STATIC ELECTRICITY.

CHAPTER V.

Static Electricity Explained—Conductors and Non-Conductors—Vitreous and Resinous Electricity—Discovery of the Leyden Jar—Franklin's Electrical Theories—Coulomb's Theories of Electro-Statics—Franklin's Reasons for believing that Lightning and Electricity were Identical—Identity of Lightning and Electricity Demonstrated—The Franklin Kite Experiment—Distribution of Electricity—Phenomena of Resistance to Induction—Phenomena of Attraction and Repulsion—Igniting Gas with the Finger—The Leyden Jar Experiments.

STATIC ELECTRICITY EXPLAINED.

THE name, *electricity*, is derived from the Greek word ἤλεκτρον, which signifies *amber*, the first substance upon which, electrical properties were seen.

Since the discovery of this mysterious phenomenon in nature, the whole world has been startled from time to time, by its extraordinary developments. It was unknown to the ancients, and as a science, it dates with the eighteenth century.

I do not propose to discuss the intricacies of this science, except in general terms, and to a very limited extent. The facts herein mentioned, are from many standard works.

Static electricity is more commonly called frictional electricity. The term "static" is applied, to distinguish the action of the force excited by friction, from that excited by chemical action. Frictional, or static electricity, exhibits itself in a state of equilibrium, and remains comparatively at rest, except during the instant of discharge; while voltaic, or chemical electricity, appears to be constantly in motion, from one pole of the voltaic battery to the other, and has hence been called current electricity. Static electricity is sometimes called "electricity at rest," and voltaic, or current, is called "electricity in motion."

The subject-matter, considered in this chapter, will be "static electricity," and in another chapter will be explained the different elements organized, to generate voltaic or "electricity in motion," as applied for telegraphic purposes.

It is supposed that electricity, in some form or other, exists in all nature, nevertheless, some substances manifest a greater degree of its presence than others.

CONDUCTORS AND NON-CONDUCTORS.

The metals were found to rank highest in this property. It has been subsequently discovered that all bodies *are conductors* of electricity more or less. No substance is at present known which is an absolutely perfect non-conductor. With all bodies, the passage through them of a *definite amount* of electricity is but a question of *time.*

The great object to be maintained in the construction of an electric telegraph is, to give the greatest possible facility for the passage of the power to a particular distant station, and to throw every possible obstacle in the way of the escape of any portion of the power in any other direction than the one desired.

For such purpose, the most perfect conductors are used for the conveyance of the power, and the most perfect insulators made to surround such conductors.

The following table exhibits the conducting power of several bodies with respect to electricity. It begins with the most perfect conductors, and ends with those which are the least perfect conductors. The properties, therefore, of these latter bodies, approximate most closely to that of non-conductors or insulators. The exact order, however, is by no means fully substantiated as yet, and the table must therefore only be taken as a general guide.

All the metals, viz.:

Silver,	Metallic ores,	Moist earths and stones,
Copper,	Animal fluids.	Powdered glass,
Gold,	Sea-water,	Flour of sulphur,
Brass,	Spring-water,	Dry metallic oxydes,
Zinc,	Rain-water,	Oils—heaviest the best,
Tin,	Ice above 13° Fahr.	Ashes, vegetable bodies,
Platinum,	Snow,	Ashes of animal bodies,
Palladium,	Living vegetables,	Many transparent crystals, dry,
Iron and	Living animals,	Ice below 13° Fahr.,
Lead,	Flame,	Phosphorus,
Well-burnt Charcoal,	Smoke,	Lime,
Plumbago,	Steam,	Dry chalk,
Concentrated acids,	Salts soluble in water,	Native carbonate of barytes,
Powdered charcoal,	Rarefied air,	Lycopodium,
Dilute acids,	Vapor of alcohol,	
Saline solutions,	Vapor of ether,	

Gum elastic,	Parchment,	Mica,
Camphor,	Dry paper,	All vitrifications,
Some silicious and argillaceous stones,	Feathers,	Glass,
Dry marble,	Hair,	Jet,
Porcelain,	Wool,	Wax,
Dry vegetable bodies,	Dyed silk,	Sulphur,
Baked wood,	Bleached silk,	Resins,
Dry gases and air,	Raw silk,	Amber,
Leather,	Transparent gems,	Shellac.
	Diamond,	

Gutta-percha, has recently been discovered, and it is found in practical service to be a better non-conductor than glass, and possibly than shellac. It has proved of wonderful utility in the art of telegraphing.

VITREOUS AND RESINOUS ELECTRICITY.

The celebrated philosopher, Dufaye, discovered that there were two distinct kinds of electricity, one of which he called *vitreous*, or that of glass, rock-crystal, precious stones, hair of animals, wool, and many other bodies: and the other *resinous*, that of amber, copal, gum-lac, silk-thread, paper, and a vast number of other substances. He showed that bodies having the same kind of electricity repel each other, but attract bodies charged with electricity of the other kind; and he proposed that test of the state of the electricity of any given substance which has ever since his time been adhered to, viz.: to charge a suspended light substance with a known species of electricity, and then to bring near it the body to be examined. If the suspended substance was repelled, the electricity of both bodies was the same; if attracted, it was different.

DISCOVERY OF THE LEYDEN JAR.

It was in the year 1746, that those celebrated experiments, which drew for many succeeding years the almost exclusive attention of men of science to the new subject, and which led the way to the introduction of the Leyden vial—were made by Muschenbroek, Cuneus, and Kleist. Professor Muschenbroek and his associates, having observed, that electrified bodies, exposed to the atmosphere, speedily lost their electric virtue, conceived the idea of surrounding them with an insulating substance, by which they thought that their electric power might be preserved for a longer time. Water contained in a glass bottle was accordingly electrified, but no remarkable results were obtained, till one of the party, who was holding the bottle, attempted to disengage the wire communicating with the prime conductor of a powerful machine; the consequence was, that he received a shock, which, though slight, compared with such as are now frequently taken for amusement from the Leyden vial, his fright magnified and exaggerated in an amusing manner. In describing the effect produced on himself, by taking the shock from a thin glass bowl, Muschenbroek stated in a letter to Réaumer, that "he felt himself struck in his arms, shoulders, and breast, so that he lost his breath, and was two days before he recovered from the effects of the blow and the terror," adding, "he would not take a second shock for the kingdom of France." M. Allamand, on taking a shock, declared, "that he lost the use of his breath for some minutes, and then felt so intense a pain along his right arm, that he feared permanent injury from it." Winkler stated, that the first time he underwent the experiment, "he suffered great convulsions through his body; that it put his blood into agitation; that he feared an ardent fever, and was obliged to have recourse to cooling medicines!" The lady of this professor took the shock twice, and was rendered so weak by it, that she could hardly walk. The third time it gave her bleeding at the nose. Such was the alarm with which these early electricians were struck, by a sensation which thousands have since experienced in a much more powerful manner, without the slightest inconvenience. It serves to show how cautious we should be in receiving the first accounts of extraordinary discoveries, where the imagination is likely to be affected.

