ductor of electricity. If a slight charge be given to the electrometer, which may be effected by touching the knob with a rod which has been rubbed by woolen cloth, the charge will remain with but little diminution for several hours, provided the air is perfectly dry; while, if the air is moist, the charge is soon dissipated. These facts show that the former is a non-conductor, and the latter a partial conductor. Dry air would be a perfect insulator of electricity, provided it were motionless; the atoms, however, which impinge against a charged body become electrified with the same kind of excitement, and are, consequently, repelled off, their place being supplied with others, and so on until the charge is gradually diminished and finally dissipated.

If, when the electrometer is charged in dry air, we touch the knob with a glass rod, the leaves will be but little affected; but, if we breathe on the surface of the rod, the glass will become a partial conductor and the leaves will slowly converge. If the ball be touched with one end of a metallic wire, the electricity will instantly be conducted off. If we make a similar experiment with a piece of dry wood, the charge will be gradually dissipated, a fact which indicates that wood is a partial conductor. By increasing the length of an imperfect conductor we shall find that the time of drawing off the charge is increased, and in this way it may be shown that there are very few bodies which are perfect conductors or non-conductors; that every body offers some resistance to the passage of an electrical current, provided we increase the length sufficiently to make it perceptible. By experimenting on various bodies in the way we have described, we may form an approximate table of the degrees in which different substances are conductors or non-conductors of electricity. The human body is a very perfect conductor of ordinary electricity, since if we touch the knob of the electrometer with the finger, the leaves instantly collapse, provided we are standing at the time on the ground. If, however, we place a non-conductor, for example, a cake of beeswax, under the feet, the whole of the charge will probably not be withdrawn but shared with the body, and the leaves will only partially converge. It may also be shown by the same instrument that in order to produce electrical excitement by friction, it is only necessary that two dissimilar substances be rubbed together, one at least of which must be a partial conductor. For example, if, while a person is standing on a cake of beeswax he place one finger on the knob of an electrometer and another person strike him on the back with a silk handkerchief, the leaves will instantly diverge, showing that the whole body has received a charge of electricity, which is prevented from escaping into the floor by the interposed non-conducting beeswax.

After the introduction of furnaces for heating rooms by warm air, the public were surprised at exhibitions of electrical excitement which previously had not been generally observed. If our shoes be very dry, and we move over the surface of a carpet, with a shuffling motion, on a very cold day, particularly in a room heated by a furnace, the friction will charge the body to such a degree that a spark may be drawn from the finger, and under favorable circumstances a jet of gas from a burner may be ignited. There is nothing new or wonderful in this experiment; it is simply an exhibition of the production of electricity by friction, which only requires the carpet, the shoes, and the air to be dry, conditions most perfectly fulfilled on a day in which the moisture of the air has been precipitated by external cold and its dryness increased by its passage through the flues of the furnace. In the ordinary state of the atmosphere, the electricity, which is evolved by friction, is dissipated as rapidly as it is developed, but in very cold weather the non-conducting or insulating power of the air is so much increased that the electricity, which is excited by the almost constant rubbing of bodies on each other, is rendered perceptible. Every person is familiar with the fact, that, on removing clothes, or shaking garments in dry weather, the electricity evolved by the rubbing exhibits itself in sparks and flashes of light. The popular idea in regard to this is, that the atmosphere, at such times, contains more electricity than at others, but these appearances are not due to the variation of the electricity in the atmosphere, but simply to the less amount of vapor which is present. When the clothes are rubbed together one part becomes positive and the other negative, and in dry air the excitement increases to such an intensity that the restoration of the equilibrium takes place by a visible spark, but in the case of moist air the equilibrium is silently restored as soon as it is disturbed, and no excitation is perceptible.

Similar effects are observed on the dry plains of the western part of our continent; in rubbing the horses or mules, sparks of electricity may be drawn from every part of the body of the animal. Persons in delicate health, whose perspiration is feebly exhaled, sometimes exhibit electrical excitement in a degree sufficient to surprise those who are not familiar with the phenomena. But these exhibitions have no connection with animal electricity, and are merely simple illustrations of the electricity developed by friction in an atmosphere too dry to permit the usual immediate and silent restoration of the electrical equilibrium.

