ELECTRICAL EXPERIMENTS;

ILLUSTRATING

THE THEORY, PRACTICE, AND APPLICATION OF THE SCIENCE

OF

FREE OR FRICTIONAL ELECTRICITY:

CONTAINING THE

METHODS OF MAKING AND MANAGING ELECTRICAL APPARATUS
OF EVERY DESCRIPTION,

WITH

Numerous Illustrative Engravings.

BY

G. FRANCIS, F.L.S.

AUTHOR OF THE DICTIONARY OF ARTS AND SCIENCES; CHEMICAL EXPERIMENTS; THE DICTIONARY OF PRACTICAL RECEIPTS; THE DICTIONARY OF TRADE COMMERCE, AND NAVIGATION THE ART OF MODELLING WAXEN FRUIT AND FLOWERS; MANUAL OF LEVELLING; LITTLE ENGLISH FLORA; FAVORITES OF THE FLOWER GARDEN; GRAMMAR OF BOTANY ETC. ETC. ETC.

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PREFACE.

A WORK entitled "Electrical Experiments" must necessarily be in some degree copied from former treatises: the more especially as the best experiments and it may be said the best-constructed apparatus, with but few exceptions, are the result of the ingenuity or the reflection of those who studied the subject half a century ago, when electricity was all in all with lecturers as well as with philosophers; and when the discoveries in it rapidly succeeded one another, each more curious, beautiful, or important than its predecessors.

At this earlier period, namely, from about 1740 to the beginning of the present century, philosophers were learning the facts of the science by long series of experiments; lecturers were teaching these facts and giving them popularity by the invention of ingenious apparatus, and showy illustrations, and authors were careful to embody these interesting particulars in their various treatises; hence the works of Priestley, Adams, Cavallo, Ferguson, Hawkesbee, Singer, and others, abound with experimental interest. This time has now past; the experiments proved the facts, the facts suggested the laws of the science, and these becoming known, the learned with few exceptions turned their attention to other matters. If they have condescended to write upon the subject of frictional electricity, they have in all the latter treatises given merely a dry explanation of facts and laws, apparently regarding the detail of experiments as beneath their notice, and forgetting that tyros in science must have their senses gratified as well as their minds enlightened; and equally oblivious of the truth, that a fact illustrated by a pleasing popular experiment often fixes itself upon the memory, which without that experiment, would fail to be remembered, or even regarded.

The Author of this little work impressed, as he has ever been, with the opinion that the more interesting and amusing a science may be made, the more it will be studied, has endeavoured to collect all the good experiments he has met with elsewhere, and has invented many, as further illustrations of certain parts of the subject. He has been accustomed to make all his own apparatus, and to lecture on natural philosophy for many years. The remarks appended therefore to numerous experiments may be considered practical, and the descriptions also of all the apparatus are original, and it is hoped as plain as they could be made. In speaking however of the originality of the descriptions, it is to be remarked, that some portions of the present work were written by the Author for the "Magazine of Science," of which he was the Editor.

This treatise contains more experiments and illustrations than any other work upon the subject, and all the facts that are known with certainty relative to frictional electricity, although some disputed matters, such as the origin of electricity, and whether there be one fluid or two, are very briefly discussed, they being matters of mere conjecture, and in whichever way they may be decided, will make no difference whatever in the practical and popular development of the science, at least according to our present applications of it.

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ELECTRICAL EXPERIMENTS

INTRODUCTION

ELECTRICITY teaches the laws and effects of a peculiar *substance* or influence called the electric fluid, and derives its name from the Greek word *electron,* amber; the first electrical effects having been observed in that substance.

Daily observations on recurrent phenomena, as well as direct experiments, prove that the whole earth and atmosphere, below, upon, and above the surface, is pervaded by this highly-elastic and subtle fluid, sometimes in a disturbed state, producing then the most stupendous phenomena; at other times in a latent condition, and although then imperceptible, yet not on that account less abundant. If it be not the very essence of life and existence, it acts a very important part in the animal and vegetable economy. Over chemical and meteorological change its power is no less extraordinary. It is easily proved identical with the vivid and withering lightning, the streaming aurora, the rapid whirlwind, the terrific waterspout, the rolling pillars of sand of the desert, and in all probability produces the falling meteor, and the devastating earthquake.

These are some of the more obvious effects of the electric fluid when in that *free* condition in which it is produced by mechanical means; without considering the modifications of it which accompany chemical action, called *galvanic;* or it might be described not merely as regulating solitary phenomena, but as occasioning all the multitudinous effects of chemical composition and decomposition; of crystallization; perhaps of light, heat and combustion; and as analogous to magnetism and gravitation. Although the earth and atmosphere are alone subject to our experimental researches, yet there is just reason to conclude that it abounds throughout the universe as the elemental fire which fills all space, and that it is the mighty power that is employed by the Great Creator, to move, restrain, and regulate the millions of worlds with which it has pleased him to fill the vast and brilliant firmament.

Besides the value of electricity in teaching us the laws and effects of the fluid we have been describing, in thus explaining so many of the grandeı phenomena of nature, and directing us to guard our persons and property in some degree against their destructive effects—the science has other claims to our notice. Its application has been found efficacious in curing some of the most lingering and painful diseases; the general laws to be remembered are few; all the apparatus necessary may be made either by ourselves or by ordinary workmen at little expense; the experiments require for their success only common care and attention, and yet are so brilliant, so varied, and so surprising, as to be a never-failing source of wonder and delight.