After the first feelings of astonishment were somewhat abated, the circumstances which influenced the force of the shock were examined. Muschenbroek observed that the success of the experiment was impaired if the glass was wet on the outer surface. Dr. Watson showed, that the shock might be transmitted through the bodies of several men touching each other, and that the force of the charge depended on the extent of the external surface of the glass in contact with the hand of the operator. Dr. Bevis proved that tin-foil might be substituted successfully for the hand outside, and for the water inside the jar; he coated panes of glass in this way, and found that they would receive and retain a charge; and lastly, Dr. Watson coated large jars inside and outside with tin-foil, and thus constructed what is now known as the Leyden vial.

FRANKLIN'S ELECTRICAL THEORIES.

It was in the year 1747, that, in consequence of a communication from Mr. Peter Collinson, a Fellow of the Royal Society of London, to the Literary Society of Philadelphia, Franklin first directed his attention to electricity; and from that period, till 1754, his experiments and observations were embodied in a series of letters, which were afterward collected and published. "Nothing," says Priestley, "was ever written upon the subject of electricity, which was more generally read and admired in all parts of Europe, than these letters. It is not easy to say, whether we are most pleased with the simplicity and perspicuity with which they are written, the modesty with which the author proposes every hypothesis of his own, or the noble frankness with which he relates his mistakes when they were corrected by subsequent experiments." The opinion adopted by Franklin with respect to the nature of electricity differed from that previously submitted by Dufaye. His hypothesis was as follows: "All bodies in their natural state are charged with a certain quantity of electricity, in each body this quantity being of definite amount. This quantity of electricity is maintained in equilibrium upon the body by an attraction which the particles of the body have for it, and does not therefore exert any attraction for other bodies. But a body may be invested with more or less electricity than satisfies its attraction. If it possesses more, it is ready to give up the surplus to any body which has less, or to share it with any body in its natural state; if it have less, it is ready to take from any body in its natural state a part of its electricity, so that each will have less than its natural amount. A body having more than its natural quantity is electrified *positively* or *plus*, and one which has less is electrified *negatively* or *minus*. One electric fluid is thus supposed to exist, and all electrical phenomena are referable either to its accumulation in bodies in quantities more than their natural share, or to its being withdrawn from them, so as to leave them *minus* their proper portion. Electrical excess then represents the vitreous, and electrical deficiency the resinous electricities of Dufaye: and hence the terms *positive* and *negative*, for *vitreous* and *resinous*." The application of this theory to the explanation of the Leyden vial will appear in its proper place.

Besides this theory, we are indebted to Franklin for the discovery of the identity of lightning and electricity, for the invention of paratonnerres, and for the discovery of induction, which latter principle was immediately taken up, and pursued through its consequences by Wilke and Œpinus, and soon led to the invention of an instrument, which in the hands of Volta, became the *condenser*, now so useful in electroscopical investigations.

Franklin's hypothesis was investigated mathematically by Œpinus and Mr. Cavendish, between the years 1759 and 1771.

About the same time the electrophorus was constructed by Volta; Watson and Canton fused metals by electricity, and Beccaria decomposed water, although at the time he had no idea he had done so, supposing it to be a simple elementary substance.

COULOMB'S THEORIES OF ELECTRO-STATICS.

In the year 1785, the foundation of *electro-statics* was laid by Coulomb, a most profound philosopher, who reduced electricity, the most subtile of all physical agents, to the rigorous sway of mathematics, and caused it to become a branch of mathematical physics. By means of his torsion electrical balance, he made three valuable additions to the science; establishing—1st, That electrical forces, viz., attraction and repulsion, vary *inversely as the square of their distances*, following, it will be observed, the same law as gravitation;—2d, That excited bodies, when insulated, gradually lose their electricity free from two causes; from the surrounding atmosphere being never free from conducting particles, and from the incapacity of the best insulators to retain the whole quantity of electricity with which any body may be charged, there being no substance known altogether impervious to electricity—Coulomb determined the effect of both these causes;—3d, That when electricity is accumulated in any body, the whole of it is deposited on the surface, and none penetrates to the interior. A thin hollow sphere may contain precisely as much electricity as a solid of the same size. Hence, accumulation is not a consequence of attraction for mass of matter, but on the contrary, is solely due to its repulsive action. These observations of Coulomb on the distribution of the electric fluid on the surfaces of conductors, illustrated satisfactorily the doctrine of points which formed so prominent a part of Franklin's researches.

FRANKLIN'S REASONS FOR BELIEVING THAT LIGHTNING AND ELECTRICITY WERE IDENTICAL.

It was in the year 1749, that the celebrated American philosopher, Franklin, in a letter to Mr. Collinson, stated fully his reasons for considering the cause of electricity and lightning to be the same physical agent, differing in nothing, save the intensity of its action. "When," says he, "a gun-barrel, in electrical experiments, has but little electrical fire in it, you must approach it very near with your knuckle before you can draw a spark; give it more fire and it will give a spark at a greater distance. Two gun-barrels united, and as highly electrified, will give a spark at a still greater distance. But if two gun-barrels electrified will strike at two inches distance, and make a loud snap, to what a great distance may ten thousand acres of electrified cloud strike, and give its fire, and how loud must be that crack ?" He next states the analogies which afford presumptive evidence of the identity of lightning and electricity. The electrical spark is zig-zag, and not straight; so is lightning. Pointed bodies attract electricity; lightning strikes mountains, trees, spires, masts, and chimneys. When different paths are offered to the escape of electricity, it chooses the best conductor; so does lightning. Electricity fires combustibles: so does lightning. Electricity fuses metals: so does lightning. Lightning rends bad conductors when it strikes them; so does electricity when rendered sufficiently strong. Lightning reverses the poles of a magnet; Electricity has the same effect. A stroke of lightning when it does not kill, often produces blindness. Lightning destroys animal life, and so do electrical shocks.

In his memorandum-book of November 7th, 1749, Franklin wrote the following reasons, which induced him to believe, that the lightning and electricity were identical:

" Electric fluid agrees with lightning in these particulars: 1, giving light; 2, color of the light; 3, crooked direction; 4, swift motion; 5, being conducted by metals; 10, melting metals; 11, firing inflammable substances; 12, sulphurous smell. The electric fluid is attracted by points. We do not know whether this property is in lightning, but since they agree in all the particulars in which we can already compare them, is it not probable they agree likewise in this? Let the experiment be made."

From the effect of points on electrified bodies, Franklin inferred that lightning might also be drawn silently and safely from the clouds, by a metallic point fixed at a great elevation, and he waited with considerable anxiety the completion of a spire at Philadelphia, to enable him to try the experiment. In the meantime, he published his discoveries, and suggested to others to make the necessary experiment.