DISTRIBUTION OF ELECTRICITY.

The mutual repulsion of the atoms of electricity, varying inversely as the square of the distance, gives rise to the distribution of the fluid in regular geometrical arrangements, the form of which may be calculated with mathematical precision. As one of the simplest cases of distribution, suppose a conductor of the form of a cylinder, with hemispherical ends—for example, one of wood, covered with tin foil—to be suspended horizontally in dry air with silk threads, and, thus insulated, to be slightly electrified by touching the middle of it with a charged body; the atoms of the fluid, by their mutual repulsion, will separate as far as possible from each other, and be found at the two extremities. If the conductor were not surrounded with a non-conducting fluid, like the air, they would be driven off by the same repulsion into space, and thus indefinitely separated.

This inference, from the theory, can readily be proved to be in accordance with the actual condition of the excitement, by bringing into contact with the middle of the length of the conductor a small carrier ball, and afterwards applying it to the knob of the electrometer. If the charge given to the conductor be small, scarcely any electricity will be found at the middle; if, however, the carrier be brought into contact with either end of the conductor, it will receive a charge of such intensity as to cause the leaves to diverge widely from each other. If a charge of electricity be imparted to the center of a conductor in the form of a thin circular disc the fluid will be found, by a similar examination, in the greatest intensity, at the outer rim.

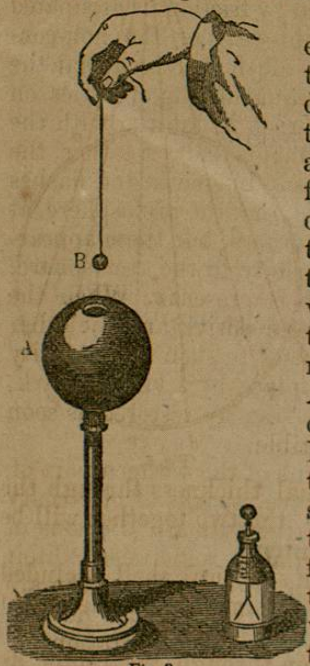

Fig. 3.

If we electrify a solid globe of metal, the excitement will be confined to an indefinitely thin stratum just at the surface of the conductor; for if the electricity be imparted to the center of the globe along a wire through a glass tube, the atoms will evidently separate from each other as far as possible, on account of their mutual repulsion, and would continue to diverge even beyond the surface, were it not they are stopped by the non-conducting air which surrounds and insulates the globe. That this inference is true may be shown by an arrangement which is exhibited in Fig. 3, in which A represents a hollow metallic globe, insulated on a glass pillar and charged with electricity. If the carrier ball B be let down into the interior of the globe, so as to touch the inner surface and then withdrawn without touching the side of the hole it will be found entirely free from electricity. If, however, it be made to touch the outside of the globe it will carry off with it a charge which will cause the leaves of the electrometer C to diverge in proportion to the original quantity imparted to the sphere. A similar effect will be exhibited if the ball be lowered into an insulated cylinder of gauze A, Fig. 4, which has been charged with electricity. Not the least sign of excitement will be found on the inside, while a spark may, perhaps, be drawn from the exterior. The same result is produced, as we shall see, whether the globe be charged negatively or positively.

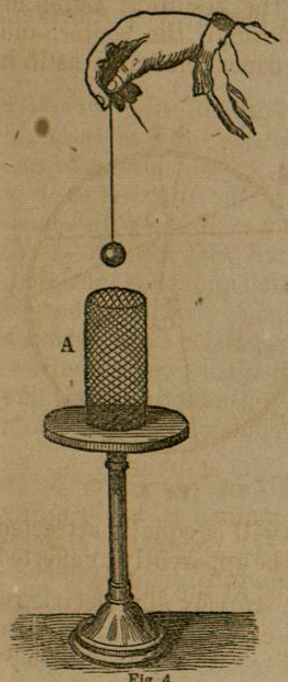

Fig. 4.

Newton has demonstrated the following propositions relative to the action of gravitation, which are equally applicable to electrical attraction and repulsion, or any other action which varies as the square of the distance:

1. A particle of matter placed outside of a hollow sphere of attracting or repelling matter of uniform thickness, is acted upon as if all the matter were at the center of the sphere.