It is surprising that a fluid thus universally distributed, and which is capable of such extensive application, should have remained almost unknown until very modern times. Although Theophrastus, who lived more than 2400 years ago, writes that amber, and another body which he called *Lyncurium*, when rubbed, were capable of attracting towards them light substances, yet this solitary experiment, not explained till so many centuries afterwards, was the whole knowledge the ancients had of electricity; and it was not till the latter part of the sixteenth century, when Dr. Gilbert, by discovering that other bodies had similar properties, drew in some degree the attention of philosophers to the subject. Still there was so little to engage public attention, that seventy years elapsed before the electric light was seen. This was discovered by Mr. Boyle, and was enough to stamp with the dignity of a science, what had before been considered as but trivial and unimportant experiments. Attempts were now made to construct a machine by which the fluid should be accumulated in greater abundance. In this Otto Guericke, the celebrated inventor of the air pump was successful, and still more so Mr. Hawkesbee, whose treatise, published in 1709, was the first upon the subject, and the discoveries he made with this improved machine, which was the first one made of glass, far exceeded those of his predecessors. The science was from this stationary for thirty years, when a Mr. Gray directed his attention to it, and arranged bodies into two classes; the first *electrics*, or those which like amber were capable of being excited, and *conductors*, or those which not capable of excitation themselves, that is, thought at that time not to be so, yet allowed the fluid to pass along them. Not long subsequent to this, M. du Fay, discovered the difference between what were then called *vitreous* and *resinous* electricity. He taught that the phenomena of attraction and repulsion were occasioned by two fluids distinct from and mutually opposed to each other. From this time electricity became more studied, though not popular till the discovery of the Leyden phial in 1746, when it spread rapidly over Europe, engaging equally the attention of all classes of people. Dr. Franklin explained the mode of action of the phial, and published his celebrated theory of there being but one fluid, the diminution or redundancy of which he supposed to be the cause of all electrical action. Soon the identity of the fluid with lightning was boldly asserted and proved both by Dr. Franklin and L'abbé Nollet at about the same period, the former venturing to bring down lightning from the clouds, and to perform with it all the experiments then known, thus boldly setting the question at rest for ever. Lightning being thus satisfactorily accounted for, the transition to other meteoric phenomena was easy, and in a very brief period the powerful agency of electricity in modifying the surface of the earth, and the atmosphere around it, was firmly established. *Mechanical electricity, free electricity, the electricity of friction, the electricity of tension,* for by all these names this particular part of the subject is called, could go no further; but the wonderful discoveries made during the present century of the intimate connexion between this science, galvanism and magnetism, not only confirm our previous views, but induce us to attribute the facts of all these different departments, as arising from one common cause, and producing effects only so far varied as might be expected from altered circumstances, and the different materials subjected to experiment. The history of this connexion or identity will lead us almost too far from our immediate object; we shall only observe that at the present time so much do these subjects engage the attention of the scientific world, and so numerous and unexpected are the discoveries made in them, that each year opens a still wider field for electrical research, and the laws which regulate the material world.

CHAP. I.

ELECTRICAL ACTION, EXCITATION, AND DIFFERENT STATES OF THE ELECTRIC FLUID.

THE electric fluid, though existing in every object around us, is, while in its natural state of rest, not perceptible to our senses; but as soon as by any cause it is disturbed, that which was before latent becomes free, and we are immediately sensible of its presence. If violently agitated, the fluid itself becomes apparent; if less moved, we are only conscious of the disturbance by the effects it produces in attracting towards it the light substances around, and repelling them when by contact the fluid in those bodies also is disturbed. The laws of this *attraction* and *repulsion* must form the subject of a future consideration; at present it will be more convenient to consider the nature of electrical action, and call attention to a few of those common experiments, which show the universality of the electric fluid, and the numerous yet simple operations by which bodies may be artificially *excited*, or thrown into a state of electrical action. However diversified experiments on excitation may be, yet *friction* will be found to attend the whole of them, and the more attentively the various phenomena are noted, the better founded must be the conviction that this alone causes electrical disturbance. The effect will be in a great measure accordant with the degree of friction employed, and with the dissimilarity of the bodies acted upon; and although it will be seen from some of the illustrations, that evaporation and change of temperature of certain substances causes them to appear electrical, yet each of these operations is attended by a motion of the particles among themselves and against the containing vessel; thus here, as in more obvious instances, friction is produced, though by natural means, rather than by that mechanical rubbing which we are accustomed to employ. The conclusion to which we must come, that friction is the ultimate cause of excitation, is impressed the more strongly upon us by the circumstance that all those bodies which become electrical by heating, cooling, crystallization, or other change of form or temperature, are still more easily and more powerfully excited by the rubbing which effects other bodies.

In performing electrical experiments of any kind it must always be borne in mind that the earth is the grand reservoir of the electric fluid; from the earth it must at all times be taken, and to be retained even for a single moment it must be prevented returning to the earth again; this is easily accomplished by the application of the different properties of *electrics* and *conductors*. The first of these classes of bodies may be excited readily, but will not suffer the fluid to pass along them; the conductors on the contrary are excited with difficulty, but suffer the fluid to escape over their surfaces with great rapidity of motion. Be it observed also, that the electric fluid takes every opportunity to return to a state of rest and quietude, and to keep it disturbed, the body in which it is excited must be *insulated*, or supported by electrics, and no conducting substance brought within its sphere of attraction. In some of the following experiments, indeed in most of them, we witness an electrical action only in one of the bodies subjected to friction, while the rubber or other body is not considered. This however is equally acted upon, and if we take proper means for detecting the electricity of both the rubber and substance rubbed, we shall find that the action is the same in amount in both, but the nature of the action is contrary in the rubber to what it is in the substance rubbed—one exhibiting what is called a redundancy, and which is therefore said to be electrified *plus* or *positively;* the other having a proportionate deficiency, or is said to be electrified *minus* or *negatively.* These two degrees or contrarieties of effect neutralize each other, and thus when two bodies are rubbed together while they remain in contact with each other, no action is apparent; but when that contact is separated, visible effects take place. These preliminary remarks will render plainer the annexed experiments.

Ex. 1. *Attraction of amber.*—Take a piece of yellow amber, warm it, rub it briskly on the coat sleeve, and hold it towards some scraps of bran, filaments of feathers, or other light bodies lying upon a book or a smooth table. The amber being excited by the friction will attract the particles of bran, &c., and hold them suspended. This is the first electrical experiment recorded. The workers in amber are so annoyed by its strong attractive, and easily excitable nature, as to have the tips of their fingers often very greatly affected by it.