He published to the world the following plan:

" To determine this question, whether the clouds that contain lightning be electrified or not, I would propose an experiment to be tried, where it may be done conveniently. On the top of some high tower or steeple, place a kind of sentry-box, big enough to contain a man and an electrical stand. From the middle of the stand let an iron rod rise, and pass, bending out of the door, and then upright twenty or thirty feet, pointed very sharp at the end. If the electrical stand be kept clear and dry, a man standing on it, when such clouds are passing low, might be electrified, and afford sparks, the rod drawing fire to him from a cloud. If any danger to the man be apprehended, let him stand on the floor of his box, and now and then bring near to the rod the loop of a wire that has one end fastened to the leads, he holding it by a wax handle; so the sparks, if the rod is electrified, will strike from the rod to the wire, and not affect him."

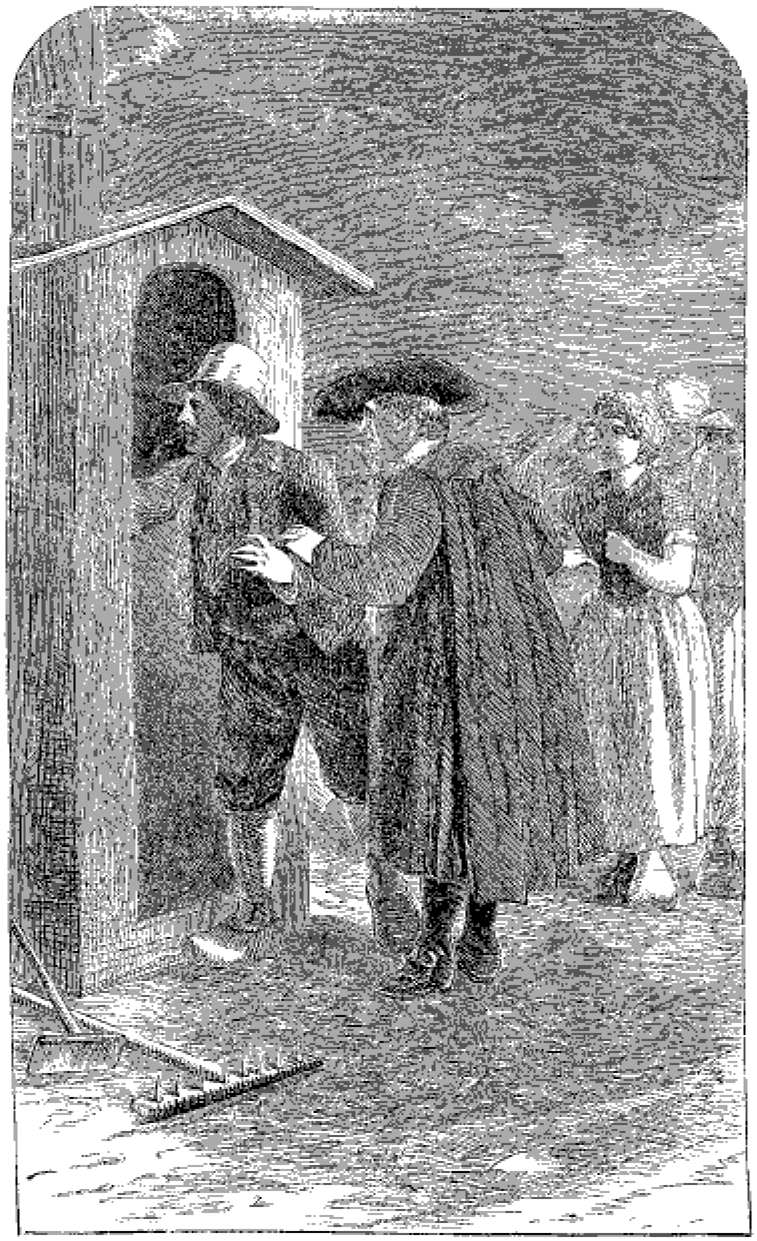
IDENTITY OF LIGHTNING AND ELECTRICITY DEMONSTRATED.

In accordance with the above suggestions, two Frenchmen, M. Dalibard and M. Delor, each erected an apparatus for the purpose of drawing from the clouds the lightning. M. Delibard coastructed his at Marly-la-ville, about six leagues from Paris, and M. Delor had his on a high part of Paris.

M. Dalibard's apparatus consisted of an iron pointed rod, forty feet long, the lower end of which was inserted in a sentry-box, protected from rain, and on the outside it was fastened to three wooden posts by silk cords, also defended from the rain. It was this rod that first attracted electricity from the clouds. M. Dalibard was absent from Marly at the time, and had left the apparatus in charge of an old soldier, named Coiffier, who was at the time engaged as a carpenter. On the 10th of May, 1752, between two and three o'clock in the afternoon, a sudden clap of thunder made Coiffier hurry to his post, and, according to the instructions given him, he presented a vial furnished with a brass wire to the rod, and immediately saw a bright spark, accompanied by a loud snapping noise. After having taken another spark stronger than the first, he called in the neighbors, and sent for the curé. The latter ran to the spot with all speed, and his parishioners seeing him running, followed at his heels, expecting that Coiffier had been killed by lightning; nor were they prevented from hastening to the spot, notwithstanding a violent hail-storm. The curé was equally successful in drawing sparks from the iron rod, and instantly dispatched an account of the important event to M. Dalibard. The curé stated that the sparks were of a blue color, an inch and a half long, and smelt strongly of sulphur. He drew sparks at least six times in about four minutes, and in the course of these experiments he received a shock in the arm, extending above the elbow, which he said left a mark, such as might have been made by a blow with the wire on the naked skin.

Eight days after this experiment, the rod erected by M. Delor, which was ninety-nine feet high, yielded electric sparks; and the same phenomenon was afterward exhibited to the French king, and to members of the nobility.

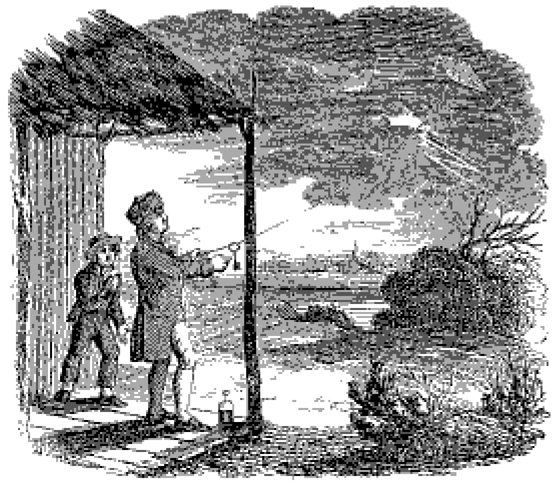
Fig. 1.