2. A particle of matter (or of free electricity) placed at any point within a hollow sphere of uniform attracting or repelling matter, will be acted upon in every direction by an equal force, and will consequently be at rest.

The form of the demonstration of the first of these propositions may be easily understood by a reference to Figure 5. In this *a* represents a particle of matter or of electricity attracted or repelled by the hollow sphere of which the center is *C*. Let the two lines *a d* and *a e* represent the projection of a pyramid having its apex in *a*, and its base in *d e*, then it will be evident that the attraction of the three sections of the cone, one through the center, another coinciding with the upper part of the spherical shell, and the third with the lower part included within *d e*, will be equal. For, although the lower section is at a greater distance from *a* than the upper, yet its greater size just compensates for the greater distance, the surface increasing, as in the case of light, as the square of the distance, while the attraction and repulsion diminish in the same ratio. For the same reason, each of the two portions of the spherical shell are equal in action to a plate of equal thickness through the center, included within the cone; and hence, the two together will be equal to a plate of double thickness at the center.

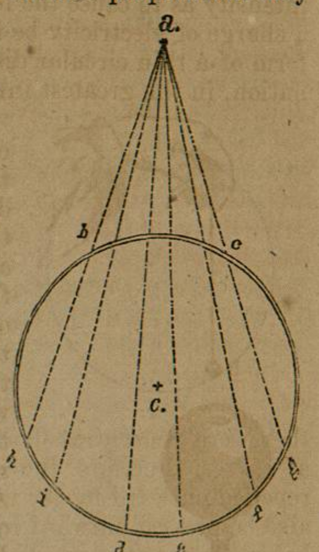

Fig. 5.

If, in the same way, we suppose the whole spherical shell included in a series of pyramids or cones, having as a common apex the point *a*, and consider this series of cones made up of equal pairs, the two members of which are on each side of the line through the center as *a h i*, and *a f g*, then it will be clear that the resultant action of each of these pairs of cones will be in a line through the center, and all the action of the sphere made up of such cones the same as if it were at this point.

That a point at the center of a hollow sphere would be equally acted upon, in all directions, is evident; but that the same should be the case when the point, for example, is at *a*, Fig. 6, is not quite so clear. It may, however, be rendered evident by considering the actions of the opposite bases of the two cones *a b c* and *a d e*, or *a f g* and *a h i*, which, for a reason similar to that given in the preceding proposition, are respectively equal to each other; and as we may consider the whole interior surface of the spherical shell made up of the opposite bases of a series of pairs of similar cones, it is clear that the particle at *a* will be equally attracted or repelled on all sides, or, in other words, will be apparently unaffected by the action of the excitement which may exist at the surface.

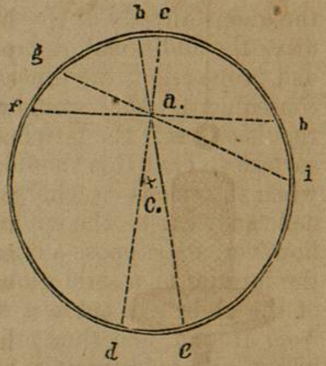

Fig. 6.

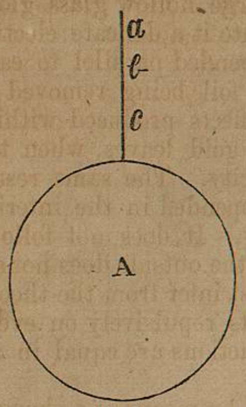

Fig. 7.

