Fig. 1.

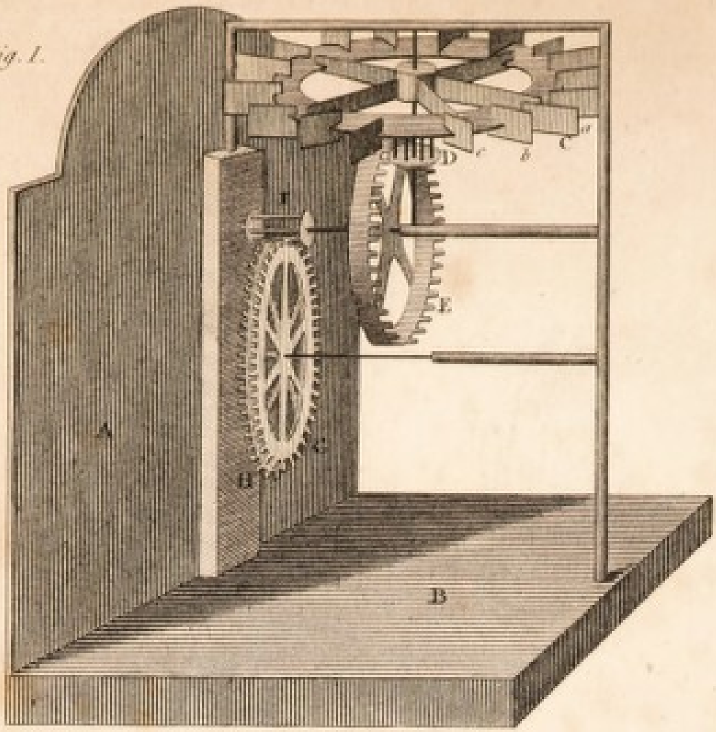


Fig. 4.

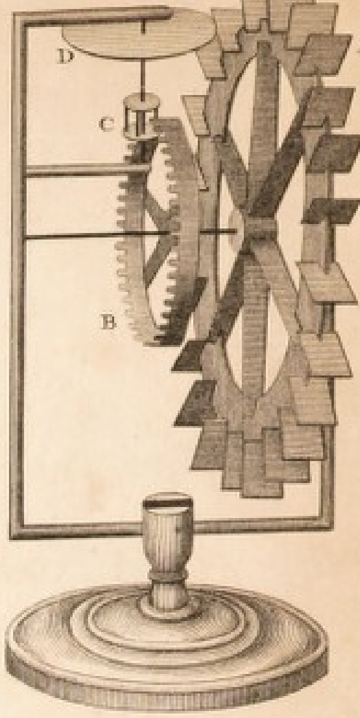


Fig. 2.

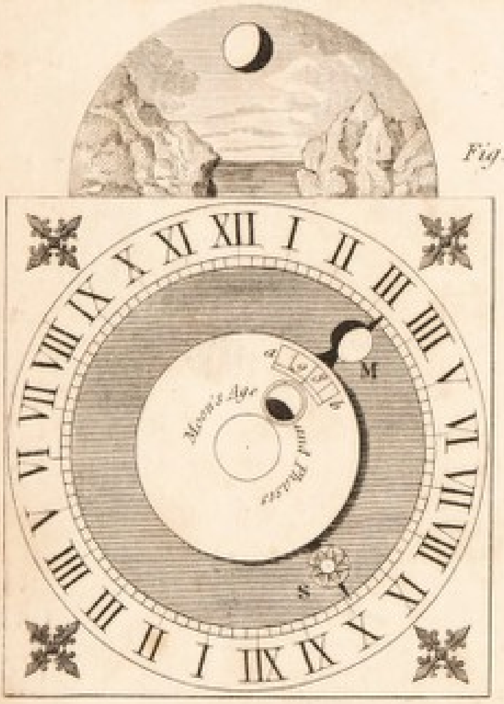


Fig. 5.

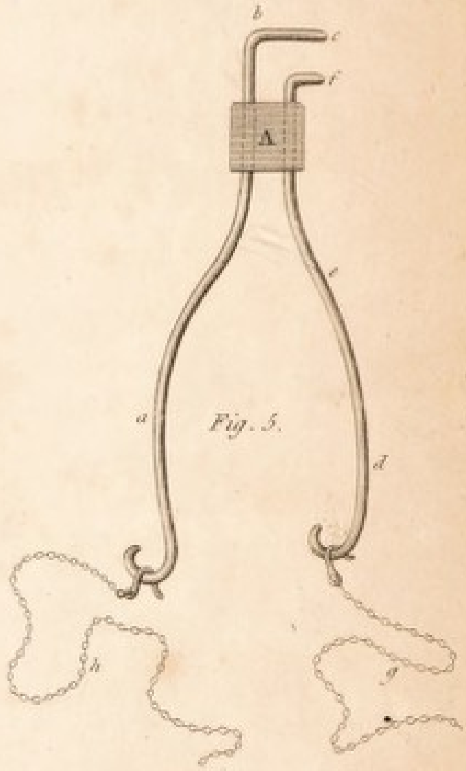


Fig. 3.

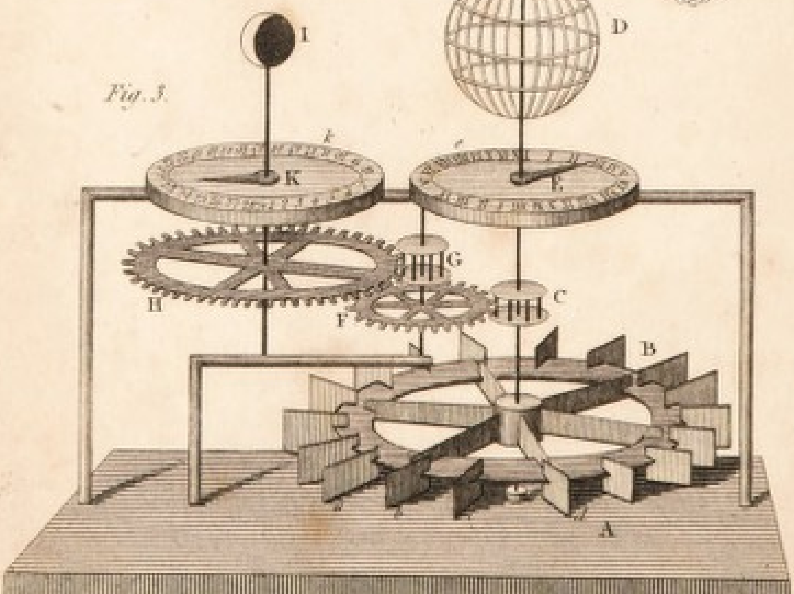
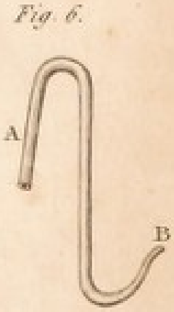


Fig. 6.



LECTURES

ON

ELECTRICITY.

BY

JAMES FERGUSON, F R.S.

A New Edition,

CORRECTED, WITH AN APPENDIX, ADAPTING THE WORK TO THE PRESENT STATE OF SCIENCE,

BY C. F. PARTINGTON,

Author of an Historical and Descriptive Account of the Steam Engine, and one of the Lecturers at the London, Russel, and Metropolitan Institutions; Mechanics' Institution, &c. &c.

LONDON:

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1825.

TO

WILLIAM L. BIRKBECK, Esq.

Dear Sir,

As a fellow-labourer in the field of Science, and, especially, as a proficient in the more recondite principles of Electricity, I beg your acceptance of the following popular view of that interesting subject.

Believe me to remain,

Dear Sir,

Your very obliged and faithful Friend,

CHARLES F. PARTINGTON.

London Institution,
May 1, 1825.

AN

INTRODUCTION

TO

ELECTRICITY.

SECTION I.

Of Electricity in general.

1. THE term ELECTRICITY is derived from ηλεκτρον, the Greek name for amber, which Theophrastus, about 300 hundred years before Christ's birth, found to attract light bodies, such as chaff and bits of straws; but now it is extended to signify the like power in all other bodies wherein it resides.[1]

Note 1. Thales the Milesian, who lived about six hundred years prior to the Christian Æra, was the first who observed the electrical properties of amber; and Theophrastus merely ascertained that the precious stone called Tourmalin produced similar phænomena.

From the time of Theophrastus there occurs a chasm in the history of this highly interesting science, of nearly two thousand years; and there are but few data preserved, connected with the subject prior to the seventeenth century. Dr. Gilbert appears to have been the first person who possessed any electrical apparatus, calculated for furthering the progress of the science; and he has, with some degree of truth, been styled, "the first real electrician." After Gilbert, the science made rapid strides, and we soon find the names of Boyle, Otto Guericke, Sir Isaac Newton, and Franklin among its most distinguished proficients. In 1722, Messrs. Grey and Wheeler, by a series of valuable experiments, ascertained the difference between conductors and non-conductors. We now come to the important facts elicited by Du Fay. This ingenious

2. All bodies that we know of have more or less of the electric virtue in them, which seems to lie dormant till it be put into action by rubbing, and then (in a dark room) it appears like fire.