THE FRANKLIN KITE EXPERIMENT.

The experiment made by Franklin was in June, 1752; the description of which will be found in the following:

Fig. 2.



"He prepared his kite by making a small cross of two light strips of cedar, the arms of sufficient length to extend to the four corners of a large silk handkerchief stretched upon them; to the extremities of the arms of the cross he tied the corners of the handkerchief. This being properly supplied with a tail, loop, and string, could be raised in the air like a common paper kite; and being made of silk, was more capable of bearing rain and wind. To the upright arm of the cross was attached an iron point, the lower end of which was in contact with the string by which the kite was raised, which was a hempen cord. At the lower extremity of this cord, near the observer, a key was fastened: and in order to intercept the electricity in its descent, and prevent it from reaching the person who held the kite, a silk ribbon was tied to the ring of the key, and continued to the hand by which the kite was held.

Furnished with this apparatus, on the approach of a storm, he went out upon the commons near Philadelphia, accompanied by his son, to whom alone he communicated his intentions, well knowing the ridicule which would have attended the report of such an attempt should it prove to be unsuccessful. Having raised the kite, he placed himself under a shed, that the ribbon by which it was held might be kept dry, as it would become a conductor of electricity when wetted by rain, and so fail to afford that protection for which it was provided. A cloud, apparently charged with thunder, soon passed directly over the kite. He observed the hempen cord; but no bristling of its fibres was apparent, such, as was wont to take place when it was electrified. He presented his knuckle to the key, but not the smallest spark was perceptible. The agony of his expectation and suspense can be adequately felt by those only who have entered into the spirit of such experimental researches. After the lapse of some time, he saw that the fibres of the cord near the key bristled, and stood on end. He presented his knuckle to the key and received a strong bright spark. *It was lightning*. The discovery was complete, and Franklin felt that he was immortal.

A shower now fell, and wetting the cord of the kite improved its conducting power. Sparks in rapid succession were drawn from the key; a Leyden jar was charged by it, and a shock given: and, in fine, all the experiments which were wont to be made by electricity were reproduced, identical in all their concomitant circumstances."

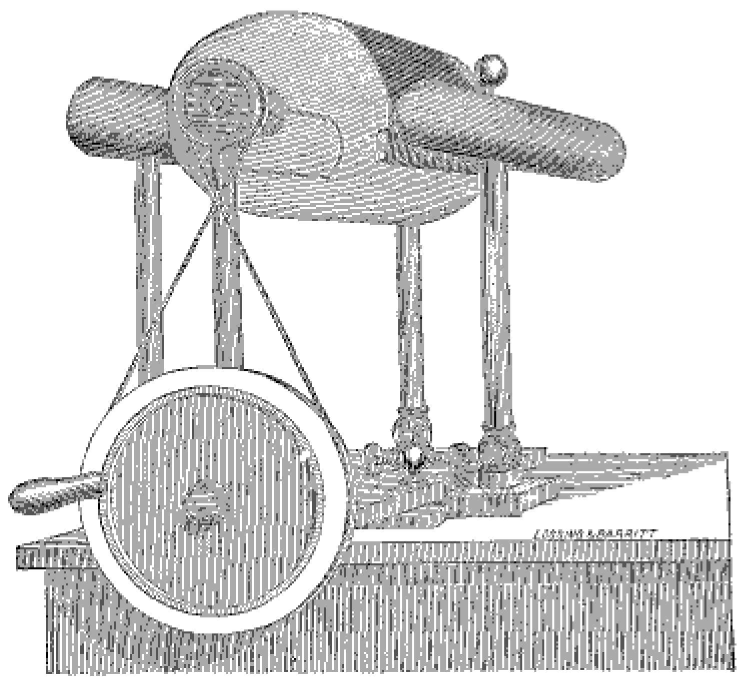
Franklin afterward raised an insulated metallic rod from one end of his house, and attached to it a chime of bells, which, by ringing, gave notice of the electrical state of the apparatus.

These interesting experiments were eagerly repeated in almost every civilized country, with variable success. In France, a grand result was obtained by M. de Romas: he constructed a kite seven feet high, which he raised to the height of 550 feet by a string, having a fine wire interwoven through its whole length. On the 26th of August, 1756, flashes of fire, ten feet long, and an inch in diameter, were given off from the conductor. In the year 1753, a fatal catastrophe from incautious experiments upon atmospheric electricity, occurred to Professor Richmann, of St. Petersburg; he had erected an apparatus in the air, making a metallic communication between it and his study, where he provided means for repeating Franklin's experiments: while engaged in describing to his engraver, Sokoloff, the nature of the apparatus, a thunder-clap was heard, louder and more violent than any which had been remembered at St. Petersburg. Richmann stooped toward the electrometer to observe the force of the electricity, and "as he stood in that posture, a great white and bluish fire appeared between the rod of the electrometer and his head. At the same time a sort of steam or vapor arose, which entirely benumbed the engraver, and made him sink on the ground." Several parts of the apparatus were broken in pieces and scattered about: the doors of the room were torn from their hinges, and the house shaken in every part. The wife of the professor, alarmed by the shock, ran to the room, and found her husband sitting on a chest, which happened to be behind him when he was struck, and leaning against the wall. He appeared to have been instantly struck dead; a red spot was found on his forehead, his shoe was burst open, and a part of his waistcoat singed; Sokoloff was at the same time struck senseless. This dreadful accident was occasioned by the neglect on the part of Richmann to provide an arrangement by which the apparatus, when too strongly electrified, might discharge itself into the earth.

DESCRIPTION OF ELECTRICAL MACHINES.

I have, now, sufficiently explained to the reader the wonderful experiments of Franklin, and those in France, made in the month of May, 1752, in accordance with the plans published by him. I will proceed to notice the means of manifesting

Fig. 3.

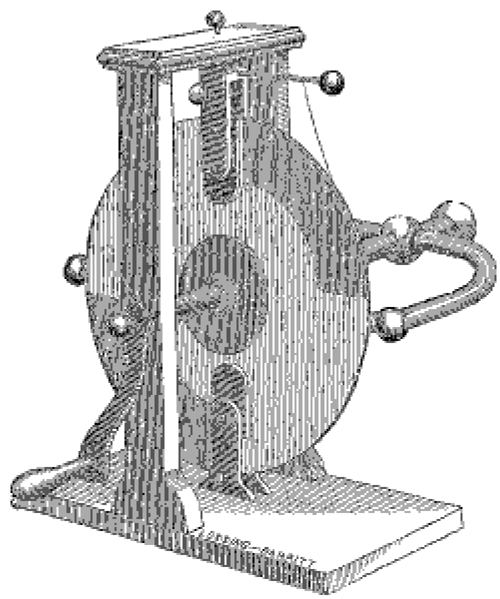


frictional electricity, commonly known as *static*, in contradistinction to that generated by chemical action. Static electricity, as I have already stated, is sometimes called "electricity at rest," and a voltaic current, is called "electricity in motion." The former remains comparatively at rest, excepting during the instant of discharge.