From the first of these propositions, it is easy to deduce the effect of a point in discharging the electricity from a globe. For if A, Fig. 7, be the center of a charged sphere, from which the slender-pointed conductor *a b c* projects, then will the action on the point *a* of all the electricity of the sphere be the same as if it were at the center; and if we suppose, for example, that the sphere is charged with positive electricity, then will the atoms of electricity of the point *a* be repelled by all the atoms of the fluid of the globe, as if they were concentrated at A, and also the atoms of the fluid at the point *b*, below *a*, will be repelled by all the atoms of the electricity of the globe, as if they were concentrated at the same point, and so on with the atoms at *c*, &c.; therefore, the atoms at the point *a* will not only be directly repelled outward by the atoms of the fluid in the sphere, but they will also be pressed outward by the repulsion exerted on each of the atoms below, so that the whole force exerted to drive off the fluid from the point *a* will be in some relation to the number of atoms in the perpendicular column below this point; and hence the tendency which must exist in a point projecting from a charged surface to rupture the air and to escape, and for a similar reason, when the globe is charged negatively, to draw in electricity from surrounding bodies.

From the second proposition, we can readily deduce the fact of the distribution of the electricity at the surface; for if we communicate to the interior of a globe, a quantity of electricity just sufficient to arrange itself in a stratum of the thickness of a single particle, it will so arrange itself, on account of the mutual repulsion of the atoms, but if an additional quantity is thrown into the interior, it might not appear evident that this would also come to the surface, since the repulsion of the atoms already at the surface, as it would seem at first sight, would drive the additional atoms back towards the center; but, from the second proposition, the inner atoms are not affected by the outer, and, consequently, they would separate from each other by their mutual repulsion, as if the latter did not exist, and arrange themselves at the surface. That this should take place, is not difficult to understand, when the sphere is charged with redundant electricity; but when a deficiency exists, the explanation has not been thought as easy. If, however, we suppose a quantity of the natural electricity drawn from the interior of a solid globe, then the unsaturated matter in the center of the globe will act as a sphere, and draw into itself the electricity from around, and thus produce a hollow sphere of attracting matter, which will draw again into itself from around the natural electricity, and in this way, it must be evident, the deficiency will finally come to exist at the surface.

These propositions, which, as we shall see, are of great importance in the study of the theory of atmospheric electricity, can be readily

demonstrated experimentally. If we coat a large hollow glass globe with tin foil, and insert through an opening into it a delicate electrometer, consisting of two slips of gold leaf suspended parallel to each other, and a small piece of the covering of tin foil being removed at two points on opposite sides to observe any effects produced within, not the slightest divergence will be seen in the gold leaves, when the globe outside is intensely charged with electricity. The same result will be obtained when a slip of gold leaf is suspended in the interior and electrified, either positively or negatively. It does not follow, from these experiments, that the electricity on the outside does not act on that of the inside. On the contrary, we must infer from the theory that every atom of electricity at the surface acts repulsively on every atom of electricity in the gold leaf; but these actions are equal in all directions, and therefore neutralize each other.

The second proposition may be demonstrated by means of a charged ball and the hollow globe, Fig. 3. If the charged ball, suspended by a silk thread, be placed at about eighteen inches above a gold-leaf electrometer, and the divergence noted, when the ball is removed and its place occupied by the center of the globe to which the electricity of the ball has been imparted, the divergence will be the same as before; or, in other words, the action on the electrometer will be the same when a given quantity of electricity is concentrated on a ball at the center of a sphere, or diffused throughout the surface of the same body. This experiment may be varied, with more striking results, by placing the hollow globe at a given distance from the electrometer, and then letting down into its interior until it reaches the center a charged ball, the leaves will be seen to diverge to a definite degree; if the ball be now made to strike the interior surface of the globe, by moving the suspending thread of silk, the whole of the charge will pass to the surface of the latter, but the leaves will exhibit the same amount of divergence as before the transfer. The electricity which is distributed throughout the surface of the globe produces precisely the same effect as it did when confined to the ball at the center.

The mathematical problem to be solved, for the purpose of calculating the distribution of a given charge of electricity in a body of any form, is to proportion the amount of the fluid in each part of the surface, so that the resultant action on the interior of a body will be completely neutralized. This problem, which is simple for the sphere, becomes too complex, even for the highest powers of mathematics, for bodies of less regular forms than those generated by the revolution of simple curves.

ELECTRICAL INDUCTION.

The attraction and repulsion of electricity, like those of magnetism, act at great distances, and produce phenomena which it is necessary clearly to understand, in order properly to comprehend the explanation of many of the facts connected with atmospheric electricity.