2. *Attraction of sealing wax.*—A similar effect takes place when a stick of sealing wax is rubbed and presented to any light matters; they will as before rise up and cling to it. If either the sealing wax or the amber be held towards the bran, &c., before it is rubbed, it will have no effect upon them.

Any thing dry and covered with sealing wax answers the same purpose as sealing wax. The best thing to use is the glass tube mentioned in *Ex.* 9, one half of it in length being heated, and red sealing wax then rubbed on it; this will adhere and form a resinous tube.

3. *Attraction of rubbed paper.*—Take two pieces of white paper, warm them at the fire, place them upon each other on a table or book, and rub strongly the upper paper with a piece of India rubber; the papers will now be found strongly electrical, so as to adhere together with such force that it requires some trouble to separate them, and when separated and then made to approach each other again, they will immediately rush together a second time.

4. *Adhesion of brown paper to a wall.*—Take a piece of common brown paper about the size of an octavo book, hold it before the fire till quite dry and hot, draw it briskly between the side of the coat and the sleeve several times, so as to rub it on both sides at once by the woollen. The paper will now be found so powerfully electrical, that if placed against a wainscot, or the papered wall of a room, it will remain there for some minutes without falling.

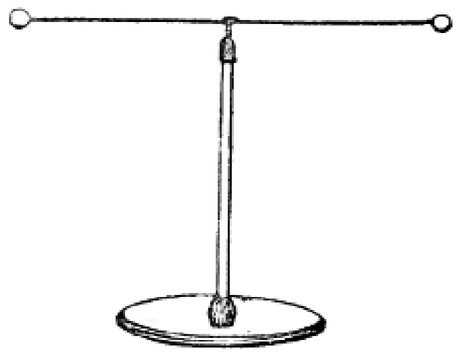
5. *Adhesion of a feather to excited paper.*—If while the paper remain fixed to the wall a light fleecy feather be placed against it, it will adhere to the paper in the same way as the paper adheres to the wall.

6. *Glass plate excited.*—Support a pane of glass, (first warmed) upon two books, one at each end—place some bran underneath it, and rub the upper side with a warm black silk handkerchief or a piece of flannel—the bran will now fly and dance up and down with much rapidity.

This experiment is the only contribution that Sir I. Newton made to electricity, but it was important, inasmuch as it proved what was unknown before, that glass showed electrical effects on the side contrary to that which was excited. The account was read to the Royal Society in 1675. It is very interesting. "Having laid upon the table a round piece of glass, about 2 inches broad, in a brass ring, so that the glass might be $\frac{1}{8}$ of an inch from the table, and then rubbing the glass briskly with the corner of his silk cloak, little fragments of paper laid on the table under the glass began to be attracted, and move nimbly to and fro; after he had done rubbing the glass the papers would continue a considerable time in various motions; sometimes leaping up to the glass, and resting there awhile; then leaping down and resting there; then leaping up and down again; and this sometimes in lines seemingly perpendicular to the table; sometimes in oblique ones; sometimes also leaping up in one arch, and leaping down in another, divers times together, without sensibly resting between; sometimes skipping in a bow from one part of the glass to another, without touching the table; and sometimes hanging by a corner, and turning often about very nimbly as if they had been carried about in the midst of a whirlwind, and being otherwise variously moved, every paper with a different motion. Upon his sliding his finger on the upper side of the glass, though neither the glass nor the inclosed air below were moved, yet he observed that the papers, as they hung under the glass, would receive some new motion, inclining this way or that, according as he moved his finger." This is done much better by a glass, 6 or 8 inches over, at the distance of an inch from the table.

7. *Coffee excited.*—In grinding coffee, particularly if it be fresh burnt, it will be seen to cling around the lower part of the mill, and also around the cup or basin held to catch it—sometimes so strongly as to cover the sides 2 inches or more above the general surface.

These experiments are all examples of electrical attraction, and some of them may be made much more conspicuous to a public audience, if the light matters to be attracted are suspended in some manner, as for example in the following instrument, which is



called a *balance* electroscope. Fix a glass rod, a common phial, a stick of sealing wax, or a slip of window glass upright upon a foot or board, cement a needle point upwards upon the top of this; and upon the needle point suspend an equally-balanced slip of very dry wood cut as thin as possible, made perfectly smooth, and about 8 inches long. At each end of the wire fix a scrap of paper, or a small ball made of cork, or the pith of elder.

To make one of these electroscopes or electrical indicators, in the best manner, the foot and supporter should be of brass, and the balance of a fine glass thread; the balls being of pith, and covered with gold leaf.

Ex. 8. *Attraction of electroscopes.*—Hold the excited sealing wax, amber, paper, ribbon or glass of these experiments towards one of the balls of the balance electroscope, the suspended filament of wood will turn round on the pivot, so that the ball will follow the excited matter held to it.

A more delicate, and perhaps more convenient electroscope is made as follows:—The foot is of wood, the upright is a stout wire, bent towards the top as shown in the figure. Upon the hook of this are suspended two pieces of sewing silk, about 6 inches long each, and which have either small disks of white paper, two pith balls, or two feathers tied at the ends. This is called the *pendulum* electroscope. For the

above experiments one thread and feather is sufficient.

9. *Glass tube excited.*—This is shown much more conspicuously by using, instead of the sealing wax, a glass tube about 2 feet long, and an inch in diameter; make this perfectly dry and warm at the fire, then rub it briskly with an old black silk handkerchief, made warm. The glass will be powerfully excited, and of course attract with great force the suspended feather.

10. Desaguliers gives the following curious experiments. He says, that when an excited tube has repelled a feather, it will attract it again, after being suddenly dipped into water, in fair weather it will not attract it, unless it hath been dipped pretty deep into the water, a foot of its length in at least; whereas in moist weather an inch or two will suffice. —*Philos. Trans. Abr.*, vol. 8, p. 429.