3. Some bodies do freely admit this fluid, or fire, to pass through their pores, and others do not.—The

philosopher, having occasion to observe that an electrified leaf of thin gold was repelled by a glass tube that had previously attracted it, was much surprised to find that the same leaf was as eagerly attracted by a piece of gum copal. And he found upon trial, that sealing-wax, sulphur, rosin, and a number of other substances produced the same effects as gum copal. To the electricity of those substances which attracted the gold leaf after excitation he gave the name of resinous electricity, as they were most of them resins; and to the electricity of glass he gave the name of the vitreous electricity, for he entertained not a doubt but their nature was as opposite as their effects. Du Fay, among other experiments, found it impossible to excite a tube in which the air was condensed; and in repeating Grey's experiments of electrical repulsion with a pack-thread, he perceived that they succeeded better by wetting the line. Du Fay, in experimenting on the effects of electricity on the animal body, suspended himself by a silk cord; and, in this situation, sparks of fire were drawn from him on his being touched by any one, and both persons felt a sharp pain at the instant of contact, which was accompained by a snapping noise. When another person, by holding a rod of metal, touched the one that was electrified, the spark was drawn as before. From the accumulation of electricity shewn in this experiment, and its being drawn off by metal, Grey inferred, and indeed his former experiments in electrifying insulated substances had proved, the fact that electricity might be collected by metal, and drawn off, during a short interval, as it was wanted. This suggested to him the propriety of that part of an electrical machine, now called the prime conductor, which he formed by suspending a piece of metal near his excited glass tube, from which he readily drew sparks.

Note 2. The term "electric fire" is frequently employed by our author, with reference to the light that is elicited by the passage of the electric fluid, through an imperfect conductor. Thus we find that luminous coruscations are invariably observed on presenting a metal rod to an electrified ball; but if a similar rod be kept in contact with the ball, the electrified fluid will invariably pass away in a silent and invisible state. This part of the subject will, however, be more fully examined in a future page.

former of these are called *Non electrics*, or *Conductors*: and of this sort are all kinds of metals, living creatures, water, and moist wood; but metals are found to be the best of all conductors. The latter, which do not admit the electric fluid to pass through their pores, are called *Electrics*, or *Non-conductors*: and of this sort are glass, wax, rosin, dry glue, baked wood, and silk. But if either of these be wetted with water, the water that adheres to it will become a conductor.—Consequently, when any body is to be used as a non-conductor, it should be well wiped with a dry warm cloth, to clear it of damps, which it may have contracted from the humidity of the air, or from people's breath.

4. The quantity of electric fire which every body has lying dormant in it, is called its natural quantity; and this would also remain motionless and invisible if nothing disturbed it. But when any more is forced into it, as, suppose at one end, the whole is instantly put into motion thereby, and begins to be driven out at the other, if it can find a passage;[3] as if a long narrow tube, open at both ends, be filled with water, and laid on level ground, the water will remain at rest in the tube; but, if a syringe be filled with water, and fixed to either end of the tube, and then the piston of the syringe be pushed inward, to force more water into the tube, the whole water in it is thereby instantly put into motion, and it begins to run out at the other end.

5. The earth is the grand source of electric fire, and no additional quantity can be forced into any body but from the earth. If the body be a free conductor, and has a communication with the earth by means of any other conducting substance, as metal, or by a table to, the floor and walls of a room, and from thence to the earth, the electric fire will run as fast from the conduc-

Note 3. In conductors of electric fire, sharp points are as free passages, as the open ends of tubes are for water.—AUTHOR.

tor to the earth, as it is by any means driven into the conductor. But if the communication between the earth and the conducting body be cut off by means of any non-conductor, some of the electric fire may be forced into the conductor, by which means it will have more than its natural quantity; and the earth, from which that additional quantity comes, will have so much the less: which could never be, if the electric fluid were not of an elastic nature, or could not be compressed.

6. When any body has more than its natural quantity of this fire or fluid, it is said to be electrified positively, or *plus;* and when it has less than its natural quantity, it is said to be electrified negatively, or *minus*. And bodies may be electrified either of these ways by the common machine.[4]

7. When bodies are electrified either of these ways, they repel each other; but if some be electrified *plus*, and others *minus*, they mutually attract: or, if one body be electrified *plus*, and the other no way at all, they also attract each other.[5]

Note 4. The above paragraph contains the outline of Franklin's hypothesis; and it allows us to generalise and arrange our facts in this science in a more simple and intelligible way than could be effected by the hypothesis of Du Fay, which is usually adopted by the French electricians.

Note 5. An amusing illustration of the nature of electrical cohesion, which may be considered as a modification of the above phænomena, is alluded to by Mr. Symmer. He had been accustomed to wear two silk stockings on the same leg, one of them white, the other black. When these stockings were drawn off together, nothing remarkable appeared; but if, while they were both on, he rubbed his hands several times over them, and then drew off the outer or black one by itself, he heard a crackling noise, and in the dark perceived sparks of fire between them. When the stockings were separated, and held at a distance from each other, both of them appeared to be highly excited; the white stocking positively, and the black negatively. While they were kept at a distance from each other, both of them appeared inflated to such a degree, that they exhibited the entire shape of the leg. Two black or two white

8. If one body, as suppose a piece of metal, be kept for some time in an electrified state, by means of the machine, and an unelectrified light body, as suppose the down of a feather, be brought near the metal, the feather will be attracted to the metal, and electrified thereby: on which it will be immediately repelled therefrom, and will not return to the metal again, till after it has touched some unelectrified body that is of the conducting kind, and deposited its fire thereon; and then, if the distance be but small, as about two or three inches, it will return to the electrified metal as before, and be repelled from it again.

9. If a fine linen thread be tied to the down of a feather, and allowed to hang downward from it, so as almost to touch the table or floor, and the feather be brought near the electrified metal, it will be attracted by the metal, and cling thereto, as long as the metal is kept in an electrified state. For then, as fast as the feather receives the electric fire, that fire will run off

repelled each other with considerable force; but a white and a black one, would, if permitted, rush together with surprising violence; their inflation subsiding at the same time, and entirely ceasing when they were in contact. On separating them, their electricity was renewed. At first, Symmer found that it required a force of from one to twelve ounces to separate them; at another time they required seven ounces to produce the same effect, which weight was twenty times that of a single stocking; and it was applied in a direction parallel to its surface. When one of the stockings was turned inside out, and put within the other, it required twenty ounces to separate them, though at that time ten ounces were sufficient, applied externally. Getting the black stockings new dyed, and the white ones washed, and whitened in the fumes of sulphur, and then putting them one within the other, with the rough sides together, it required three pounds three ounces to separate them. With stockings of a more substantial make, the cohesion was greater. In like manner, electrical effects will be obtained by rubbing with the hand or other substances any small pieces of black and white silk. A number of experiments were made with black and white ribbons, which, with a slight difference in the mode of rubbing, or of the surfaces of the bodies in contact with them, acquired negative and positive electricity by turns.

the thread to the table or floor, so that the feather can retain no more fire than what is equal to its natural quantity. But, if the thread be cut off close by the feather with a pair of scissars, the feather will then be immediately electrified *plus*, and repelled from the metal.

10. If a round piece of metal be electrified, and any pointed piece of metal be held near it, the point will draw off the fire from the electrified metal, if that which has the point be supported by any conducting substance.

11. If the middle of a wire that is pointed at both ends, be fixed to a stick of wax, and either of the points be held near the metal which is kept in an electrified state by the machine, that point will draw off the fire from the metal, and the fire will run off from the other point into the air. This shews that metal points throw off fire as well as they attract it; which is very remarkable. If this experiment be made in a dark room, the electric fire drawn from the metal will appear like a round spark on the point that attracts, and be seen going off in the form of a cone from the other point.

12. If a large globe of metal be electrified positively, it will retain the electric fire for some considerable time. For the surrounding air prevents the accumulated fire from issuing so fast from the globe as it otherwise would. If two globes of metal be hung by silk lines, or placed on wax, at about two feet from each other, and one globe be then electrified, and the other be hung or placed near it, the former will soon lose part of the electric virtue, which will be drawn off by the latter; but the point of a needle would draw it off much sooner.

SECTION II.

A Description of the Electrical Machine.

13. The electrical machine, mostly now in use, and as it is made in the greatest perfection by Messrs. Jones of Holborn, London,[6] is represented by Fig. 1. of Plate I. in which *A* is a glass globe, *B* the handle or winch that turns it, by means of some wheel-work within the brass box *C*; and *D* is a cushion, covered with red Basil leather, for rubbing lightly against the globe. The cushion is supported by a brass spring *E*, and may be made to press more or less against the globe, by turning the screw *F*, forward or backward; *G H* is the prime conductor, which is a brass tube with a round hollow ball at each end. The brass piece *I* is stuck into a hole in the ball *G*, and has several small forks of brass or steel, with sharp points, which almost touch the globe. The barrel of the conductor is put into the brass socket *a*, (which may be done after taking off the ball *G*,) and to this socket is joined the brass socket *K*, in which the upper end of the glass tube *L* is fixed with cement, and the lower end is cemented into the wooden foot, *M*. The glass tube being a non-conductor, insulates (as it were) the prime conductor *G H*, by cutting off all conducting communication between it and the earth. For, as the electric fire comes from the earth to the machine, and is put into motion and action by the rubbing of the glass globe against the cushion, and this fire goes round with the globe to the points *I*, which attract it and carry it to the prime conductor; if the conductor were not insulated in this manner, or hung by silk lines, the fire would run as fast from it to the ground, as it received

Note 6. Our Author introduces the name of Edward Nairne; but that very respectable Optician being long since deceased, the Editor believes that he is doing a real service to the scientific world by substituting the names of the above very ingenious artists, who have very much improved the machine.

the fire from the globe; and then the whole machine would be good for nothing.[7]

14. These are all the parts of the electrifying machine itself:—the rest to be here described are only the different parts of the apparatus belonging to it, for making experiments. And note, that when any of these is used, all the others should be set at least one foot from the machine. For, as the electric fire spreads about to some distance in the air, if any conducting substance be near any person or thing that is to be electrified, it will attract and carry off part of the fire, and make the experiment the more tedious and less successful.—So that, when either the balls *O* and *P* are used, or the crooked wire *c d* with the fly *e f g h i k*, or the piece *Q* with the bells *R, S, T*, or the Plates *X* and *Y*, or the feather *b*, or cotton *m*, it must be used by itself after all the rest are taken away.—And they are only put to the conductor in this figure, to shew how each is to be put thereto by itself, when an experiment is to be made with it.