For the exhibition of these phenomena, which are classified under the name of inductive effects, we may make use of the arrangement represented in Fig. 8, in which A is a metallic globe suspended in

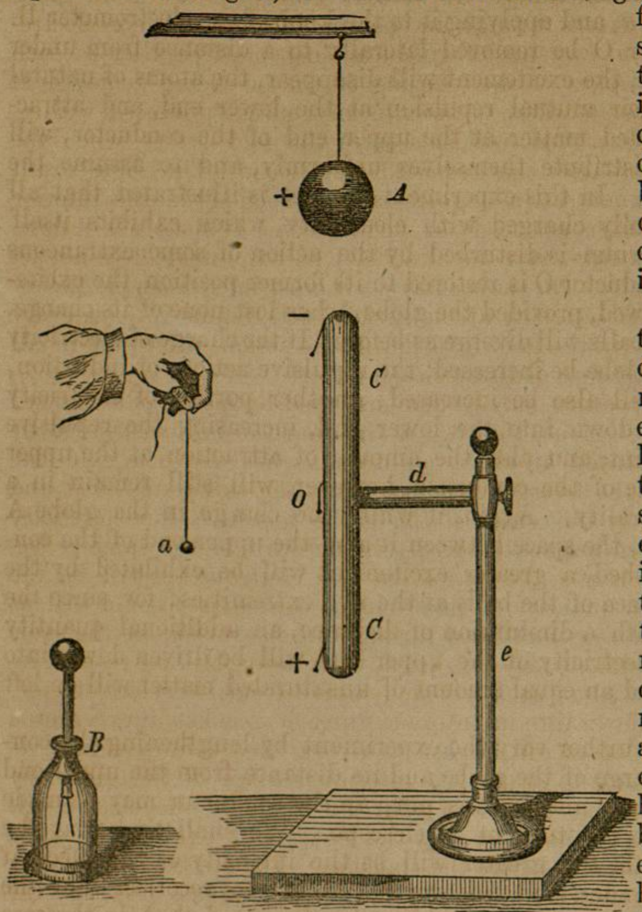

Fig. 8.

free air by a fine silk thread, and is thus insulated. O is a long cylindrical metallic conductor, supported by a rod of shellac or sealing-wax *d*, on a stand *e*, having a glass stem.

Now, each of these metallic bodies contains its natural share of electricity, and, as long as this continues to be the same, no electrical effects are exhibited; for although the natural electricity of A will repel the electricity of O, yet the matter of A will attract it with an equal force, and hence there will be no perceptible effect. Let us, however, suppose that there be imparted to the globe A, a redundant quantity of electricity, then the equilibrium will be disturbed in the conductor O, the repulsion of the redundant fluid will be greater than the attraction of the unsaturated matter, and hence a portion of the natural electricity of O will be driven down to its lower end, and consequently the upper end will become negatively electrified, while the lower is positive. It must be evident, therefore, that, between the two extremes, there will be a point near the middle which will be in its ordinary condition.

These inferences may readily be shown to be true by observing three movable pith balls suspended by linen threads, one near the top, another at the middle, and the third at the lower end. Those at the two extremities will diverge, exhibiting excitement at the two ends, while the one at the middle will remain unmoved, indicating that this point is in a natural condition. To be assured that the upper end is negatively electrified, and the lower positively, it is only necessary to rub a stick of sealing-wax with woolen cloth, and to bring it in succession near the two balls; the upper one will be repelled and the lower one attracted; or we may arrive at the same results by touching in succession the two extremities and the middle of the conductor with the small carrier ball *a*, and applying it to the knob of the electrometer B.

If the conductor O be removed laterally to a distance from under the charged globe, the excitement will disappear, the atoms of natural electricity, by their mutual repulsion at the lower end, and attraction for unsaturated matter at the upper end of the conductor, will cause them to distribute themselves uniformly, and to assume the natural condition. In this experiment the fact is illustrated that all bodies are naturally charged with electricity, which exhibits itself when the equilibrium is disturbed by the action of some extraneous force. If the conductor O is restored to its former position, the excitement will be renewed, provided the globe A has lost none of its charge, and the two pith balls will diverge as before. If the charge of electricity in the insulated globe be increased, the repulsive action, or induction, as it is called, will also be increased; another portion of electricity will be impelled down into the lower end, increasing the repulsive action at that point, and also the amount of attraction at the upper end. The middle of the conductor, however, will still remain in a condition of neutrality. Again, if while the charge in the globe A remains the same, the space between it and the upper end of the conductor is diminished, a greater excitement will be exhibited by the increased divergence of the balls at the two extremities; for, since the force increases with a diminution of distance, an additional quantity of the natural electricity of the upper end will be driven down into the lower end, and an equal amount of unsaturated matter will be left at the upper end.