11. The attraction of water by an excited tube is shown by bringing the tube to a stream issuing from a condensing fountain, which thereupon is evidently attracted to it. —*Desaguliers.*

12. *Recession of charged objects.*—Hold the glass tube in contact with the suspended feather for a short time, the feather which at first was attracted will soon become what is called *charged*, that is filled with electrical fluid. It will in this state become fleecy, the filaments will diverge from each other, and the feather *fly away* from the glass tube, and most likely adhere to the wire support of the electroscope. Sometimes if the tube be powerfully excited, the feather will fly backwards and forwards, giving a good example of electrical attraction and repulsion.

Note.—It is here to be observed, that we use the terms repelled, charged, filled with electrical fluid, &c. in their popular sense only, so also until we can consider more fully the nature, effects and laws of electricity, cannot enter into a discussion, whether there be in reality no repulsion at all, or if there be one electric fluid or two.

13. *Repulsion of electrified feathers.*—Let there be two feathers suspended upon the electroscope by different silk threads, they will both adhere at first to the glass, and then recede from it, and also from each other. If there be three or more feathers, the same effect will be exhibited.

14. *Feather driven about the room.*—If, while still excited, a light fleecy feather be brought near, it will at first cling to the glass rod, and afterwards fly away from it, and may be driven about a room, by holding the glass between it and any surrounding object. If it should touch any thing not electrified, it will fly back to the glass again. It will be observed, that the same side of the feather is always presented to the excited tube.

15. *Electrified hair.*—Another instance of electric repulsion is seen when a bunch of long hair is combed before a fire, "each particular hair will stand on end," and get as far as possible from its neighbour.

The above experiments show the electric disturbance of various bodies, so as to inform us that some power exists which is called into action by friction, assisted by perfect dryness of the materials employed, but they do not communicate any intelligence of what this power really is; yet a very trifling increase of the intensity of any of the foregoing will render the fluid itself perceptible to our corporeal senses, sight, hearing, feeling, smelling, and as we shall show hereafter taste also, though we believe this cannot be made perceptible by the simple means we are now employing.

The ancients were quite unacquainted with any other electric effect of amber, but that recorded in the first experiment. Dr. Hall discovered many other electric properties of it, as recorded in *Philo. Trans. Abr.*, Vol. 2, He says—

16. "I found by gently rubbing a well polished piece of amber with my hand in the dark, that it produced a light; whereupon I got a pretty large piece of amber, which I caused to be made long and taper, and drawing it gently through my hand it afforded a considerable light. I then used many kinds of soft animal substances, and found that none did so well as wool. And now new phenomena presented themselves, for upon drawing the piece of amber through the woollen cloth, and squeezing it pretty hard with my hand, a prodigious number of little cracklings were heard, and every one of these produced a little flash of light; but when the amber was drawn gently and lightly through the cloth, it only produced a light, but no cracklings; but by holding one's finger at a little distance

from the amber, a large crackling is produced with a great flash of light, and what to me is very surprising is, that upon its eruption it strikes the finger very sensibly, wheresoever applied, with a push or puff like wind. The crackling is full as loud as charcoal on fire, and five or six cracklings or more, according to the quickness of placing the finger, have been produced from one single friction, light always succeeding each of them. Now I make no question, but upon using a longer and larger piece of amber, both the cracklings and light would be much greater, because I never yet found any crackling from the head of my cane, though it is a pretty large one. This light and crackling seem in some degree to resemble thunder and lightning." Dr. Hall also states that light can be produced from jet, sealing wax and the diamond.

17. Break a large lump of loaf sugar in the dark, or pound it in a mortar, when it will appear covered with a beautiful lambent blue flame. When grocers are sawing up loaves of sugar as samples, the dust is most luminous and beautiful.

18. *The electric light and snapping obtained from paper.*—Excite a piece of brown paper, after having made it quite hot before the fire, as in *Ex.* 4; make it adhere to the wall in a dark room, and immediately tear it from the wall, a light attended by a faint snapping noise will arise. This is the electric spark.

19. The same is very perceptible, if the two pieces of white paper, excited as in *Ex.*3, are taken and torn asunder in the dark.

20. *Electric light and odour obtained from quartz.*—Rub or grate together two round uncut stones of quartz, calcedony, cornelian, &c., and a strong phosphoric light and odour will be produced, showing another peculiarity: viz., that the electric fluid is perceptible to our sense of smelling.

21. *The spark felt.*—Support a round plate of metal upon the top of a very dry wine glass. Excite the brown paper as in *Ex.* 4, and place it on the metal plate; if now you hold your knuckle quickly to the metal plate, a small but very perceptible spark will pass from the metal to the hand, showing the fluid is perceptible to the touch, and also that it will pass from one body to another, for it is the fluid from the excited paper, which passing through the metal is felt by the hand.

22. *Sensation of cobwebs.*—Hold the excited glass tube close to the face, a sensation like that of cobwebs spread over the face will be immediately apparent, and the hair will be sensibly moved at the near approach of the tube.

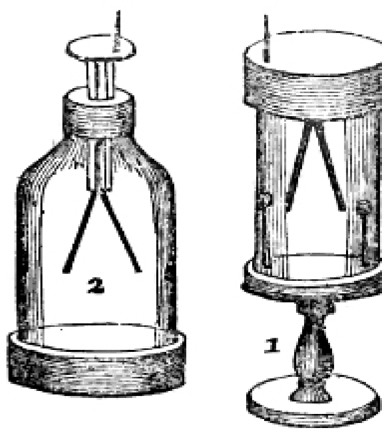
23. *Shock from a cat.*—Take up in the lap a black cat which has been lying for some time before the fire; hold it by one hand under the throat, and with the other hand rub the cat several times along the back. The hair will soon become so excited, and overcharged with the electric fluid, that a complete shock may sometimes be felt, and generally a succession of small sparks. We need scarcely observe, that Miss Pussey must be a consenting party. This experiment, as indeed do all of an electrical nature, succeeds best in frosty weather.

24. *Metallic ball electrified.*—Suspend from the ceiling a metallic ball by a silk cord, and touch it with the excited glass tube. This ball will now attract the feathers or the balls of the common electroscope in the same manner as the glass rod itself does. This shows that electricity is communicated from one body to another, as it is very evident that the metallic ball became electrical by contact with the tube.