15. The holes in the prime conductor, for receiving the ends of the wires *N, c d*, and the feather *b*, should be well rounded off, and made smooth about the edges. For, if the edges are left sharp, they will be of the same nature as points, in throwing off the electric fire; and this would spoil the experiments.—I shall next describe the different parts of the apparatus belonging to my electrical machine, of which those in Plate II. are entirely new; at least they are so to me.

Note 7. From this it will be seen, that the prime conductor is a sort of magazine or reservoir for holding the electric fluid; and that if the particles of vapour, which are held in solution by the atmosphere, be deposited on the glass leg or silk, it will cease to retain this property. A reference to this fact will shew how necessary it is to keep the glass at a higher temperature than the room in which the experiments are made. An improved machine by which this important desideratum may be readily effected, is introduced in the Supplement.

SECTION III.

A Description of an Apparatus, belonging to the Machine, for making Electrical Experiments.

PLATE I. Fig. 1.

16. *O* and *P* are two little balls, made of pith of elder, to which the ends of a fine linen thread (about seven or eight inches long) are fixed. When they are used, they are hung by the middle of the thread upon a wire *N*, close by a round ball of metal, which is fixed upon one end of the wire; and the other end is then stuck into a hole in the end *G* of the prime conductor *G H*.

17. *c d* is a crooked wire (which must not be sharp at the bended parts) to be stuck into a hole in the uppermost side of the prime conductor-ball *G*. The top of this wire must be sharp above *d*; and *e f g h i k* is a fly made of small brass wire; the ends of each arm next the centre being fixed into a brass cap, which is to be put upon the point of the crooked wire; and the other ends of all the arms are bent one way, in a horizontal direction, and terminate in sharp points. Each bended part *e, f, g, h, i, k,* must make a sort of a right angle with the rest of the arm between it and the center, and these bendings must be roundish, not sharp corners.—When this fly is put upon the top of the crooked wire *c d,* it hangs like a mariner's compass upon the pin that supports it.

18. *Q* is a brass hook fixed to a cross bar of brass, from which hang three bells *R, S, T,* with their clappers *U* and *V*, which are small brass balls.—The bells *R* and *T* are hung by metal chains; the middle bell *S* by a silk line, and the clappers by silk threads.—A metal chain *W,* hangs from the middle bell, the lower part of this chain lies on the table (to which the electrical machine is fixed) and a piece of silk cord *w* is tied to the lower end of the chain.

19. *X* is a thin brass plate, to be hung to the prime conductor by a metal hook; and *Y* is another of the same sort, but a little larger, to be placed below it. A brass wire is fixed into the middle of the plate *Y*, and is moveable up or down in a brass socket *Z*, for raising or letting down the plate, which may be fixed at any proper height by means of the screw *z*; and the lowest end of the socket may either be stuck into a hole in the wooden foot *M* of the prime conductor, or have a metal stand of its own, which is the most usual way. For, in making experiments with it is, no matter under what part of the conductor it be placed, if the other plate be hung directly over it.

20. *b* is a large plumy feather, such as young ladies wear in their caps. That of an ostrich is the best.

21. *m* is a small lock of cotton, part of which must be drawn out into a short thread, and thereby fixed with a bit of bees-wax to any part of the undermost side of the prime conductor, (any where between *Q* and *X* would be better than where it is represented) and then, before the experiment with it be made, it should be pulled out by the hands into such a lax state, as that the different parts of it may only hang together by small shreds, and the lowest part of it should be drawn out to a shred.

22. In Fig. 6, *A B C* is a bended wire, the end *A* being made blunt, and of such a size as to fit either of the round holes in the prime conductor, instead of either the straight wire *N*, or the crooked wire *c d*; and the end *c* must be a sharp point.

23. In Fig. 2, *A* is a glass jar, coated on the outside, and lined on the inside with tinfoil to about two inches short of its top, which is stopped with a thin cork, first dipt all over in melted wax.[8] A straight brass wire is put down through the middle of the cork, quite to the

Note 8. A top, turned from dry mahogany, is better adapted to the purpose, as carbonised cork is a conductor of electricity.

lining which covers the inside of the bottom of the jar; and a smooth ball *a* is fixed on the top of the wire, which must be of such a height as to touch the ball of the prime conductor when the jar is set near enough to it on the table.—*B* is the discharger, which is made of strong brass wire, bent into the form of part of a circle; and has two balls *c* and *d* fixed on its ends. *N. B.* The brass ball on the tops of all the wires belonging to the several jars ought to be of equal height when they are set upon a table. The thinner these jars are, they are so much the better for electrical experiments. The coating and lining are generally fixed to them with thick starch, or bookbinder's paste; but I find that thick varnish, such as is used by coachmakers, does better for that purpose, and dries immediately, which the other does not.

24. In Fig. 3, *A* is just such a jar as the one above described; only it has an additional wire *B*, bent into the form of a ring, so as to fit the outside, and remain on any part of the coating over which it is placed; with a brass ball *D* on its top, of equal height with the ball *C* from the table. *E* is a bit of cork, cut in to the form of a spider, with legs of linen thread, fixed into it by drawing them through with a small needle, and then cut with scissars to a proper length. It is hung by a silk thread to the ceiling of the room, and at such a height above the table that its legs may touch the balls *C* and *D*, if it be made to swing between them. Before the legs are put to it, it must be put upon the point of a wire, and turned round and round in the flame of a candle, to burn off the roughness and sharp edges which the knife had left on its surface; and then the burnt parts must be rubbed off between a wet finger and thumb, to smooth it.

25. In Fig. 4, *A a* is a thin glass, blown into the shape of a Florence flask, left open at the small end *a*. A cork, through which a small hole has been made by

a red-hot iron wire, is cemented into this glass at the mouth *a;* and a narrow slip of thin bladder, that had been moistened before, is tied over the hole, by way of a valve.[9] The glass is then put under a receiver on the air-pump, and exhausted of air; then taken out, and a brass cap *a,* in which some hot sealing-wax has been poured, is put on, over the valve, to prevent any air from getting afterward into the glass. The inside of this glass must be perfectly clean and dry: for, if there be any dust or damp within it, it will be of no use for an experiment.

26. Fig. 5 is the artificial *thunder-house,* with its appurtenances. *A* is a mahogany board, half an inch thick, and shaped like the gable-end of a house, which is all that is necessary of the house for an experiment. It is fixed upright on the horizontal board or stand *B,* in which is also fixed the lower end of an upright glass tube *C D;* in the upper end of which, the end *D* of a crooked brass wire *D E w F* is cemented; and on the other end of the wire is fixed the smooth brass ball *F;* above which some down feathers *H* are hung around the wire by linen threads, which are tied round the wire by a thread of the same sort. One end of a metal chain *I K* is hung by a hook on this wire, and the other end is hung by a hook to the farthest end *L* of the prime conductor of the electrical machine; and the coated jar *M* is so placed, in making the experiment, that the ball *m* on the top of its wire may touch that end of the conductor.—A square hole *a b c d,* a full quarter of an inch deep and three quarters wide, is made in the gable-board *A,* and filled with a square piece of wood *N* just as thick as the hole is deep; but it must go so easily into the hole, that it would drop out if *A* were turned over toward *B.* A wire *a N c* is let into this board, very

Note 9. A brass tube, furnished with a valve, is usually substituted for the cork.

fast in a diagonal channel just as deep as the wire is thick, so as never to be taken out again. And, in the same manner, the wires *g d* and *b h* are fixed in the gable-board, the lower end of the former being at the corner *d* of the square hole, and the upper end of the latter at the opposite corner *b*. The wire *g d* has a brass ball *G* on its top, directly below the ball *F*, and about half an inch from it: the wire *b h* is turned up at the lower end, in the form of a hook, on which one end of a metal chain *i k* is hooked, and the other end of the chain is put round the bottom of the coated jar *M*. When the square board *N* is put into the hole *a b c d* in the way represented in the figure, its diagonal wire *a N c* has no connection with the wires *g d* and *b h:* but, if it be taken out, and turned a quarter round, and then put in again, the wire *a N c* will be in the position *b N d;* and then its ends will touch the nearest ends of both the other wires at *d* and *b*, and the whole will seem as if it were only one continued wire, bent at the opposite corners *b* and *d*.—This was contrived by Dr. James Lind of Edinburgh, for verifying Dr. Franklin's method of preserving houses by means of metal rods, from damage by lightning, when it breaks upon them; the rods collecting the whole of the lightning into themselves, and conducting it harmlessly down into the ground.