The following are descriptions of electrical machines, viz.: There are two kinds of electrical machines in general use—the cylindrical, and the plate machine. The former is shown in fig. 3. It consists of a hollow cylinder of glass, supported on brass bearings, which revolve in upright pieces of wood attached to a rectangular base; a cushion of leather stuffed with horse-hair, and fixed to a pillar of glass, furnished with a screw to regulate the degree of pressure on the cylinder; a cylinder of metal or wood covered with tin-foil, mounted on a glass stand, and terminated on one side by a series of points to draw the electricity from the glass, and on the other side by a brass ball. A flap of oiled silk is attached to the rubber to prevent the dissipation of the electricity from the surface of the cylinder before it reaches the points. On turning the cylinder, the friction of the cushion occasions the evolution of electricity, but the production is not sufficiently rapid or abundant without the aid of a more effective exciter, which experience has shown to be a metallic substance. The surface of the leather cushion is therefore smeared by certain amalgams of metals, which thus become the real rubber. The amalgam employed by Canton, consisted of two parts of mercury, and one of tin, with the addition of a little chalk. Singer proposed a compound of two parts by weight of zinc, and one of tin, with which in a fluid state six parts by weight of mercury are mixed, and the whole shaken in an iron, or thick wooden box, until it cools. It is then reduced to a fine powder in a mortar, and mixed with lard in sufficient quantity to reduce it to the consistency of paste. This preparation should be spread cleanly over the surface of the cushion, up to the line formed by the junction of the silk flap with the cushion; but care should be taken that the amalgam should not be extended to the silk flap. It is necessary occasionally to wipe the cushion, flap, and cylinder, to cleanse them from the dust which the electricity evolved upon the cylinder always attracts in a greater or less quantity. It is found that from this cause, a very rapid accumulation of dirt takes place on the cylinder, which appears in black spots and lines upon its surface. As this obstructs the action of the machine, it should be constantly removed, which may be done by applying to the cylinder, as it revolves, a rag wetted with spirits of wine. The production of electricity is greatly promoted by applying, with the hand to the cylinder, a piece of soft leather, five or six inches square, covered with amalgam. This is, in fact, equivalent to giving a temporary enlargement to the cushion.

The use of the oiled silk flap is to prevent the dissipation of the electricity evolved on the glass by contact with the air; it is thus retained on the cylinder till it encounters the points of the prime conductor, by which it is rapidly drawn off. It is usual to cover with a varnish of gum lac, those parts of the glass beyond the ends of the rubber, with a view of preventing the escape of the electricity through the metallic caps at the extremities of the cylinder, and the inside of the flap is also sometimes coated with a resinous cement, consisting of four parts of Venice turpentine, one part of resin, and one of bees' wax, boiled together for about two hours in an earthen pipkin over a slow fire.

Fig. 4.



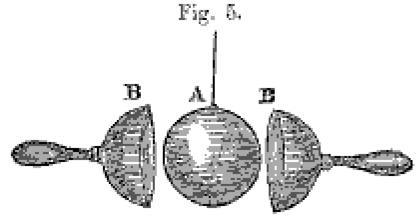
When the cylindrical machine is arranged for the development of either positive or negative electricity, the conductor is placed with its length parallel to the cylinder, and the points project from its side, as in the machine shown in the figure. The *negative* conductor supports the rubber, and receives from it the negative electricity, not by induction, as is the case with the positive conductor, but by *communication*. If it be required to accumulate positive electricity, a chain must be carried from the negative conductor (which of course is insulated) to the ground. If on the other hand, negative electricity be required, then the conductor must be put in communication with the earth, and the rubber insulated.

The plate electrical machine is shown in fig. 4. It consists of a circular plate of thick glass, revolving vertically by means of a winch between two uprights: two pairs of rubbers, formed of slips of elastic wood, covered with leather, and furnished with silk flaps, are placed at two equi-distant portions of the plate, on which their pressure may be increased or diminished by means of brass screws. The prime conductor consists of hollow brass, supported horizontally from one of the uprights; its arms, where they approach the plate, being furnished with points.

With respect to the merits of these two forms of the electrical machine, it is difficult to decide to which to give the preference. For an equal surface of glass, the plate appears to be the most powerful; it is not, however, so easily arranged for negative electricity, in consequence of the uninsulated state of the rubbers, though several ingenious methods of obviating this inconvenience have been lately devised.

DISTRIBUTION OF ELECTRICITY.

Fig. 5.

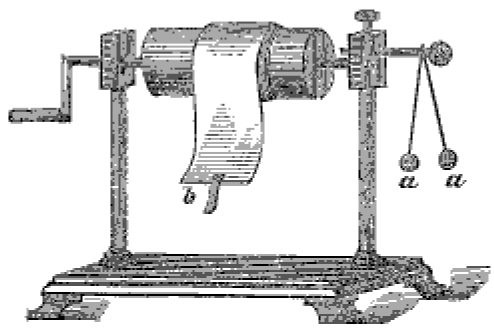


When a substance becomes charged with electricity, it is extremely probable, in the opinion of philosophers, that the fluid is confined to its surface, or, at any rate, that it does not penetrate into the mass to any extent. This is a question difficult to demonstrate, and my observations have induced me to believe, that in the case of voltaic currents the electricity moves upon or at the surface, but that the interior of the metallic conductor is under the influence of the fluid, though in a state of rest.

Experiments have been made with static or frictional electricity by Biot, and the following facts were arrived at: A ball formed of any kind of material, will be equally electrified whether it be solid or hollow, and if it be hollow, the charge which it receives will be the same whether the shell of matter of which it is formed be thick or thin.

A sphere of conducting matter, A, is insulated by a silk thread, and two thin hollow hemispheres, B B, made of metallic foil or gilt paper, and provided with glass handles, corresponding with the shape and magnitude of the conductor. The sphere A, is electrified, and the covers are then applied, being held by the glass handles. After withdrawing them from A, they are found to be charged with the same kind of electricity as was communicated to A, and the ball will be found to have lost the whole of its charge, proving that the electricity resided on the surface only.

Fig 6.



To further demonstrate that the electricity holds its position on the surface, fig. 6 is to illustrate. At the ends of the cylinder, are attached an electroscope, composed of two elder-pith balls, suspended to linen threads. The whole is to be electrified, and the pith-balls, *a a*, will diverge as seen in the figure. In this state take hold of the silken thread at *b*, and then unroll the metallic ribbon *b*. When it is unrolled, the pith-balls will come into or near a contact. Replace the ribbon, and the balls diverge again. When the metallic ribbon is taken off, it carries from the cylinder the whole of the electric charge. The outer layer of the metallic ribbon, when around the cylinder, is charged plus, as compared with the inner layer, but as soon as the ribbon has been taken from its circular position, the electricity immediately distributes itself equally throughout the ribbon's surface. Restore the ribbon around the cylinder, and the plus will be found on the exterior surface.