The above experiments, and which show the various effects of the electrical fluid, are made with somewhat brisk and continued friction, and therefore produce effects of sufficient plainness and strength to be perceptible to us without any instrument of superior delicacy. It will naturally be concluded, that a less degree of friction will still produce similar effects, although they will be proportionably less in amount. Indeed we shall soon have occasion to show that the most trivial actions we do, and the most casual operations of nature, require only favorable circumstances to make their electrical character apparent. Among these circumstances, the most important is, that we should perform the experiments with care, and the second, that the instruments we use to detect the disturbance of the fluid should be of extreme delicacy. These instruments are called *electroscopes* and *electrometers*. The first indicates an apparatus which shows that a disturbance has taken place in the fluid of an excited body, as is the case with the *pendulum* and *balance* electroscopes we have described, and the other, (the electrometer) is capable of measuring the exact amount of this disturbance. It is necessary to describe one of each of these, that we may see the effects produced by other, and less obvious, or at least less powerful modes of excitation.

THE GOLD LEAF ELECTROSCOPE.

The gold leaf electrometer is made of two forms, as shown in the following cut. In that marked 1, and which is called from its inventor, *Bennett's gold leaf electroscope* consists of a wooden foot, which supports a glass tube about $2\frac{1}{2}$ inches wide, and 5 long. This has two slips of tin foil pasted on the opposite sides as represented. The cylinder is closed at top by a brass cap, which fits tight round the sides, but takes off and on, in order that if the two slips of gold leaf which hang from the middle of the cap in the inside should become broken, they may be repaired. The cap should not in any other case be removed. The gold leaves are about 3½ inches long, and ½ an inch wide; they are best fastened on by a little piece of flatted brass, soldered to the inner side of the cap, and the leaves, attached by gum water, gold size, paste, or any thing similar. They should hang so as to touch each other when not in an electrified state, and when divergent, as shown in the cut, they should approach to the slips of tin foil on the glass. The cap has occasionally a point which screws upon it, as shown; this however is never used, except in trying experiments upon the electricity of the atmosphere.



Sausseur's gold leaf electroscope, which is represented in fig. 2 of the above cut, differs from the former in the manner in which the gold leaves are insulated. The cap is a flat plate, with a wire soldered beneath. The gold leaves are soldered at the lower end of the wire, and the whole wire is inclosed in a glass tube. The outer surface of this tube is best covered with sealing wax, as the insulation of resinous substances is much better in damp weather than that of glass, which rapidly attracts the moisture of the breath, or of the apartment. The diameter of the glass may be 4 inches, the height of it 8 inches. The size of the plate at top from 2 to 4 inches, as most convenient. The cap which incloses the top of the glass, and into which the glass tube is cemented, may be of wood or metal; the former is preferable.

A cheap and good substitute for the above may be made of a common six-ounce phial, a wire passing through the cork of it, having the gold leaves within the phial, and a brass ball or a bullet above. A lamp glass, also, with a cork above and below, (ball and gold leaves similarly arranged,) answers every purpose, the bit of card also is of little consequence; and let it be remarked, once for all, that whenever glass apparatus is employed, it must be kept perfectly dry, slightly warm, and free from dust. Of so much consequence is this, that should there have been a failure in any of the simple experiments, it most probably has arisen from neglect of this precaution. There are numerous variations of this instrument, according to the purposes for which they are required. One of extreme delicacy, though not so much so as that with gold leaves, is made with two fine strips of straw, suspended on little wire loops. Another is furnished with two extremely delicate silver wires, with small pith balls attached: this is used chiefly for experiments upon the electrical state of the atmosphere. This with numerous other electroscopes wil be described hereafter.

Note.—We would remind the young electrician that the *whole* of his apparatus may be made by himself with ordinary care, and that he may do so with greater facility, we will fully describe the various parts of each instrument. Let him at all times remember to round off all sharp edges and corners, and to make the wood work smooth. Every thing in glass, except plates, whether cylinders, tubes, rods or handles, he may purchase at per lb., at the glass works, Holland Street, Blackfriars. Tinfoil may be cheapest bought at a pewterer's. A maker of it lives in Brown's Lane, Spitalfields, London. A roll 5 feet long, and 10 inches wide, costs 5*d*, or a smaller roll 3½*d*. Tinfoil for electrical purposes may be as thin as possible; it is best put on to wood or glass with common paste. When silk is used, let it be always black, except when otherwise specified. The best varnish for electrical apparatus is copal varnish or shell lac varnish; and if they are required to be ornamented with a colored varnish, let it be by two or three coats of sealing wax dissolved in spirits of wine, laid on with a small brush. Both the shell lac varnish and the sealing wax varnish are easily made by breaking the lac or the wax in small pieces, putting it in a phial with spirits of wine, brandy or whiskey, enough to cover it, and then placing the phial on the hob till the resinous substance is dissolved. These varnishes dry in a few minutes, but copal varnish takes two days. The mode of action and degree of susceptibility of these electrometers are shown by the following series of experiments:—

25. Take the paper which was before experimented with, and after again exciting it well, lay it upon a plate of tin, supported by a dry wine glass. Immediately and suddenly apply the knuckle to the under surface of the tin, and a spark will be felt. A better substance than tin would be a round piece of

wood 6 or 8 inches in diameter, ½ an inch thick, rounded at the edges, and covered neatly with tin foil, as by this means sharp edges are avoided.

26. Suspend a pair of pith balls to the under surface of the plate of tin or wood; place the excited paper upon it as before, and observe that the pith balls will recede from each other, or show electrical repulsion. This then explains the mode of action of the electroscope, and the appearance it presents. In this experiment the disturbed fluid of the paper acts upon the fluid of the metal plate, and that upon the fluid in the pith balls. In gold leaf electroscopes the fluid is in like manner disturbed, and of course according to its amount or degree of disturbance so will be the greater or less divergence of the gold leaves.