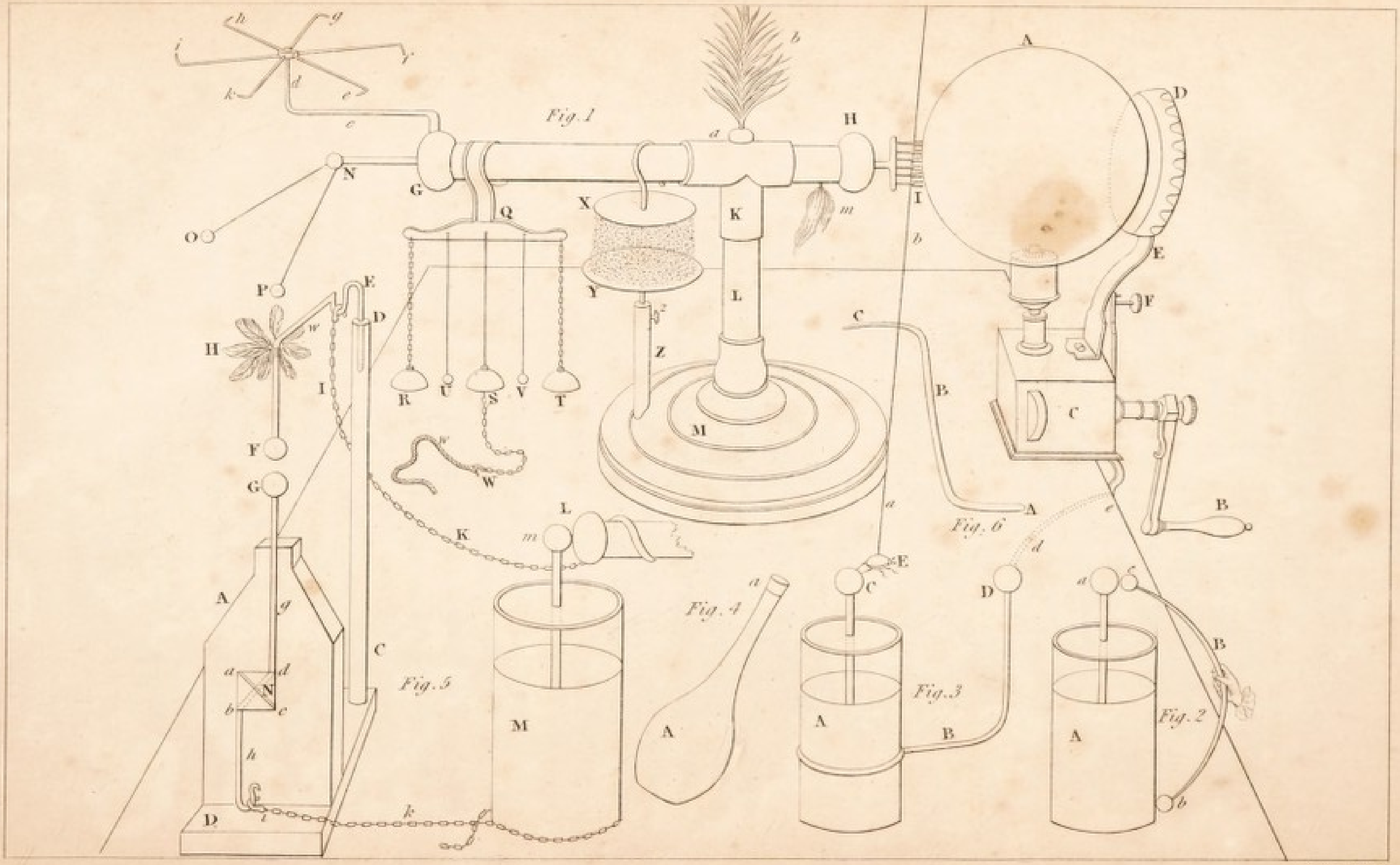
27. The magical picture, contrived by Mr. Kinnersley,[10] is made thus: "Having a large mezzotinto with a frame and glass, suppose of the KING, (God preserve him) take out the print, and cut a pannel out of it, near two inches distant from the frame all around. With thin paste, or gum-water, fix the border that is cut off on the inside of the glass, pressing it smooth and close: then fill up the vacancy by gilding the glass with leaf-gold or brass. Gild likewise the inner edge of the

Note 10. Franklin's Letters, page 29. printed in the year 1769.—AUTHOR back of the frame all round, except the top part, and form a communication between that gilding and the gilding behind the glass; then put in the board, and that side is finished. Turn up the glass, and gild the foreside exactly over the back-gilding, and when it is dry, cover it, by pasting on the pannel of the picture that had been cut out, observing to bring the correspondent parts of the border and picture together, by which the picture will appear of a piece, as at first, only part is behind the glass, and part before."

28. The stool on which people are electrified, is a mahogany board, supported by four pillars of solid glass, each about half a foot long; but if they were eight inches in length, it would be so much the better. The edges and corners of the board ought to be well rounded off, and nothing about it left rough or sharp. Those who apply electricity for medical purposes, ought to have a chair, with glass feet, eight inches long, for patients to sit in, who cannot stand on a stool.

29. I shall now describe the figures on Plate II. which are representations of some models of machines that I have lately made; and, for the amusement of those who attend my lectures, I set these moddles in motion by a stream of electric fire.[11] It must be confessed, they do not properly belong to the class of electrical experiments, because they might be put into motion by water, wind, or weights. Yet, as it is not unpleasing to see them move by electricity, perhaps some gentlemen who have a mechanical turn, and are provided with electrical machines, may like to copy these moddles, both for their own amusement and that of their friends.—All the wheels and trundle-heads are made of card-paper,

Note 11. Instead of the "stream of electrical fire," producing this motion we may more philosophically ascribe it to the current of electrified air, which possessing a similar electricity with the point, is repelled by it, and striking against the vanes, impels them round.



J. Shury, Sculp.t

the axles of common knitting wires, the trundle-staves of wood, the frames (in which the ends of the axles turn round) of thick brass-wire, and the supporting foot of wood.—The biggest wheel, which resembles the water-wheel of a common breast-mill, is five inches in diameter; and all the rest of the wheels much in the same proportion thereto, as the figures represent them. The whole work is made so free, easy, and light, that a force equal to one grain weight, acting on the great wheel, will put all the rest into motion.

30. Fig. 1 of Plate II. is a clock for shewing the apparent diurnal motions of the sun and moon, with the moon's age and phases.—*A* is the back of the dial-plate (the face of which is shewn by Fig. 2) *B* the horizontal board or foot that supports the whole; and *C* is the great wheel which is turned by the electrical stream, according to the order of the letters *a b c*. On the axis of the great wheel is a trundle *D*, turning the contrate wheel *E*, on whose axis is the trundle *F*, turning two wheels *G* and *H*; *G* having 59 teeth, and *H* 57; and these are the only two wheels in which the numbers of teeth need be regarded, for all the use of the rest is only to put these two in motion. The axis of the wheel *H* is a short hollow socket, and the wire-axis of *G* turns within it: the former of these carries a sun round the dial-plate, and the latter carries a moon round the same. If the sun's motion round the dial-plate be accounted 24 hours, the moon will not go round it in less than 24 hours 50 minutes 32 seconds: for as 57 teeth are to 24 hours, so are 59 teeth to 24 hours 50 minutes 32 seconds; which is very near the truth: for the moon in the heavens is 50 minutes 28 seconds later in coming to the meridian every day, than she was in the day before.

The face of the dial-plate (Fig. 2) has all the 24 hours upon it; and a point from the sun *S* serves for the index or hour-hand. In the middle are two round plates, equal in size, one directly over the other, so that the lowest is hid from sight by the uppermost, in a front view. The sun *S* is a part of the lowest plate, and the moon *M* a part of the uppermost; so that, if these plates be turned round, they carry the sun and moon round with them.—The sun's plate has a circular space all around, divided into $29\frac{1}{2}$ equal parts, which shew the days of the moon's age from change to change, and appear successively through an opening *a b* in the upper plate: and between that opening and the center, is a round hole, through which the moon's different phases are seen on the under plate, according to all the different days of her age. The undermost plate, which carries the sun, is fixed on the hollow axis of the wheel *H* (Fig. 1) and the uppermost plate, which carries the moon, is fixed on the axis of the wheel *G:* so that the revolutions of these plates will be just as different as the revolutions of their two wheels are; viz. in the time the wheel that carries the sun makes $29\frac{1}{2}$ revolutions, the wheel that carries the moon will make only $28\frac{1}{2}$. And this will carry the moon so much slower round than the sun, that she will be 50 minutes, 32 seconds, later in coming to the meridian, or uppermost XII, every day, than she was on the day before; accounting each complete revolution of the sun to be 24 hours, which includes both the day and the night. So that the moon will go off, and round from the sun to the sun again in $29\frac{1}{2}$ days and nights, which is the time between change and change. In each revolution of the sun a different day of the moon's age will be seen through the opening *a b;* and a different phase of the moon will appear through the round hole. I need not inform any clock-maker how easy it would be for him to have such an apparent diurnal motion of the sun and moon in a real clock.