Fig. 7.

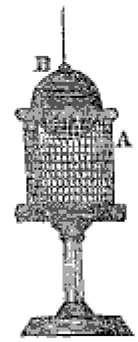


Figure 7 is another illustration of the diffusion of electricity on the outside of vessels. This is a cylinder made of wire-gauze. Let the insulated B be lowered into a wire-gauze cylinder, A, fig. 7, when electrified and mounted on an insulating stand. It may touch every part of the interior without receiving any portion of the electricity, with which the exterior surface is charged, though the slightest touch on the other side of the open wire mesh communicates electricity to the ball.

I am fully sensible of the fact, that this important principle in philosophy has not been clearly demonstrated in the foregoing, but the room allowed in this work renders further explanations impossible, and the reader must refer to the standard works on electricity for fuller information in the premises.

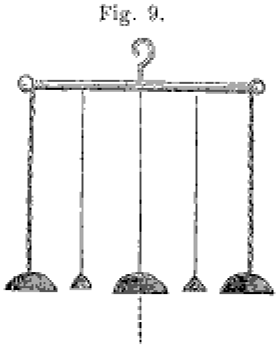
PHENOMENA OF RESISTANCE TO INDUCTION.

Fig. 8.

Figure 8 represents the resistance to induction and discharge offered by any given media, such as atmospheric air, &c. The glass tube, *a b*, two feet long, is furnished at either end with a brass ball projecting into its interior, and carefully exhausted of its air by means of an air-pump; on connecting the end *a*, with the prime conductor, and the end *b*, with the earth, when the machine is turned, *a* becomes positive, and induces the contrary state on the ball *b;* induction taking place with facility, in consequence of the atmospheric pressure being removed—and is followed by a discharge of the two electricities in the form of a beautiful blue flame filling the whole tube, and closely resembling the aurora borealis.

PHENOMENA OF ATTRACTION AND REPULSION.

Fig. 9.



The phenomena of attraction and repulsion are well illustrated by the apparatus known as the electric bells, fig. 9. They are suspended from the prime conductor by means of the hook; the two outer bells are suspended by brass chains, while the central, and the two clappers, hang from silken strings; the middle bell is connected with the earth by a wire or chain; on turning the cylinder, the two outside bells, become positively electrified, and by induction the central one becomes negative, a luminous discharge taking place between them, if the electricity be in too high a state of tension. But if the cylinder be slowly revolved, the little brass clappers will become alternately attracted and repelled by the outermost and inner bells, producing a constant ringing as long as the machine is worked.

Fig. 10.

Another experiment is often given with the toy-head. When attached to the prime conductor of the machine, the hairs stand erect, presenting an exaggerated representation of fright, as seen by fig. 10.

Figure 11 represents an experiment with the dancing toys. A brass plate is suspended from the prime conductor, and under it is placed a sliding stand, on which is laid a little bran or sand, or little figures made of pith: on turning the machine, the bran, or sand, or figure is attracted and repelled by the upper plate with such rapidity, that the motion is almost imperceptible, and appears like a white cloud between the plates, and the little figures appear to be animated, dance, and exhibit very singular motions, dependent on inductive action.

Fig. 11.

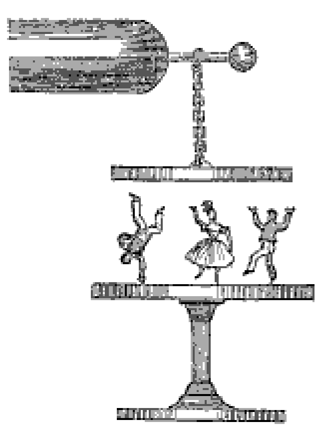
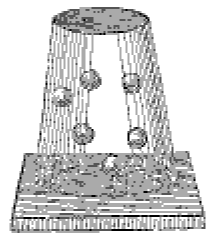


Figure 12, represents an inverted tumbler, wiped thoroughly dry, warmed, and the inside charged by holding it in such a direction that a wire proceeding from the prime conductor of a machine in action, shall touch it nearly in every part; then invert it over a number of pith-balls; they will be attracted and repelled backward and forward, and effect the discharge of the electricity which induces from the interior toward the plate. They will then remain at rest; but, if the electricity which has been disengaged on the outside, toward surrounding objects be removed by a touch of the hand, a fresh portion will be set free on the interior, and the attraction and repulsion of the balls will again take place, and thus for many times successively the action will be renewed until the glass returns to its natural state.

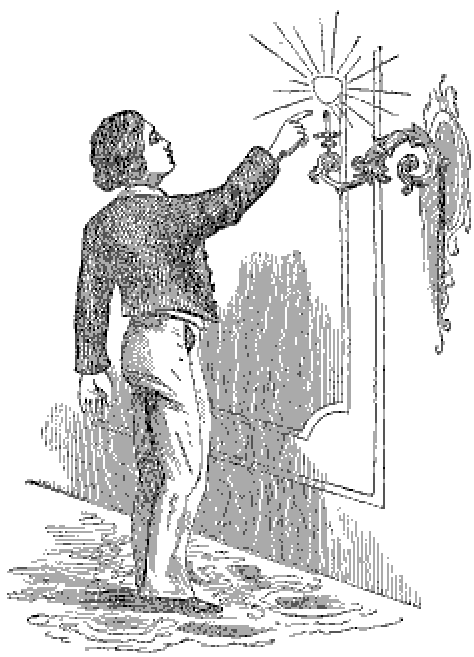
Fig. 12.



IGNITING GAS WITH THE FINGER.

A very interesting experiment is represented by figure 13, showing the lighting of gas with an electric spark from the finger. In my apartments, it has been the mischievous practice of my son, to pass several times around a room, rubbing or sliding his shoes on the carpet, charging his body with electricity, in the same manner as produced by the machine. The body being fully electrified in

Fig. 13.



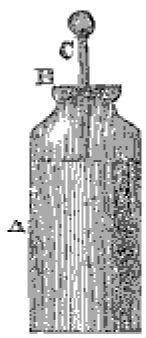
this manner, he would point his finger within a few inches of the nose of some one present; the spark would pass with a noise from the finger to the nose, giving the recipient a sensible shock, unpleasant to the nose, but amusing to others present.

In this manner he frequently lighted the gas. It is a very simple amusement, and any one can, in like manner, at their own homes perform the experiment. The room must be warm, the carpet must have a nap, and the shoes must be perfectly dry.

THE LEYDEN JAR EXPERIMENTS.