27. Hold near the above instrument any of the excited bodies used before—such as the paper, or the glass rod, and the gold leaves will diverge to a considerable distance from each other, and remain so for some time. A well-excited glass tube will stimulate it at a distance of 2 or 3 feet, and must not be brought too rapidly close to it, or the gold leaves will be rent to atoms by the violence of the action.

28. Brush the cap of the electroscope with the feathery part of a quill, and the gold leaves will instantly diverge.

29. Give the cap a blow or two with the corner of a black silk handkerchief, previously warmed, and the friction, small as it is, will be found to have the same effect as before.

30. Take a knife, with a glass or ivory handle, and cut some small pieces off a slip of deal, so that they shall fall upon the cap as before. Each piece carrying down with it a portion of the fluid disturbed, will, in a similar manner, affect the instrument.

31. After playing a tune upon a violin with a well-rosined bow, hold the bow towards the cap of the electroscope, the gold leaves will immediately diverge.

32. Sift some steel, brass, or other metallic filings, upon the cap of the electroscope, from out of a metallic sieve. These filings become electrical by the friction merely of passing through the holes of the sieve, and will consequently affect the gold leaves. The same may be done with charcoal, putty powder, black-lead, lime, and numerous other bodies.

33. Let the metallic sieve out of which they are sifted be held by a sealing wax or dry glass handle. Sift some metallic powder through it, but at a distance from the electroscope; then hold the sieve to the electroscope, that will be found to be excited; and if the means be taken which are explained in the after-part of this chapter to ascertain the nature of the excitement, it will be found that the sieve is in a contrary state to that of the powder.

34. *Bombazine excited by rending.*—Warm a piece of this stuff at the fire, or any other kind of material formed of two substances, such as woollen and silk, silk and cotton, silk and hair, &c.; when warm and dry, draw out the various threads, of one of the substances, and put them on the cap of the electroscope; it will immediately become affected. The weavers of bombazine are well aware of these electrical properties.

35. Melt some chocolate in an iron cup, adding a few drops of olive oil; place the cup upon the top of the electroscope to cool, as it cools, it will become electric, and show this by the divergence of the gold leaves.

36. Clean a piece of dry glass with whiting, and let the particles fall upon the top of the electroscope, they will sensibly affect it. Dust brushed off a coat will generally affect it in like manner.

37. Break a stick of sealing wax in half, and hold one of the broken ends towards the cap, and the gold leaves will diverge.

38. Varnish a piece of glass; when the varnish is dry, scrape some of it off, letting it fall upon the electroscope; this also will show a sensible effect.

The student will perhaps desire to vary these experiments, and being observant will soon ascertain that there are apparent anomalies in the mode of action, or in the effect produced, for which he will, until such are explained, be unable to account for.

39. For example, let him hold the glass tube to the gold leaf electroscope, so as to make the leaves diverge, but so as not to touch it; he will observe that immediately he removes the exciting cause, the effect will cease; as the glass is withdrawn, the leaves will collapse. Now let him touch the cap with the excited glass, and then withdraw it. The gold leaves will now continue to diverge, and not collapse as before.

40. While they are thus divergent, let the glass still excited be made to approach a second time, the leaves will recede still farther from each other than before.

In the former of these experiments the electricity is *induced;* that is, no electricity is really communicated to the leaves, but the approach of the excited electric has had sufficient power to disturb the fluid of the whole apparatus, and to drive it to the extremity of the gold leaves; they being both electrified repel each other, but the effect is transient only, and when the exciting cause is removed, of course the effect ceases. In the latter experiment, in which the exciter touches the apparatus, it positively charges it with some of its own fluid, and therefore it is in this case not merely the extremity of the gold leaves which become electric, but the whole apparatus, and they being the only delicate parts of it, show that it is so; this then is an instance of *accumulated* or communicated, and not induced electricity. The next two or three experiments open to us a new field of inquiry.

41. Roll up a band of flannel, warm one end of it at the fire, and hold it by the other. Excite the sealing wax by the warmed end, hold the excited wax to the gold leaf electroscope, and it will show the usual signs. Next remove the wax and hold the flannel; this will also show that it is excited. Next hold them both together towards the instrument, and no effect will be apparent.

It is then evident that in every instance of friction, as there must be two bodies rubbed together, so both of them become equally excited. In the one body the fluid accumulates, and that body becomes *positively* electrified; the other is to an exactly equal degree deprived of its fluid by the first, and it becomes electrified *negatively*, and these two degrees of disturbance are such as exactly at all times to destroy each other, as was proved in one instance in the last experiment, where the wax and flannel being held together produced no effect. Yet although this is known to be the case, the general result of the operation of presenting the flannel and the wax is the same, the gold leaves were divergent in both instances; this is because two bodies electrified, whether negatively or positively, repel each other. When the wax was presented, as wax when rubbed by flannel becomes negative, it attracts to itself the fluid of the apparatus. This is collected near to the wax, and the opposite end is consequently deficient; when the flannel is presented, as that is positive, it drives the fluid of the apparatus to as great a distance as it can, and the gold leaves are consequently divergent from excess of fluid. These effects, though apparently the same, may be proved to be contrary to each other, as follows:—

42. Touch the cap with the excited wax, so that the gold leaves are affected by communicated electricity, then bring the wax near them a second time, and they will diverge still more, but bring instead of this the excited flannel towards them, and they will collapse; in fact, the fluid in the flannel being of a contrary character has annulled the effect of the wax.

43. Next, while the leaves are divergent with negative electricity by the wax having touched them, excite a glass tube and hold it towards the instrument. The leaves will collapse as in the last instance, showing that the effect of the flannel in the last experiment, is the same as that of the glass in this, or that they are both electrified positively by the friction that has been used.

44. Suppose that the glass tube in the last experiment be rubbed by flannel, instead of the silk handkerchief recommended in *Ex.* 9, the effect would be the same, as may be tried; if so, the flannel with which it is rubbed must be negative; whereas, in the last experiment the flannel was positive; thus the same substance may be positively or negatively electrified, according to circumstances.

45. Try an experiment similar to *Ex.* 44 with a glass tube, rubbed with a black cat's skin, and the glass is then negative, and the skin positive.