31. Fig. 3, of Plate II. is a kind of Orrery, for

shewing the earth's motion round its axis in 24 hours, the age of the moon from change to change, and all her various phases during that time. *A* is the horizontal board or stand of this machine, and *B* is the great wheel, with 18 floats or wings for the electric stream to act upon, and turn the wheel according to the order of the letters *a b c d*. On the axis of this wheel is a trundle *C*, of 8 staves, for turning the wheel *F*, of 32 teeth, on whose axis is a trundle *G*, of 8 staves, for turning the wheel *H*, of 59 teeth, which will go once round in the time the great wheel *A*, goes 29½ times round. A light hollow globe *D*, representing the earth, with its meridians, equator, tropics, polar circles and poles, is put upon the top of the axis of the great wheel *A*, and on the same axis is an index *E*, which goes round a small dial-plate *e* of 24 hours, in the time that the earth *D* turns round. And an ivory ball *I* is placed on the top of the axis of the wheel *H*, half black half white, to represent the moon; below which, on the same axis, is an index *K*, which goes round a small plate *k* divided into 29½ equal parts, for the days of the moon's age from change to change.—So that, in the time the great wheel *A*, the earth *D*, and hour-index *E*, make 29½ revolutions, the moon *I* and her index *K* make only 1; and in that time, by shewing herself all round to the observers, they see all her different phases or appearances, like those of the real moon in the heavens.

32. Fig. 4 is a model of a common mill for grinding corn. *A* is the water wheel, *B* the cog-wheel on its axis, *C* the trundle turned by that wheel, and *D* the running millstone on the top of the axis of the trundle. I have made another mill (to be turned also by electricity) in which, instead of the round plate *D* for the millstone, there is a horizontal wheel on the axis of the trundle *C* with spur-cogs, which turn two trundles placed on its opposite sides; and on the top of each

of these trundle's axis is a round plate representing a millstone ; so that this model has all the working parts of a double water-mill, turning two millstones.

33. Fig. 5 is an instrument that I have contrived for curing the toothache by means of an electrical shock ; and I never found it to fail except when the tooth was very much spoiled and decayed : in which case, perhaps, drawing may be the only effectual cure. *A* is a flat square piece of box-wood, about an inch broad and a quarter of an inch thick ; two longitudinal holes are made quite through it, near its opposite edges, through which the brass wires *a b c* and *d e f* are put while they are straight; then fixed with sealing wax, and bent as in the figure, so as to receive the tooth and gum between their points *c* and *f*, which must not be made too sharp, for fear of hurting the gum. When it is used, two chains *g* and *h* must be hooked to the other ends of the wires. The method of using it will be shewn in the 31st experiment.

SECTION IV.

How to know whether the electrical Machine be in good Order for performing the Experiments, and to make it so if it be not.

35. Take away both the cushion and prime conductor from the glass globe, then wipe the globe quite dry and clean with an old soft linen cloth that has been just warmed by the fire ; and then put on the cushion, making it press gently against the globe by means of the adjusting screw *F*, (Fig. 1 of Plate I.) This done, turn the globe by the winch, and hold a knuckle of any finger near the side of the globe. Then, if you hear the fire hissing from the globe, and feel it like a gentle wind blowing through a pipe against your knuckle, the

machine is in good order. But, if you neither hear nor feel any fire, take off the cushion, put a little candle-tallow upon it, and then rub on a little amalgama[12] by means of a piece of brown paper between your hand and the cushion: this done, put on the cushion again, and the machine will work much stronger; as you will find by turning the globe, and presenting your knuckle as before, or by placing the conductor so that the points *I* may be about an eighth part of an inch from the globe, and holding your knuckle near any part of the conductor whilst you turn the globe: for then bright sparks of electric fire will snap from the conductor to your knuckle, which will give a disagreeable but not a painful sensation.

36. In working the machine, the globe must be often wiped, and so must the prime conductor and jars, &c. to clear them of all damps and dust; especially if there be much company in the room; for damps and dust spoil all the experiments, especially when any of them come upon the glass tube *L* that insulates the conductor.

37. When any of the amalgama sticks to the globe, it must be picked off. When the working of the globe has made the amalgama smooth and glossy, the cushion must be taken off, and rubbed with a piece of rough

Note 12. This amalgama is made with two ounces of quicksilver, and one ounce of tinfoil, or of pewter-shavings, well mixed together with a small quantity of powdered chalk, by beating them with a marble pestle in a marble mortar, the pestle having been first made warm.—This was Mr. Canton's invention.—AUTHOR.

The amalgama, recommended by Mr. Singer, is made by melting together one ounce of tin and two ounces of zinc, which are mixed whilst fluid, with six ounces of mercury, and agitated in an iron or thick wooden box until cold. It is then reduced to very fine powder in a mortar, and mixed with sufficient hogs' lard to form a paste. Amalgams have sometimes a much larger proportion of mercury, but their action is more variable and transient; as is also the effect of their partial application to the surface of the machine during its action, as recommended by some electricians.

brown paper, to take off the polish. And when amalgama has been put on three or four times, at different times of using the machine, it will form into a hard crust on the cushion, and there will be no occasion to use any more afterwards; only, when the globe has made the surface smooth and glossy again, take off the cushion, and rub it to a rough surface by brown paper.

38. Sometimes, especially in very dry weather, it is necessary to take off the leather from the cushion, and moisten the back of the leather a little by a wet sponge. For, although the experiments will not succeed if either the globe, conductor, or jars be damp, they will not if the leather of the cushion be perfectly dry; because, as all the fire comes from the earth to the globe by the cushion, and moisture is a good conductor of this fire, it must come in the greatest quantity when it finds the best conductor. I generally use a piece of leather, with the amalgama upon it, put in loose between the leather of the cushion and the globe; because it may be easily drawn out, and rubbed or moistened, without taking off the cushion.[13]

39. One day, last summer, when the weather had continued long dry and warm, I could not make my electrical machine work at all, either by rubbing the cushion, moistening its leather, or putting more amalgama thereon. For both the earth and floor of the room were so dry, that no electric fire could come to the cushion. I then dipped a hempen cord in water, tied one end of it to the brass spring that supports the cushion, and put the cord out at the window to the ground, under a large water-tub, which by constantly dripping had well moistened that part of the ground; and then the machine did very well. I afterwards told this circumstance to Dr. FRANKLIN, and he informed

Note 13. The process of moistening the rubber described in the above paragraph, may be dispensed with, if the leather be soaked in tallow.

me that he had often, at Philadelphia, when the weather and ground were very dry, been obliged to put one end of a long wire down into his pump, and hook the other end to the cushion; and then he had fire enough to his electrical machine.[14]

40. If the coated jars (sec. 23, 24, 26.) be warmed a little before they are used, the experiments made by them will succeed the better.

41. The machine always works best when the air is in the most dense state, which is when it is heaviest; and it is always so when the quicksilver in the barometer is at the highest. When the air is light, as it always is in wet or hazy weather, the electrical experiments do not suceeed so well, for want of a sufficient resistance against the surface of the prime conductor, &c. to keep the electric fire condensed therein until it be drawn off by some other conducting body. If there were no air round the prime conductor, the fire would fly from all parts of its surface to the walls of the room.

SECTION V.

How to make the electrical Experiments, and to preserve Buildings from Damage by Lightning.

EXPERIMENT I.

Electric Attraction.

42. Tie one end of a fine linen thread to a small downy feather, and let the other end hang down to the table. Then turn the globe of the machine by the winch; and holding the feather near the ball *G* of the prime con-

Note 14. A small light chain is usually employed to connect the rubber with the ground.

ductor, the feather will fly to the ball, and adhere to it as long as you keep working the machine.[15]

As fast as the feather receives the electric fire from the prime conductor, the fire runs off from the feather by the thread to the table, or to the hand that holds the thread. So that, although the feather is still receiving new fire, it parts with it as fast; and therefore there is no increase of its natural quantity: if there were, the feather would then be repelled from the prime conductor. —*See Sec.* I. § 4, 5, 6, and 7.

EXPERIMENT II.

Electric Attraction.

43. Make a ring of wire, at least a foot larger in diameter than the glass globe of the machine, and tie pieces of fine linen threads to it, each about five inches long, and about two inches from each other. Then, having taken away the conductor *G H*, hold the ring in a horizontal position round the globe, and turn the globe by the winch. As soon as the globe begins to turn round, all the threads will be attracted towards it, and point toward its center, standing horizontally inward, and resembling the radii or spokes of a wheel.

The person who holds the ring (*Sect.* I. § 3) carries off the electric fire from the threads and ring as fast as they receive it from the globe: and so they remain attracted by the globe as long as it is kept in motion, and brings fire from the cushion to the threads.

Note 15. The feather and prime conductor attract each other (we suppose) in proportion to their weights or quantities of matter: but the conductor, being heavy, cannot be sensibly moved by the attraction of the light feather.—AUTHOR.

In answer to this observation, it may be stated, that in electricity, it is surface, and not mass, on which the attractive power depends.

EXPERIMENT III.

Electric Repulsion.

44. Stick the wire *N* into the ball *G* of the prime conductor (Fig. 1 of Plate I.) and place the conductor so as the points *I* may almost touch the glass globe *A* of the machine. Then take the two little pith-balls *O* and *P* (§ 16) and hang them by the thread upon the wire, so as the middle of the thread may be upon the wire, and the balls will hang close together, keeping the two parts of the thread perpendicular to the table, by means of their little weight. But turn the glass globe by the winch, to electrify the balls, and they will repel each other, and stand apart, as in the figure, and continue so as long as you keep turning.

The balls having nothing to draw off the fire from them which they receive from the machine, they are both electrified positively; and cannot dissipate the fire so fast around them in the air as they receive it: and therefore, they acquire a quantity of fire beyond that which they had in their natural state; and so they repel each other, according to § 6 and 7.

EXPERIMENT IV.

That Metals are Conductors of Electric Fire, and Wax is not.