We may still further vary the experiment by lengthening the conductor O, the charge of the globe and its distance from the upper end remaining the same, and for this purpose the conductor may be made to draw out like the tube of a telescope. We shall find that the greater the length, the greater will be the intensity of the effect at each end. To understand this we have only to recollect that the atoms of electricity constantly repel each other, and that, in the case of a short conductor, but little, comparatively, can be driven from the upper end, because the self-repulsion of the electricity of the lower end and the attraction of the unsaturated matter of the upper end, both conspire to restore the distribution, but when we give a greater length to the conductor for the free electricity of the lower part to expand into, and thereby lessen the intensity of the repulsion and also remove the free electricity further from the center of attraction of the redundant matter, the tendency to restore the normal condition is much lessened, and a new quantity will be repelled into the lower end from the upper, and thus produce at that end a greater intensity of excitement. If we increase indefinitely the length of the conductor, or, what amounts to the same thing, if we connect the lower end of it by means of a metallic wire or other conductor with the earth, or elongate it till it touches the earth, then we shall have the maximum of effect. The neutral point will descend to the earth, while the conductor, throughout its entire length, will be charged negatively.

The effects which we have described are those which would take place if we supposed the electricity in the globe suffered no change in its distribution on account of the induction; but this cannot be the case, since, in the action of one body on another, an equal reaction must be produced, hence the unsaturated matter in O will react on the free electricity in the globe, and draw down into its lower side a portion of that which before existed in the upper side, and thus render the lower side more intensely redundant than before. This additional quantity of free electricity in the lower side, will tend to increase the amount of unsaturated matter in the upper part of the conductor. The maximum effect will be produced, as we have before stated, when the lower end of the conductor is brought in contact with the earth, which may be considered as a conductor of infinite capacity. In this condition the self-repulsion of the atoms of the fluid in the lower part of the globe, and the attraction of the unsaturated matter in the upper end of the conductor, may become so great as to cause a rupture of the intervening air and a transfer of the redundant electricity in the form of a spark from the upper to the lower body.

If, instead of the metallic conductor, we substitute a rod of shellac or glass of the same length and diameter, under the same conditions, no spark, or but a very feeble one, will be produced. The natural electricity cannot be driven down on account of the nonconducting character of the material, and while it remains at the top it repels the free electricity of the globe as much as the matter of the globe attracts it. For a similar reason, if a small brass ball be placed on the top of a rod of glass and presented to the globe, but a feeble spark will be elicited; the inductive influence will act in this case under unfavorable conditions, a portion of the natural electricity, it is true, will be driven down into the lower surface of the ball, and an equal amount of unsaturated matter will exist at the upper surface; but the attractions and repulsions will be so nearly at the same distance that comparatively but a feeble effect will be produced. An attentive consideration of these facts is essential to a knowledge of atmospheric electricity, and necessary to understand and guard against the effects of the destructive discharges from the thunder cloud.

The inductive action we have described takes place, at a distance, through an intervening stratum of air, but the same effect is produced, and with nearly the same intensity, when the intervening space is occupied with glass, or any other nonconducting substance. If a disk of wood, which is a partial conductor, is interposed, the effect will be slightly modified, because an inductive action will take place in the substance of this, which will tend to increase the effect in the conductor O, below.