46. Roughen the glass, and rub it with silk, and the rough glass is then negative, and the silk positive.

47. Rub the sealing wax with a piece of tinfoil held tightly in the hand, and upon trying the effect, the wax will now be found positive, although in all our former experiments it has been negative.

It is important then to observe, that no body has any peculiar character of fluid inherent in it. Glass and sealing wax only show their ordinary effect under ordinary circumstances, each as we have seen takes the place of the other occasionally; this however was not suspected at first. M. Du Fay, who ascertained the negative character of the latter, and the positive character of the glass, imagined that these effects were constant, so much so as to designate the two states of negative and positive, by the terms *resinous* and *vitreous*; supposing, and in which he has had many followers in our day, that there were two distinct fluids, the disturbance of which was at all times simultaneous and equal. It was not till the experiments of Mr. Canton in the latter part of the year 1753, and of Mr. Wilson soon afterwards, that showed the impropriety of the terms vitreous and resinous, though they were not able to affect the question of whether there is one fluid or two.

These experiments may be varied without end, and we have by them a ready means of ascertaining at all times the electric properties of all substances which will admit of friction; for we have only to electrify any electroscope with one substance, the effects of which we are certain, and we can by that test all others.

48. Excite a glass tube, let it touch an insulated body, for example, the balls of the pendulum electroscope, and then hold the body to be tested close to it, if the balls

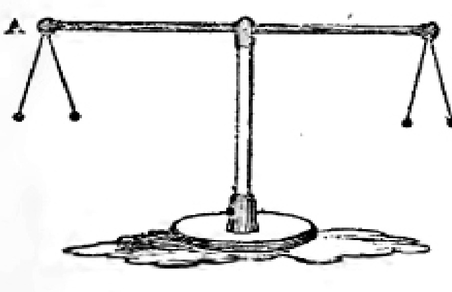
recede still more when electrified by this body, it is electrified positively, and if they collapse, it is electrified negatively. The two states of the fluid may also be shown, as follows :—

49. Excite a rod of sealing wax, and another of glass, both by flannel. Hold them one on each side of a pith ball suspended by silk, the ball will vibrate backwards and forwards from one to the other. The moving body may be made in the shape of a fly or spider.

In all the above experiments it must be observed, that the excited body to be tested must be held towards the same part of the apparatus as the test object was, or the result will be indecisive, and may even appear contrary to what it is in reality. As before observed, when an excited glass tube is held to the electroscope, if it do not touch it, it drives the fluid to the farther extremity, which extremity is the part that shows the positive effect. If it be held towards that extremity, immediately the effect may cease, because it drives that redundancy to the other end. This curious effect may be tried thus :—

50. Make a pendulum electroscope with a glass support, and linen threads instead of silk ones, or what will do as well, damp the silk threads with the mouth, touch the top of the strings with the excited tube, and the balls will diverge, the fluid being driven to them ; then present the tube a second time also at the top, and they will diverge still more ; hold it sideways towards them, and although they will approach the tube, their divergence will be but little altered. Hold the tube beneath them, and they will collapse. The effect of the induction now produced by the tube being to repel the fluid towards the top, and consequently away from where it shows itself.

51. Try the same experiment with an electroscope made of the following shape ; the



cross arm being a metallic wire, the support being glass. The excited glass tube being allowed to touch the end A, and then being withdrawn, both pairs of pith balls will show signs of divergence. Hold the glass tube a second time to the end A, but without touching it, the pair at A will partly collapse, while that at B will diverge still more. Reverse the experiment by holding the excited glass to B, and the balls at B will collapse, while those at A will increase their divergence.

Instead of giving other experiments to this, which necessarily have a great sameness in their result, we have appended the following table, taken from *Cavallo's Electricity*, and by the inspection of which the positive or negative result of the friction of all ordinary substances may be at once ascertained.

CAT SKIN is rendered *positive* by friction with every substance with which it has hitherto been tried.

SMOOTH GLASS is *positive* with every substance, except cat skin. (We believe that this will hold good with several other furs ; for example, that of a black rabbit.)

ROUGH GLASS is *positive* with dry oiled silk, sulphur and metals ; *negative* with woollen cloth, quills, wood, paper, sealing wax, white wax, and the human hand.

TOURMALIN is *positive* with amber, and the blast of air from bellows ; *negative* with diamonds and the human hand.

HARE'S SKIN is *positive* with metals, silk, loadstone, leather, the hand, paper, and baked wood ; *negative* with other finer furs.

WHITE SILK is *positive* with black silk, metals, black cloth ; *negative* with the hand, paper, hair, and weasel's skin.

BLACK SILK is *positive* with sealing wax ; *negative* with hare's, weasel's, and ferret's skin, the hand, brass, silver, iron, and white silk.

SEALING WAX is *positive* with some metals ; *negative* with hare's, weasel's, and ferret's skin, the hand, silk, leather, woollen cloth, paper, and some metals.

BAKED WOOD is *positive* with silk ; *negative* with flannel.

Mr. Singer justly remarks, that " the result of experiments of this kind is much influenced by the state of the bodies employed, and the manner in which friction is applied to them. In general, strong electric signs can only be produced by the friction of dissimilar substances, but similar substances, when rubbed together, so that the motion they individually experience is unequal, are sometimes electrified, and in such cases, the substance whose friction is limited to the least extent of surface is usually negative ; thus the violin bow of *Ex.* 31, was positive, while if the strings had been also tried, they would have been found negative." Another remarkable circumstance is that color makes a considerable difference, black and white having in many cases a contrary effect. The following curious experiments on ribbons, stockings, &c., will illustrate many of these effects :—

52. *Adhesive Ribbons.*—Take two silk ribbons, one black, the other white, each about 3 feet long ; warm them at the fire, holding them up flat against each other with one hand, draw the thumb and fingers of the other hand briskly over them several times ; they will thus become powerfully excited, and although the upper ends of the ribbons be forcibly separated to the distance of a foot or more, the lower ends will still cling together. The black will be negative.