45. While the balls stand asunder, and you keep turning the machine, touch any part of the prime conductor by a piece of metal; and the balls *O* and *P* will instantly come close together: which shews that the electric fire runs off by the metal. But touch the prime conductor by a stick of wax (or by any piece of glass) and the balls will still keep asunder as before, which shews that wax and glass are non-conductors, as none of the electric fluid is drawn off by them.

N. B. These balls are very good for trying the strength of the electrical machine, which may be done as follows :—Remove the prime conductor, and every other part of the electrical apparatus, from the table, three feet at least from the glass globe of the machine. Then turn the globe by the winch, and hang the balls by the middle of the double thread about two feet from the globe. If they begin to separate from each other at that distance, the machine is in very good order ; but if they do not, bring them gradually nearer, until you see them begin to separate. And wherever they do, it shews that the air is electrified to that distance, all around the globe.

EXPERIMENT V.

The Electrical-fly.

46. The prime conductor being set properly to the globe, (as in Fig. 1.) and every thing at a proper distance from it,[16] put the blunt end of the crooked wire *c d* into the hole in the top of the ball *G* of the prime conductor (§ 17;) and hang the fly *e f g h i k* upon the sharp-pointed top of the wire. Then turn the globe by the winch, and the fly will turn round, with a very brisk motion, in a contrary direction to the way that its points are bent, or according to the order of the letters *e f g h i k*. If this experiment be made in a dark room, the moment when the globe of the machine begins to be turned, a bright spark of electric fire will appear at each point of the fly : and when it acquires a quick motion, these sparks will form a complete luminous ring.

The reason of this motion is, that the fire which runs in the arms of the fly presses against the bended parts

Note 16. When any thing is to be electrified, every other thing ought to be set one foot from it at least.

near the points, but most against the outside parts of the bendings opposite to the points; and presses not at all in the points themselves, because they throw it freely off, and it has a free egress from them. But as it comes to the round bendings, and cannot get off there, it exerts a pressure against them, sufficient to turn the fly that way.[17]

EXPERIMENT VI.

The ringing of Bells.

47. Hang the hook *Q* upon the prime conductor, and the lower part of the chain *W* that hangs from the middle bell *S* (§ 18) will lie upon the table. Then turn the globe by the winch, and the clappers *U* and *V* will fly from bell to bell with a very quick motion; and all the three bells *R*, *S*, and *T* will continue to ring as long as you keep turning the globe. In a darkened room, sparks of electric fire will be seen between the clappers and bells.

Note 17. This view of the matter appears altogether erroneous, and the true solution of this apparently singular phænomenon will be found in the attraction and recession of the electrified air which surrounds the wire. For if we suppose the prime conductor to be positively electrical, and the air in contact with the point to possess a similar electricity it must be repelled against the surrounding particles of air, and by its re-action produce a rotatory motion. This must continue as long as the machine is turned, as new portions of air must continually be attracted against the points, and a new impetus given by their subsequent reaction.

If the figures of horses, cut in paper, be fastened upon the fly mentioned by our Author, and so contrived that the points shall be in their tails, the experiment will be very beautiful; the horses will seem to pursue one another, though without a possibility of any of them over-taking the rest; this is called the electrical horse-race. It is possible to make several of these wires, each having a considerable number of points bent backwards, with horses, &c. fastened to each of them, and turning one above another; and then some of them may be contrived to move faster than the others. They may also be made to move different ways. By means of the stream of electricity that issues from a point, several other amusing experiments have been contrived.

The two bells *R* and *T*, being hung by metal chains, are electrified from the prime conductor ; but the middle bell *S*, and the two clappers *U* and *V*, being hung by silk lines, cannot be electrified thereby (§ 3,) because the silk transmits no fire from the conductor to them. The outside bells, being electrified, attract the unelectrified clappers, and deposit part of their fire upon them. The clappers, being then electrified as well as the bells, are repelled from them to the unelectrified middle bell, which takes the fire from them the moment they touch it ; and that fire immediately runs off from the middle bell, by the chain *W*, to the table. The clappers being then unelectrified (as well as the middle bell,) they are attracted back again to the two electrified bells *R* and *T*, and being then again electrified, they are repelled from these bells (as before) toward the middle bell. And thus the ringing must continue as long as the outside bells are kept in an electrified state by the machine.

If a person takes hold of the chain *W*, and lifts it up from the table, the ringing will continue, because he (being a conductor, § 3,) will draw off the fire from the middle bell, as the table did, as fast as it receives the fire from the clappers. But if he takes hold of the silk cord *w*, which is fixed to the lower end of the chain *W*, and thereby raises the chain from the table, the ringing will immediately stop, which shews that silk is a non-conductor of electric fire, and so stops that fire from running off from the middle bell ; which having its natural quantity before, will receive no additional quantity, unless that quantity be allowed to run off.

If the middle bell were hung by a metal chain, as the outside bells are, they would be all equally electrified from the prime conductor ; and then, as the clappers would be equally attracted on both their sides by the three bells, they could not move toward either side ; and therefore they would hang motionless.

EXPERIMENT VII.

Drawing off Streams of Electric Fire.

48. Hang the thin brass-plate *X* (§ 19,) upon the prime conductor, and darken the room. Then turn the glass globe of the machine by the winch, and hold your knuckles near the edge of the plate; and you will see streams of fire issuing from the plate to your knuckles, and feel it like a gentle wind. If you move your hand round the edge of the plate, the fire will follow your hand, and come to it.

The knuckles, being conductors, draw off the fire from the electrified plate.[18]

EXPERIMENT VIII.

Dancing of Electrified Bran, Images, &c.

49. Set the brass-plate *Y* (§ 19,) directly under the plate *X*, and about two or three inches from it, as you will soon find by experience what distance is best. Then put a little dry sand, bran, or pollard upon the plate *Y*. This done, turn the globe by the winch; and the sand or bran will move up and down with a surprising rapidity between the plate, so that you cannot distinguish the particles, but the whole will look like a white mist.

Note 18. Several amusing experiments depend on this property of pointed bodies, to transmit the electric fluid. If a plate of tin be cut into the form of a star, and be supported on its centre by a wire projecting from the prime conductor, as soon as the wheel of the machine is turned, and this apparatus electrified, a flame will appear at the extremity of every angle of the star, which will be very beautiful; and if the star be made to turn swiftly on its centre, an entire circle of fire will be seen in the dark. This experiment will appear very surprising to persons unacquainted with electricity, if the operator now and then privately touch the prime conductor, which may easily be managed, as the experiment is performed in the dark; for by this means he may command the appearance or disappearance of the star, or circle of fire, at pleasure.

Or, put some little images, of cut paper between the plates ; and when you turn the globe, the images will dance, between the plates, in such antic postures as will probably make a whole company laugh, that had never seen the experiment before.

All this depends upon the same principle as the 6th experiment : the bran or images being attracted and repelled as the clappers were, between the bells.—If the images and bells be used at the same time, it will seem as if the former danced to the music of the latter.[19]

EXPERIMENT IX.

Dancing of Electrified Cotton.

50. Turn the globe by the winch with one hand, and hold the other about three or four inches from the end *G* of the prime conductor. While you are doing this, desire any person to let a small lock of cotton drop from his hand upon yours which is near the conductor ; and the cotton will jump from your hand to the conductor, and back to your hand again, with a quick motion, stretching itself out into a longish form both ways, and moving so quick that you will not well be able to perceive its form, and can only see its colour.

This depends upon the same principle of attraction and repulsion as shewn in the 6th experiment ; for the electrified conductor attracts the unelectrified cotton, which becomes electrified on touching the conductor, and is then repelled from it to the hand, which unelectrifies it, by drawing off the additional fire that the conductor had given it just before ; and then, being unelectrified, it is again attracted by the electrified conductor.

Note 19. Small figures, made from the pith of the elder-tree, are better adapted for the purpose.

EXPERIMENT X.

The Electrified Feather.

51. Stick the plumy feather *b* (§ 20,) into the prime conductor, and turn the globe as above.—The feather will then be all electrified alike; and its *plumulæ* will repel each other, and stand bristling out from the rib of the feather. Then if any part of the conductor be touched by a finger, or piece of metal, it will draw off the fire that way, and the feather will immediately shrink; or it will do the same if the point of a needle or wire be held near it, or near the prime conductor; which shews that pointed metals draw off the electric fire. But if the point of a finger, or any piece of round metal be held near the feather, it will come to the finger or metal, and cling round it: and if either of these be moved round the feather, it will bend about, and follow the moving body.

The first part of this experiment shews electric repulsion: and the last part, electric attraction, as in the third, first, and second experiments.

EXPERIMENT XI.

Water Electrified in a Cup.

52. Take a metal cup, that has a bow to it over its top; fill it almost full of water, and hang it upon the prime conductor, as high from the table as can be, and remove every other part of the apparatus to a good distance from it. Then turn the globe by the winch, to electrify the water, and hold a finger, pointing perpendicularly downward, over the middle of the surface of the water, and very near it. The electrified water will then rise up, in the form of a cone, toward the end of the unelectrified finger; which shews that an unelectrified body, if it be of the conducting kind, will attract

an electrified one. In a dark room, a stream of fire will be seen issuing from the water to the finger; which shews that water is a conductor of electric fire. *See* § 3.

EXPERIMENT XII.

The Electrified Water-jet.