As an illustration of the inductive influence of free electricity at a distance on the natural electricity of a conductor, we shall direct the attention of the reader to an arrangement exhibited in Figure 9, which is that of an experiment made by the author of this paper in Princeton, in 1845. Two circular disks of wood, *a* and *b*, each of about 4 feet in diameter, were entirely covered with tin foil; one was insulated in connection with a large conductor of an electrical machine, in the upper story of a building, the other was supported on a glass foot in the lowest story, at the distance of about 20 feet below, with two floors and ceilings intervening. The upper disk being charged by

the machine, the lower one was touched with the finger, so as to suffer the induced electricity to escape into the ground. If, when in this condition, the knuckle was held near the lower disk and the upper one suddenly discharged by a spark received on a ball attached to the end of a wire connected with the earth, a spark was seen to pass between the knuckle and the lower disk, a similar effect was produced when the upper plate was suddenly charged by powerful sparks from the machine, though the intensity in this case was somewhat less.

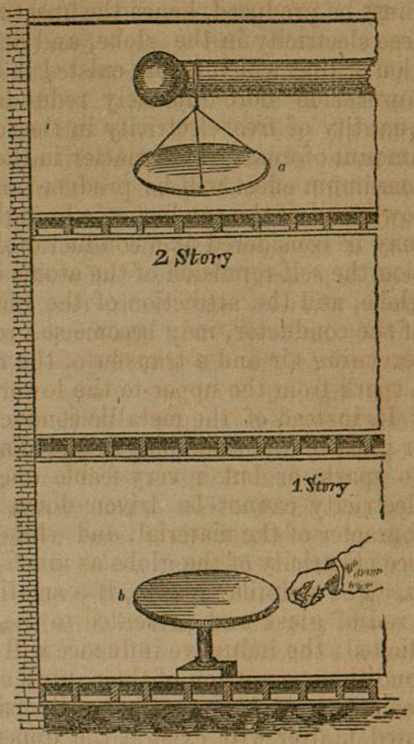

Fig. 9.

In this experiment, the upper disk may represent a charged thunder-cloud, and the lower one the ground, or any conducting body within a house. While the charged cloud is passing over the building, all conducting bodies in it, by this inductive action at a distance, have their natural electrical equilibrium disturbed; the upper part of each body becoming negatively electrified, and the lower part positively; and if the cloud continue in this position for a few minutes, the free electricity of the lower part of the conductor will be gradually driven into the earth, through the imperfect insulation of the floor. If, in this case, the lower part of the cloud is suddenly discharged, sparks of electricity may be perceived, and perhaps shocks experienced, by the inmates of the dwelling, produced by the sudden restoration of the equilibrium, due to the removal of the repulsive force of the cloud on the natural electricity of the bodies below.

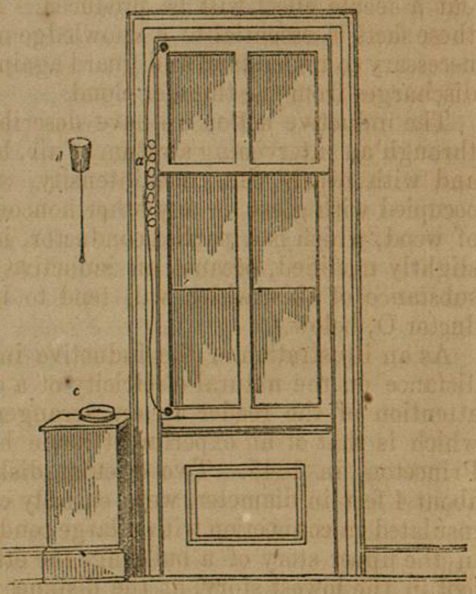
Fig. 10.

The inductive action of the electrical discharge at a distance is still more surprisingly exhibited, by an arrangement shown in Figure 10, which the writer of this article adopted during his electrical investigations at Princeton.