53. Instead of a black and white ribbon, use two that are white, or two that are black ; excite them in the same way, and they will become repellant of each other, both being positive if white, and negative if black.

54. Take a single ribbon, either white or black, warm it, hold it by one end, while another person holds the other end ; draw backwards and forwards over it briskly any negative electric, such as amber, sealing wax or rosin. The ribbon will be excited positively, whether white or black. If instead of being held at each end, it be laid upon a quire of smooth dry paper, and then rubbed, the effect will be the same. If positive electrics be drawn over the ribbons, they will be excited negatively.

55. A strip of flannel and black ribbon will excite, and show the same effect as two differently colored ribbons.

56. Dry two white silk ribbons at the fire, extend them on any smooth plane, draw the edge of a short ivory rule over them several times. While they continue on the plane, they do not seem to have acquired any electricity ; yet, when taken up separately, they are observed to be negatively electrified, and repel each other. When they are separated from each other, electric sparks may be sometimes perceived between them ; but when they are again put on the plane, no electrical appearances are seen without a second friction.

57. Place the ribbons on a rough conducting substance, rub them as before, and they will, on their separation, show contrary electricities, which will also disappear when they are joined together. The upper ribbon is negative, the lower positive.

58. Place the white ribbons which have been rubbed upon the rough surface, upon that surface again after they have been separated from it, and suffering them to remain there a few minutes, they will then upon being separated be found to attract each other ; the uppermost being positively, the lowermost negatively electrified.

59. When two ribbons are made to repel each other, draw the point of a needle lengthways down one of them, and they will rush together.

60. Bring an electrified ribbon near a small insulated metallic plate—it will be attracted but feebly. Bring a finger near the plate, a spark will be observed between them, though both together show no signs of electricity ; on the separation of the ribbon they again appear to be electrified, and a spark is perceived between the plate and finger.

61. Lay a number of ribbons of the same color upon a smooth conducting substance, draw the ivory rule or paper knife over them, take them up singly, and each will give a spark where it is separated from the other. The last will do the same with the conductor, and they are all negatively electrified. Take them from the plate together, and they will all endeavour to recede from each other.

62. Let them be placed on a rough conducting substance, and then be separated singly, beginning with the lowermost, sparks appear as before ; but all the ribbons will be electrified positively, except the uppermost, or that upon which the ivory knife has acted. If they receive the friction upon the rough conductor, and are all taken up at once, all the intermediate ribbons acquire the electricity of the highest or lowest, according as the separation is begun with the highest or lowest.

63. If we take two ribbons of white silk, cut from the same piece, and make them rub against each other, while they cross at right angles, the piece which crosses the other transversely assumes negative electricity, and the other becomes positive,

64. The same effect is sometimes produced by rubbing two sticks of sealing wax, placed at right angles with each other. It would appear from these, and other experiments, that the substance which is subjected to the greatest friction becomes negative, and the other positive.

Mr. Symmer, an electrician of the last century, made some very curious observations and experiments on silk stockings. He was accustomed to wear two pair at the same time, and from the remarks he made upon taking them off and putting them on, the following experiments are deduced :—

65. *Electrified stockings.*—Put upon the same leg a worsted stocking, and over this a silk one. Warm the leg at the fire, and rub the hand over the stockings. This done, slip off the silk stocking suddenly, and the two sides of it will recede from each other, and

the whole retain the same shape as if the leg still remained in it.

66. If the stockings are both of silk, the one white and the other black, and they be warmed, rubbed, and then pulled off together, they will show no sign of electricity; but on pulling off the black one from the white a crackling of sparks may be heard, and a light may be perceived upon their separation, if performed in the dark.

67. When the stockings are separated, and held at a distance from each other, both of them appear to be highly excited—the white stocking positively, the black negatively; and while separated they are both inflated, as in *Ex.* 65.

68. If the stockings be of different colors they will attract each other; if of the same color they will repel, in the same way as the ribbons of former experiments.

69. Let the stockings thus inflated by different electricities be suffered to meet; the inflation immediately subsides, and they stick together with considerable force, each becoming quite flat. If they be again separated they will be inflated almost as strongly as at first.

70. Take a ribbon of hot paper, and draw it backwards and forwards upon a dry linen cloth, laid on the knee, and the paper will always be negative.

71. If rubbed against a metal it will become negative, unless the latter has received a high degree of polish, when it will sometimes become positive.

72. When paper is rubbed against white silk it is generally negative, unless the silk be very hot, when the paper often becomes positive. With black silk it always becomes positive, except the silk be worn thin, when the paper is generally negative.

73. Draw a black or white silk ribbon backwards and forwards over a piece of metal, and it becomes negative, whether the metal be polished or not.

74. Take a piece of silk cloth, and swing it backwards and forwards in the air of a dry room, and it will show signs of negative electricity when held to the electrometer.

75. A ribbon of silk, paper, or linen, rubbed against the skin of an animal still covered with hair, will always become very strongly and negatively excited.

CHAP. II.

ELECTROMETERS. EXCITATION BY HEAT, PRESSURE, CONTACT, CLEAVAGE, CHEMICAL ACTION, AND EVAPORATION.

It has been already observed, that friction is the cause of electrical disturbance, and that its extent agrees mainly with the degree of friction employed; thus there are many operations in which friction is produced in a very small degree—these are, no less than more obvious examples, proportionably productive of electrical appearances. The mere contact of substances, the separation of two bodies which are united, heating, cooling, evaporation, impulse of steam, chemical actions, animal muscular motion, even the slow vegetation of plants and seeds give out certain electrical signs; nay, it is probable that there is not an action we can do, or a change of motion in an inanimate object we can occasion, which does not in a greater or less degree disturb the electrical fluid, sometimes exhibiting it in one character, and sometimes in another. Thus clouds drifting through the atmosphere, the wind impinging upon the earth's surface, the rolling of the ocean upon the shore, the rise and fall of dew, the occurrence of rain, hail, snow, and numerous other phenomena of daily occurrence do, in their immensity, produce often well-known effects. These are apparent to us when insulated as in our ordinary experiments; in other cases