53. Hang the leg *A* of a small glass syphon (Fig. 6 of Plate II.) into the water in the cup, the other end *B* of the syphon having been turned a little upward, and drawn out into a small capillary bore. Put your mouth to the end *B*, and draw the air out of the syphon, and then the water will follow, and fall from the syphon in drops. But, turn the globe by the winch, to electrify the water, and it will fly to a good distance from the end *B* of the syphon, in one continued jet, which will have the appearance of fire if the room be darkened. If an unelectrified person puts his finger, or any piece of metal, upon the prime conductor, the fire will immediately cease, and the jet will stop: but when the finger or metal is taken away from the conductor, the fire will appear again, and the jet will fly out as before.

From this it should seem, that when a person's blood circulates too slow, electrifying him would quicken the circulation. And I have heard, that when a vein has been opened by a lancet, and the blood only dropped from it; electrifying the person has caused the blood to run in a brisk stream. But I never saw the experiment tried. The method of electrifying people will be shewn in the 18th experiment.

EXPERIMENT XIII.

A Clock put in Motion by Electricity.

54. Put the end *A* of the crooked wire *A B C* into the hole next above *G* (Fig. 1) in the end of the prime

conductor; and place the wire so, as that its sharp point *C* may be just as high from the table as the great wheel of the clock (Fig. 1, of Plate II.) is. Then place the clock so on the table that the point of the wire may be about an inch from the wings of the wheel; and in such a direction, that if the wire were hollow, and wind were blown through it, the wind might turn the wheel according to the order of the letters *a b c*. Then turn the globe of the electrical machine by the winch, and the clock will be put into motion by the small force of the electric stream thrown off by the point of the wire against the wings of the wheel; and the sun and moon will be carried round the dial-plate (the face of which is represented by Fig. 2,) so as to shew their apparent diurnal motions, the different ages and phases of the moon (as described in § 30,) and the time of her coming to the meridian every day of her age, accounted from any change to the next change after it.

EXPERIMENT XIV.

A simple Orrery put into motion by Electricity.

55. Having set the orrery (§ 31. Fig. 2, of Plate II.) properly, near the prime conductor, and placed the above-mentioned crooked wire so that its point may be even with the great wheel *B*, and tend to turn it in the direction *a b c d;* turn the glass globe of the electrical machine by the winch, and a stream of fire will issue from the wire to the wheel, and turn the whole of the moveable work: by which means the earth *D* will be turned round its axis, from west, by south, to east; and, in each turn of the earth, the index *E* will go round all the 24 hours on the dial-plate *e*. In the time the earth and index turn $29\frac{1}{2}$ times round, the moon *I* will turn once round her axis, shewing all her various phases; and the index *K* will go over all the $29\frac{1}{2}$ days of the moon's age on the plate *k*.

EXPERIMENT XV.

A Model of a Water-mill turned by a stream of Electric Fire.

56. Set the mill (§ 32. Fig. 3, of Plate II.) properly, near the prime conductor, and place the crooked wire so that its point may be directed towards the uppermost side of the great wheel *A*. Then turn the glass globe by the winch, and the stream of fire that issues from the point of the wire will turn the wheel; and, consequently, all the other working parts of the mill.

I have often found, that either of these machines will be put into motion when the point of the crooked wire is four inches from the wings of the great wheel. And yet my electrical machine is far from being one of the strongest kind.

EXPERIMENT XVI.

The luminous Glass, or Aurora Borealis.

57. This is one of the finest of all electrical experiments, and owes its invention to Mr. John Canton.—Take the glass *A a* (Fig. 4, of Plate I.) by either of its ends, and hold the other end to the prime conductor. Then make the room quite dark, and turn the globe of the machine by the winch. On doing this, the glass will be full of electric fire, which will stream and flash, exactly resembling the *Aurora borealis,* or northern lights in the heavens; and the flashing will continue for some time after the glass is removed from the conductor. When the flashing ceases, and you continue to hold the glass by either end in one hand, apply the palm of the other hand to the other end of the glass, and the fire will appear within it again. The method of preparing this glass is shewn in § 25.

The fire is always within the glass, but adheres invisibly to it until it is thrown off therefrom, and put into action by electrifying, or by rubbing. It is plain that it is not the electric fire from the machine that goes through the glass and appears within it; for, after it has been ever so long from the conductor, if it be rubbed on the outside by a dry hand, it will be luminous within. If it were not very nearly exhausted of air, so as to leave the small quantity within it rare and thin, it could not be made luminous either by means of the electrical machine, or by rubbing; which shews that air acts against the electrical fire, and keeps it the longer from flying off, at the surfaces of bodies.[20]

EXPERIMENT XVII

Electrical Sparks taken from the Prime Conductor.

58. While the globe is turned by the winch, the points *I* (Fig. 1, of Plate I.) attract the fire from the globe to the prime conductor, wherein the fire becomes accumulated and condensed, when there is no other conductor therefrom to carry the fire to the ground. But if any person, standing on the floor, holds a knuckle of any finger near the conductor, as suppose about an

Note 20. If electricity be passed through an exhausted receiver or tube gradually, it assumes the appearance of the northern lights, as our Author describes; but, if a considerable electrical accumulation be suddenly transmitted, it will pass through the receiver with all the straightness and brilliance of a falling star. If the receiver is six inches diameter, and fourteen or sixteen inches high, the full charge of a moderate sized jar is necessary to produce this effect, and it occurs most readily when the receiver is but moderately exhausted, so that the rarefied air it contains may have some degree of resistance. The artificial imitation of the two phænomena, therefore, require the same conditions for their production as appear to obtain in nature; for the aurora occurs in the highest parts of the atmosphere, where the air is most rarefied; and the most accurate imitation of its appearance is obtained in the most perfectly exhausted receiver; falling stars take place much lower where the air has more density, and to imitate them, it is necessary to employ a medium that opposes some resistance.

inch from it, the condensed fire will snap from the conductor in large sparks to his knuckle; and give him rather a disagreeable than painful sensation: and as fast as the fire lies to his knuckles, it runs off by his arms and body to the ground. If he holds his knuckle very near the conductor, he will not feel the fire so sharp, because he has it more gradually, and in a constant small stream; and if he puts his finger upon the conductor, he will not feel the fire in the least, although he receives it just as fast from the conductor as it is given thereto by the globe.

EXPERIMENT XVIII.

Electric Sparks taken from the human body.

59. Having warmed the glass-footed stool (§ 28) a little by the fire, and wiped it all over to clear it of dust, set it upon the floor, and let any person stand upon it, holding one end of a chain (or rather of a wire,) the other end of which is hooked to the prime conductor; the chain or wire being held up at some distance from the table, and no chair, table, or person in the room being within a foot of the person who stands on the stool. Then turn the glass globe of the machine by the winch, and all the fire that the prime conductor receives from the globe will be conducted from it by the chain or wire to the person on the stool, and he will be strongly electrified, without feeling any thing from the fire he receives, unless some person who stands on the floor touches him any where with a finger; and if he does, all the fire will snap against his finger from the electrified person, and both these persons will feel it smartly but it will do no harm to either of them. By this method, all the electric fire, which a person receives while he stands on the stool, may be drawn off from any part of his body that is touched by a person standing on the ground. But the person who touches, should

present his finger or knuckle very briskly each time, and withdraw it quickly each time he takes off the spark.

In this experiment, the person on the stool may be considered as part of the prime conductor; for he is connected with it by means of a wire or chain, and the glass feet of the stool cuts off all electric communication between him and the ground; so that he retains the fire till it be drawn off from any part of his body, as it was drawn off from the prime conductor itself in the 16th experiment. And the glass tube *L*, on which the prime conductor is supported, cuts off all electric communication between it and the table. If it were supported by any substance (§ 3) that conducts the electric virtue, no sparks could be taken from it, nor could any thing be electrified by it, for all the electric matter would run from it by the conducting substance to the table and ground, as fast as it received that matter or virtue from the globe.

If a smooth ball of metal be fixed on one end of a long thick wire, and the person who is electrified on the stood holds the other end of the wire in his hand, and touches any other person in the company with the ball, the fire will snap from the ball to that person, and he will feel it smartly; but the person who holds the wire will scarce feel any sensation from the fire.

EXPERIMENT XIX.

The Electric Kiss.

60. Suppose the two above mentioned persons to be a gentleman and a lady. Let either of them be electrified on the glass-footed stool, whilst the other stands at a little distance on the floor, so that the clothes of the one may not touch the clothes of the other. Then, if they incline their heads, and offer to salute each other, the fire will

snap from the lips of the electrified person to those of the other, and will give them both such a smart and mutual rebuff, as will make them separate without being able to accomplish their design, unless they have been apprised of the consequence before, and have resolution enough to bear the smart of the electric fire. In this experiment, nothing but the lips should touch; for if the gentleman puts his hand upon the lady, it will draw off the fire.

EXPERIMENT XX.

Setting Spirits of Wine on Fire.

61. Let one person be electrified, as in the last experiment, while another stands at some distance on the floor. If either of them holds a silver spoon with some rectified spirits of wine in it, and warms the spirits a little, by holding the spoon over the flame of a candle, and the other person then presents the tip of his finger briskly towards the spirits, a snap of electric fire will ensue, which will set the spirits all in a flame directly. The person who presents his finger must withdraw it immediately, lest the flame should hurt him.[21]

EXPERIMENT XXI.

The diverging Electrical Flame.