The principles of the Leyden jar have become more or less interesting to the telegrapher, particularly with reference to submarine and subterranean lines. The following, from Bakewell, contains a concise description of the principles of this important apparatus. It is called a Leyden jar because it was first constructed by Muschenbroek and his friends, at Leyden, Holland, in the year 1746.

Fig. 14.

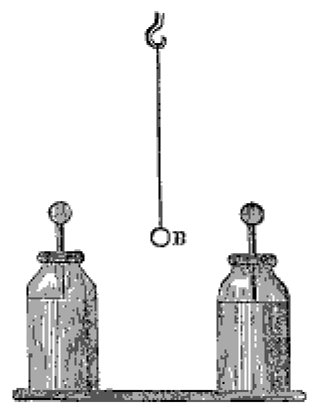


"The power of accumulating electricity by means of the Leyden jar has placed in the hands of electricians a force of almost unlimited extent. In our sketch of the history of electric science, we have already adverted to the nature of the apparatus. As at present constructed, it consists of a thin glass jar A, fig. 14, coated within and without with tin-foil, which reaches to about three inches from the top. A wooden cover, B, serves as a support to a straight thick brass wire, C, that passes through the centre of the cover, and has a metallic connection by a chain or wire with the interior coating. This wire rises a few inches above the cover, and is surmounted by a hollow brass ball, which is screwed on to the top of the wire to prevent the dispersion of the electricity from the end. The sizes of the jars vary from half a pint to ten gallons. One holding about a pint will give a shock as strong as most persons like to receive.

To charge a jar with positive electricity, connect its small brass ball with the prime conductor of the machine, and make a connection between the outside coating and the ground. When fully charged it will give indications of its electrical condition by a muttering sound; and in the dark, rays of light will be seen issuing from the edges of the tin-foil and from the ball. The notion of Muschenbroek, which led to the discovery of the Leyden jar, was to collect electricity within a phial to prevent its dispersion, and thereby to store up an increased quantity of the electric fluid; but it is now ascertained that a jar when highly charged does not contain more electricity than it did before it was applied to the conductor. The effect produced by charging is not to increase the quantity, but only to disturb the natural electricity previously present in a latent state on the inside and outside of the glass. There is injected into the inside, by connection with the electrical machine, an amount of positive electricity, while an equal amount of negative electricity is driven from the outside by the force of electrical induction; and unless the electricity on the outer surface of the glass can be thus driven off by affording it a connection with the ground, the inside cannot receive a charge.

Let a Leyden jar be insulated from the earth by placing it on a glass stand, and it will receive scarcely any electricity from the conductor; not more than equal to the quantity which can escape from the outside to the surrounding air. If the knob of another insulated jar be connected with the ground, and the outside coatings of the two jars be brought near together, sparks will then pass rapidly from the prime conductor to the knob of the first, and they will also pass as rapidly between the outside coatings of the two jars. In this manner both the Leyden jars become charged, and it will be found that they are charged equally, but with electricity of opposite kinds. The first one, that derived its electricity directly from the prime conductor, will be charged positively; the second, that derived its charge from the electricity escaping from the knob to the ground, will be negative. Place the two jars on the table, and suspend between them a pith ball, B, or other light substance, and it will be attracted alternately from one to the other in rapid vibrations, clearly showing that the electricity in the two jars is of opposite kinds.

Fig. 15.

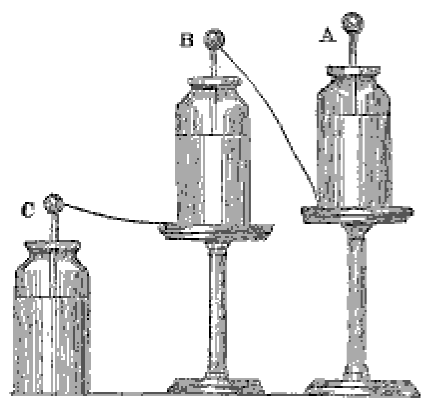


The phenomena that occur during the charge of a Leyden jar have been adduced as evidence in support of the Franklinian theory of a single electric fluid, the outside being supposed to be in a *minus* state after parting with its natural quantity to the other jar. But the phenomena are explicable also on the hypothesis of two fluids, it being assumed that they are separated from their neutral state by the coercing force of the free electricity communicated to the inside of the jar.

Franklin attempted to apply practically the charging of one jar from the escaping electricity of another. He inferred, that, if a series of insulated jars were arranged with the outside coatings and knobs alternately touching, the coating of the last one being connected with the ground, by this arrangement the positive electricity expelled from the outside of the first jar would charge the second; that the electricity from the outside of the second would charge the third positively, and so on to any number; and that an immense electric force might be thus accumulated from the same quantity of electricity that is required to charge a single jar.

Let A B C represent a series of three jars, A and B being mounted on insulating glass stands, fig. 16.

Fig. 16.



On making connection from the prime conductor of an electrical machine to the knob of A, that jar will be charged positively, and an equal amount of electricity will be expelled from the outside into B, which will also be positively charged. The third jar, C, will in like manner be charged from the outside of B, and the electricity which was expelled from A, on arriving at the outside of the last jar of the series, will be conducted to the earth.

To effect the discharge of a jar, it is requisite that a connection be made between the positive electricity within and the negative electricity without, so that the equilibrium may be restored. Now if a metallic connection be made from the knob of B to the knob of A, there will be a discharge of the first jar only; for though the connection is made with the knob of B, none of the positive electricity within can be discharged, for it is restrained by the coercing force of the opposite electricity on the outside If metallic connection be made between the outside of B and the knob of A, both those jars will be discharged, and the third will remain charged; but by bringing a wire from the outside of C to the knob of A, the three jars will be at once discharged.

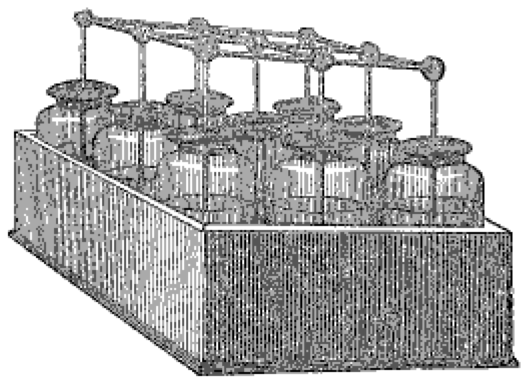
The phenomena exhibited in charging the Leyden jar has been explained; the cause of its accumulating electricity, and discharging the force instantaneously, will be next considered. We have stated that the cause depends on inductive action operating through the substance of the non-conducting glass. Exemplifications of this action through glass have been previously given. A pane of glass when excited by friction on one side has negative electricity induced on the other, and a glass tumbler may be charged with electricity by exposing the inside to the influence of an electrified point, while the outside is grasped by the hand. The electricity thus collected on the surfaces of the pane of glass and the tumbler is sluggish in its action, and is dissipated by slow degrees, on account of the non-conducting property of the glass surfaces; but if metal plates be applied on each side of the pane of glass, the electricity is instantly concentrated at any point, and on connecting the two surfaces with a wire, a discharge takes place, exactly as in the Leyden jar. The charged tumbler might also be converted into a Leyden jar by the application of interior and exterior casings of metal foil, to serve as conductors, to concentrate at any point the electricity distributed over the surface of the glass.