The roof of the house which he occupied in the college campus was covered with tinned iron, and this covering was therefore in the condition of an insulated plate, on account of the imperfect conduction of the wood and brick-work which intervened between it and the ground. To one of the lower edges of this covering was soldered a copper wire, which was continued downwards to the first story and passed through a gimlet-hole in the window-frame into the interior of the author's study, and was then passed out of the lower side of the same window, and thence into a well, in which it terminated in a metallic plate below the surface of the water. Within the study the wire was cut in two, and the two ends thus formed were joined by a spiral of finer wire *a* covered with silk thread. Into the axis of this spiral a large-sized sewing-needle *d* was inserted, the point having been previously attached to a cork, which served as a handle for removing it. With this arrangement, the needle was found to become magnetic whenever a flash of lightning was perceived, though it might be at the distance of several miles. The intensity of magnetism and the direction of the current were ascertained by presenting the end of the needle to a small compass represented by *c*. In several instances the inductive action took place at such a distance that, after seeing the flash, the needle was removed, its magnetic condition observed, and another needle put in its place, before the noise of the thunder reached the ear. In this experiment, the inductive action of the electrical discharge in the heavens was exerted on the natural electricity of a surface of about 1,600 square feet, and a considerable portion of this passed down through the wire into the well. The arrangement served to indicate an action which would otherwise be too feeble to produce sensible effects.

It must be observed that the effect here described was not produced by the actual transfer of any electricity from the cloud, but was simply the result of induction at a distance, and would probably have been nearly the same had the intervening space been filled with glass or any other solid non-conducting substance. We say probably, very nearly the same, because Mr. Faraday has shown that the inductive effect at a distance is modified by a change in the intervening medium.

It is also proper to mention, in this place, although we cannot stop to give the full explanation of the means by which the result was obtained, that the electricity along the wire was not that due to a single discharge into the well, but to a series of oscillations up and down in alternate directions, until the equilibrium was restored.

ELECTRICITY IN MOTION.

The phenomena we have thus far described relate principally to electricity at rest. Those which relate to ordinary or frictional electricity in motion have not been so minutely investigated as the other class, and present much more difficulty in ascertaining the laws to which they are subjected. The discharge of electricity from the clouds, or from an ordinary electrical machine, is so instantaneous that we are principally confined in our investigations to the effects which remain along its path after its transfer.

The electricity, however, which is developed by chemical action in a galvanic battery, is of sufficient quantity to produce a continuous stream, or at least a series of impulses in such rapid succession that they may be considered continuous. By employing electricity of this kind, it has been supposed that we can study the fluid while it is actually in motion, and from the results deduce inferences as to the mode in which some of the effects are produced in the discharge of frictional electricity. The two classes of phenomena, however, though referable to the same cause, are, in many respects, so different in character that considerable caution is required in regard to inferences from analogy. The phenomena of ordinary electricity are characterized by an intensity of action which indicates a repulsive force between the atoms of the hypothetical fluid, which, in some way is, at least, partially neutralized in the case of galvanism.

Ordinary electricity in a state of equilibrium appears to produce but a very feeble effect upon bodies in which it is accumulated. However great may be the quantity present, no perceptible effect is perceived in the pulse when a person is insulated on a glass stool, and charged either positively or negatively, so long as the electricity remains at rest. If, however, it is drawn from him in the form of a spark, then a disagreeable pricking sensation is experienced at the point of rupture. Dr. Faraday constructed a small metallic house or room, which he suspended by silk ropes in mid air, and charged it so strongly that long sparks could be drawn from the outside, yet not the least effect was perceived by the persons within; even when the air of the interior of the house was strongly electrified, the excitement was only perceptible on the outside.

It is fully established by the most satisfactory experiments that, in all cases in which a discharge of electricity takes place by breaking through a stratum of non-conducting substance like air, there is an actual transfer of matter each way between the two ends or sides of the opening in the conductor along the path which the spark traverses. If an opening be made in a rod, and each end terminated by a brass ball, one of which is covered with gold leaf, and the other with silver, a transfer in opposite directions of these two metals will be observed. A similar effect is produced in the discharge of lightning from the clouds, and there are several well authenticated cases on record, in which a picture as it were of one body has been impressed on another between which the electrical discharge took place.

Another effect produced by the discharge which has an important bearing upon the explanation of some of the mechanical results of electricity, is a sudden and violent repulsive energy given to the atoms of air and other substances through which it passes, and which causes them to separate with an explosive violence.

This may be shown by transmitting a discharge from an electrical battery between two brass balls projecting into the inside of a glass bulb, to the lower side of which is joined an air-tight tube containing a small quantity of water, and opening at the end into a cup of water, the arrangement with the exception of the balls being similar to that