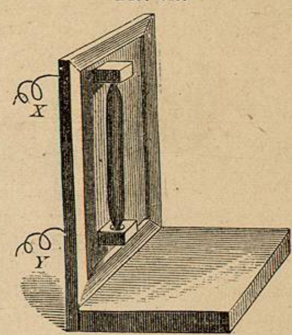
The Telephone.

* A telephone in parts, ready to be put together by the experimenter, is sold by the apparatus dealers. A simple but effective instrument can be made, at a slight expense, by a pupil with ordinary mechanical ability. One process, with illustrative drawings, is given in the "Popular Science Monthly," March, 1878, and another in the "Scientific American," Vol. XXXIX., No. 5. In Vol. XXXIX., No. 16, is also described a method of constructing a microphone; and in the "Scientific American Supplement," No. 133, is an account of a home-made phonograph. These numbers can be procured by any newsdealer. In using the telephone, two instruments exactly alike are employed. One is held to the mouth of the speaker, and the other to the ear of the listener.

distant telephone they vary the strength of its magnet. Minute clicking sounds are produced as the molecules of the magnet yield to these disturbances. The disk re-enforces these like a sounding-board, and gives out vibrations to the air, with such rapidity as to constitute a faithful reproduction of what was talked into the transmitting telephone.*

11. The Microphone is a modification of the telephone transmitter. It consists of a rod of gas carbon whose ends rest loosely in cups hollowed out of the same material, and these in turn fixed upon a sounding-board. The current from a battery passes through the microphone carbons and through a receiving telephone. If the sounding-board be made to vibrate in the least, whether by sound-waves or by slight mechanical motion, variations are produced in the pressure of the rod against its cups. Two pieces of carbon firmly in contact conduct electricity moderately well; but if the pressure

Fig. 240.



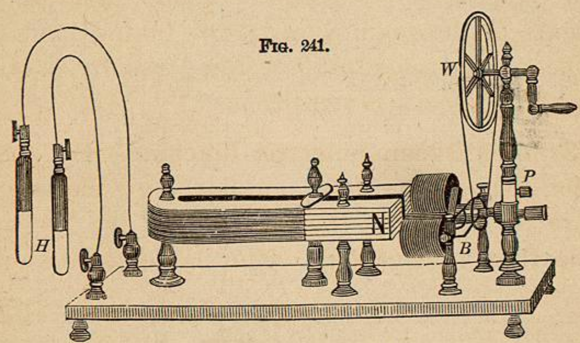
Microphone.

* It should be observed that the presence of a disk is not necessary for the perception of sound from the receiving telephone. The motion is probably among the molecules of the steel magnet, and conducted from them to the disk if this be added.

The telephone described in the text is the simplest that can be made. Many improvements have been effected in the instrument. The transmitting telephone is now generally made in such manner as to send an induced current, like that of the Ruhmkorff coil, through the line wire to the receiver.

between them is diminished, the resistance is increased and the current becomes fainter. The microphone is thus the last refinement of the telegraph combined with the telephone receiver. The sound of the voice, the patter of a fly's foot in walking over the sounding-board, or the gentlest ticking of a watch rested upon it, are thus made audible in a telephone many miles away.

FIG. 241.



The Magneto-electric Machine.

12. The Magneto-electric Machine.—If the magnet represented in Fig. 238 be fixed and the coil be swept past it, the effect is the same as if the coil were fixed and the magnet swept past it. The magneto-electric machine consists of a powerful horseshoe magnet, through whose field a pair of connected coils is made to rotate. This pair is called the armature. Each coil contains a core of soft iron, which acquires and then loses magnetism, as it approaches, passes, and then recedes from a pole of the permanent magnet. In the coil these

rapid variations of magnetic strength produce alternating currents whose electro-motive force is determined by the speed of rotation and the strength of the magnetic field. The two ends of the coil are connected with insulated plates of metal on opposite sides of the axle. On each of these a conducting spring presses, which carries the currents to the handles, *H*. This arrangement, called a *commutator*, is so adapted as to secure but one direction to the currents in the main wires. On taking hold of the handles while the shaft is rotated rapidly, a series of convulsive shocks is experienced.*

13. The Dynamo-electric Machine.—For the generation of currents to be employed in electric lighting it is necessary that they shall be continuous rather than intermittent. The name *dynamo* is ap-

* The machine represented in Fig. 241 is known as Clarke's machine, and was one of the first of its kind invented. Many improvements have been subsequently made. In 1866, Mr. Wilde discovered that if the induced current be passed through the coil of an electro-magnet, the strength it produces in this is far greater than that of the permanent magnet employed. An additional and larger armature was made to rotate in front of this electro-magnet, and the current induced in it was made to excite a second and still larger electro-magnet, whose armature then generated currents greatly stronger than any previously known. Such a machine, driven by a steam-engine of 15-horse power, produces an electric light dazzling as the noonday sun, throwing the flame of the street-lamps into shade at a quarter-mile distance. Its heat is sufficient to fuse a ¼-inch bar of iron fifteen inches long or 7 feet of No. 6 iron wire.—"A Yankee once threw the industrial world of Europe into a wonderful excitement by announcing a new theory of perpetual motion based on the magneto-electric machine. He proposed to decompose water by the current of electricity; then burn the hydrogen and oxygen thus obtained. In this way he would drive a small steam-engine, which, in turn, would keep the magneto-electric machine in motion. This would certainly be a splendid discovery. It would be a steam-engine which would prepare its own fuel, and, in addition, dispense light and heat to all around."—HELMHOLTZ.