To prove most conclusively that the charge of a Leyden jar is retained on the surface of the glass, and not in the metallic coatings, Leyden jars are made with tin inside and outside casings, so contrived that they may be easily removed. A jar of this kind, when charged and placed on an insulating stand, may have the metal casings removed and others substituted for them; yet after this change the jar will be found to retain its charge. The metal serves only to conduct the electricity simultaneously from all parts of the glass.

A plate of glass affords the most convenient mode of illustrating that the electrical charge is retained by the glass and not by the metal. Let a pane of glass, about one foot square, be covered on one side with tin-foil, and laid horizontally on the table. To the other side apply the insulated metal disk of an electrophorus; connect the disk with the prime conductor, and a few turns of the machine will charge the glass. Remove the disk by the insulating handle, and it will manifest scarcely any trace of electricity. Let the same or another disk be again applied to the surface of the glass, and on making connection between the metals on the opposite sides a strong discharge will take place. A moveable metal disk might be applied to each surface of the glass with similar results; but the arrangement indicated is more convenient.

When a more powerful charge of electricity is required than a single jar will retain, several are combined to form an electrical battery. For convenience, the jars are placed in a box with divisions, the bottom being lined with tin-foil, to make connection with all the exterior coatings. The knobs of the jars are connected together by wires, as represented in fig. 16; and there is a metal hook projecting from the side of the box connected with the tin-foil lining. Thus all the interior

Fig. 17.



and all the outside coatings of the jars are connected; and when communication is made between the prime conductor and any of the knobs of the jars, the whole are simultaneously charged. They are also discharged simultaneously by making connection between the projecting hook and any one of the knobs.

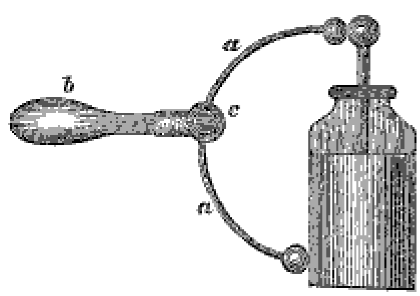
The combination of several small jars is found better than having a smaller number of large ones, because the thickness of the glass necessary in jars of large size obstructs induction through it. By an arrangement of many jars, an amount of electric force may be accumulated that would almost equal the destructive power of lightning. The battery used by Faraday in his experiments consisted of fifteen equal jars, coated eight inches upward from the bottom, and twenty-three inches in circumference; so that each contained one hundred and eighty-four square inches of glass coated on both sides, independently of the bottoms of the jars, which were of thicker glass, and contained each about fifty square inches. The total coated surface of the battery consequently comprised three thousand five hundred square inches of coated surface. The electrical battery at the Polytechnic Institution exposes a coated surface of nearly eighty square feet. To receive the full charge of such a battery would be instant death. A battery of nine quart jars is sufficient to exhibit the deflagrating effects of electricity on a small scale; nor would it be safe to receive a shock from a battery of that size.

It is a fact deserving consideration that the accumulation of quantity diminishes the intensity of electricity. For instance, an electrical machine when in good action will emit sparks four inches long. When a Leyden jar is charged with twelve such sparks, the accumulated electricity will not force its passage through more than a quarter of an inch; and if the same quantity be distributed among the jars of an electrical battery, the discharge will not take place through the eighth of an inch. The quantity of electricity is in each case the same, but the state of intensity diminishes in proportion to the surface over which it is diffused. The difference between quantity and intensity is still more remarkably manifested in the different conditions of frictional and voltaic electricity, as will be subsequently noticed.

One of the peculiar phenomena of the electrical battery is the *residual charge.* When communication is made between the inside and outside coatings of a battery consisting of several jars, the whole of the electricity is not immediately discharged. On again making connection between the inside and outside coatings, after a short interval, a second discharge will occur, which, though comparatively feeble, might occasion a disagreeable shock. The cause of this residual charge is partly attributable to the accumulation of electricity on those parts of the jar just above the metallic coating; which portions, not being in direct contact with the metal, are not conducted with equal rapidity. Part of the charge also enters into the pores of the glass, and is thus removed from immediate contact with the metal.

The simplest kind of instrument employed for discharging a Leyden jar or an electrical battery is a thick curved piece of brass wire, fitted with a small ball at each end. One of these balls is applied to the outside coating, and when the other is brought near to the knob of the jar the electricity instantly passes through the wire with a smart snap or report, connection being thus made between the two charged surfaces of the jar. When, however, a discharger of this kind is employed for an electrical battery a slight shock is felt, owing to what is termed the *lateral discharge;* therefore, to avoid the inconvenience and the danger that might arise from holding the wire in the hand, an insulated wire is generally employed. Its form is represented in fig. 18, as applied in discharging a Leyden jar. Two thick brass wires, *a a*, of equal lengths, and terminated with brass balls, are jointed together at *c* for the convenience of adjustment, and are cemented to a glass handle, *b*, which serves to insulate the wires from the hand, and prevents the liability of any perceptible portion of the charge being received by the operator.

Fig. 18.



There has been much discussion among electricians on the subject of lateral discharges, in reference more particularly to the safety of lightning-conductors; we shall therefore notice in this place the cause of the phenomenon.

It is the case with electricity, even to a greater extent than with all fluid bodies, that it will discharge itself into every channel that is open to it. Thus, as in a mountain torrent some portion of the water will deviate from the straight and broad course into circuitous and narrow crevices, so will the highly tensive electric fluid force its passage through every conducting medium. Thus when a Leyden jar is discharged with an insulated wire, a small part of the charge passes through the circuitous and comparatively obstructive course offered by the body of the operator, by the floor, and by the table whereon the jar is placed. In the case of a single jar, the quantity of electricity that passes in that direction is imperceptibly small; but when several jars are combined, the lateral discharge may become unpleasantly strong, especially if the wire of the discharging-rod be not very thick. Even when an insulated discharging-rod is employed, it may be inferred that some portion of electricity will force its way along the glass; but it is so infinitesimally small as to be inappreciable.

Applying the experience and inferences deducible from experiments with the electrical battery to the more powerful effects of lightning, we are led to consider that every flash of lightning must be accompanied by lateral discharge, and that the quantity thus diverted from the direct and easiest path between the clouds and the earth will depend on the amount of resistance which that direct course offers. Therefore, though lateral discharge must, to some extent always occur, it may be rendered entirely innocuous by a sufficiently thick and unbroken lightning conductor.