62. Let the person electrified on the stool hold a sword in his hand, or any other pointed piece of metal that is well polished. Then if the room be darkened, a bluish flame will be seen to issue, in a diverging state, from the point; and continue as long as the globe of the machine is turned by the winch, unless some person standing on the floor touches him who holds the sword; and if this be done, the flame will immediately disap-

Note 21. Ether is much more readily inflamed than spirits of wine, and as such, better adapted for the purpose.

pear, because the person who touches, draws off all the electric virtue from him who holds the sword. The same will happen, if a person standing on the floor puts his finger upon the prime conductor ; but the moment he withdraws his finger the flame will appear again.

EXPERIMENT XXII.

The Diadem of Beatification.

63. Put a hoop of leather that is silvered and lackered round a person's head, and let him be electrified on the glass-footed stool ; then let a person standing on the floor hold the tips of his fingers near the hoop, moving them round and round it, and brisk flashes of electric lightning will come from the hoop to the fingers, and be felt like a gentle cool breeze of wind.

EXPERIMENT XXIII.

Giving a Shock to the Teeth.

64. Let the electrified person hold a piece of money between his teeth, and a person standing on the floor touch it ; the shock will be so strong as will probably make him drop the money, especially if his lips do not touch it.

EXPERIMENT XXIV.

That an electrified Person may be considered as an additional Part to the Prime Conductor.

65. Let the fly *e f g h i k* (Exp. 5) be hung upon the sharp point of the crooked wire *c d* (Fig. 1, of Plate I.) and a person electrified on the glass stool hold the wire by the other end in his hand. Then, as long as the glass globe is turned by the winch, the fly will turn round with as quick a motion as it did when the wire was stuck into the prime conductor, in the 5th experiment.

EXPERIMENT XXV.

Charging and discharging coated glass Jars.

66. Place the jar *A* (§ 23. Fig. 2, of Plate I.) so on the table, that the ball *a*, on the top of its wire, may be about the eighth part of an inch from the ball *G* (Fig. 1,) of the prime conductor. Then turn the glass globe of the machine by the winch, and all the electric fire, which the points *I* take from the globe to the conductor, will fly from its ball *G* to the ball *a* of the jar, and thence it will run down the wire to the lining on the bottom of the jar, and diffuse itself all over the inside of the jar as far as the lining goes, and will be accumulated and condensed there in the glass. Continue turning, as long as you see the fire between the prime conductor and ball *a* of the jar; and when the fire ceases, you may leave off turning, for the jar has got its full charge, and can receive no more, if you should continue to turn ever so long afterward. This done, take hold of the discharger *B* (Fig. 2,) by the middle, and first apply the knob *b* (on the lower end of the discharger) to the outside of the jar near the bottom; and keeping it there, put the upper knob *c* to the ball *a* of the jar-wire, and the jar will be discharged of its fire, with a loud snap; but the person who holds the discharger will feel nothing from the fire.[22]

The jar has no more fire when it is charged than what it had before; for the metal coating conducts just as much fire from its outside to the table and ground, as the prime conductor threw into its inside by the wire and the metal lining; by which means, the inside is electrified *plus* (§ 6) and the outside *minus*. So that what

Note 22. Care should be taken that the electric fluid accumulated on the surface of a charged jar be not too great for the thickness of the glass, as the concussion, in that case, will produce the destruction of the instrument.

we here call charging, is only forcing more fire into the inside than it naturally had, (§ 2 and 4,) whilst the table carries off just as much of the natural quantity from the outside by the coating. And what we call discharging, is only making a conducting communication between the lining and the coating of the jar, by means of the bended wire *B*, through which the accumulated fire flies from the surcharged inside to the vacant outside of the jar, and so restores the equilibrium; which could not have been restored if the outside had not lost as much as was forced into the inside.

When the jar is charged, a person may take hold of it very safely with one hand, by the coating near the bottom, and set it down upon any other part of the table before he discharges it. But he must be careful not to touch the ball *a* with his other hand: for, if he does, he will act the part of a discharger himself, and receive the whole fire of the jar through his arms and breast; which not only will give him a violent shock, but will also endanger the jar, by letting it drop from his hand, and it may be broke by the fall.

In charging the jar, especially if it be large, it should be set upon a pewter plate; that when it is to be discharged, the lower knob of the bended wire *B* may be applied to the edge of the plate, before the upper knob be applied to the ball *a* of the jar wire. For then the fire will be diffused all over the plate, and go equally to all parts of the outside of the jar by the coating. Experience has taught me this—having found, that when all the discharged fire has struck upon one point of the outside, it has made a hole quite through the coating, glass, and lining; and when this happens, the jar is made useless.

I have sometimes found, that although a jar received the fire very freely into its inside from the prime conductor, yet it could not be in the least charged thereby;

for, on applying the discharger *B*, there was no flash. And always, on stripping off the coating from such a jar, I have found the glass to be cracked or rent. So that, all the electric virtue, which the inside had received from the machine, ran through the crack to the outside, and was carried off by the coating and table. This, I think, shews very plainly, that the electric virtue cannot pass through sound glass, unless it comes with a force sufficient to break it, as lightning often breaks glass windows

EXPERIMENT XXVI.

Shewing, that in Charging a Jar, as much Fire is carried off from its outside by the coating, as is thrown into its inside by the lining.

67. Put a crooked wire, as *d e* (Fig. 3, of Plate I.) into a hole in the top of the ball *D*, which is fixed on the top of the bended wire *B* (*See* § 24,) the point *e* of the wire *d e* being made sharp, and of equal height with the top of the great wheel *A* of the mill (Fig. 4, of Plate II.) which, in the 15th experiment, was turned by a stream of electric fire, from the point *C* of the crooked wire (Fig. 6, of Plate I.) when the blunt end *A* was stuck into a hole in the prime conductor. Things being thus prepared, set the jar *A* (Fig. 3, of Plate I.) upon a large pane of glass, dry and free from dust; which will cut off all electric communication between the jar and the table. And let the jar and mill be so placed, that the ball *C* of the jar-wire may be within the eighth part of an inch of the prime conductor, and the wings of the great wheel of the mill about an inch from the point *e* of the additional bended wire *d e*. Then, turn the glass globe of the electrical machine by the winch, to charge the inside of the jar; and the electric fire from the outside will go off from the coating, by the wire *B D d e*, and turn the mill the same way, and with the

same velocity, as it was turned in the 15th experiment by the fire directly from the prime conductor. When the jar has received its full charge, and no more fire appears between the ball *C* and the prime conductor, the mill will stop. But, discharge the jar, as in the foregoing experiment, and begin to charge it again; and then, the mill will begin to go, and continue going till the jar has got its full charge.

This proves, to a demonstration, that electric fire goes as fast from the outside of the jar, as the machine throws fire into the inside. For the wire *B*, that goes from the outside coating to the mill, has no communication either with the inside of the jar or with the prime conductor. And that the outside has parted with all its natural quantity of fire (or at least with as much as the inside had received from the machine,) seeing that the mill stops when the fire ceases to go from the prime conductor into the jar.

If the jar be placed upon the table, without having the pane of glass between it and the table, the mill will not be put into motion by charging the jar; which shews that the fire runs off from its outside to the table, as fast as the machine throws fire into its inside.

EXPERIMENT XXVIII.

Striking à Hole through a Card.

68. Having charged the jar *A* (Fig. 2,) as in the 24th experiment, hold a card with one hand close to the coating of the jar near the bottom. Then apply the lowest knob of the discharger *B* to the card, and keeping it there, put the uppermost knob to the ball of the jar-wire; and the whole contents of the jar will be discharged through the card, and will make a hole through that part of it; and it will have a strong sulphureous, or rather phosphoreal smell.

DR. FRANKLIN has shewn, that electric fire is the very same with that of lightning from the thunder-clouds; for he has drawn it from them, and charged his jars therewith, and found all the effects of discharging to be the same as if the jars had been charged by the electrical machine. No wonder then, if the small quantity that a jar can hold will strike a hole through a card, or even through a quire of paper, if the jar be large, that the lightning from a cloud, whose surface is equal to several hundred acres, should tear trees or destroy buildings, when it breaks upon them. Lightning kills animals and melts metals: the same has been done by electricity. Lightning smells like sulphur or phosphorus where it breaks, and electric fire does the same.

Dr. James Lind at Edinburgh has put up a long rod, with a wire twisted round it, on one of the chimneys of his house, and hooked one end of a long chain to the foot of the rod at the chimney-top, letting the other end go down into the ground. From any convenient part of the chain, he brings a wire to a coated jar in his room. When a thunder-cloud passes over the house, the lightning comes silently from it to the rod, and is conducted down by the wire twisted round it, to the chain, which conducts the greatest part of the lightning silently down to the earth, although a sufficient quantity thereof will go by the cross wire from the chain to his electric jars; and when they are fully charged, no more of the lightning can go that way.—I have seen him charge them by that method, and discharge them in the common way: all the same as when he charged them by his electrical machine.

He has also connected a set of bells (See Exp. 6) after DR. FRANKLIN'S method, with a wire from his chain, and insulated them by hanging the hook *Q* upon a tube of glass. So that whenever a low thunder-cloud goes over his house, the rod draws lightning from the cloud to the bells, which sets them a ringing, as if they were made to ring by electricity.

Persons who are fond of shooting ought never to go out with their guns when there is any appearance of thunder.—For, as all metals attract the lightning, if it should happen to break upon the gun-barrel, the man who carries the gun would be in the most imminent danger of his life. If he sees a thunder-cloud near him, the best thing he could do, would be to set the gun upright on the ground, against any thing which would keep it in that position, and run away from it as fast as he can: and then, if the thunder should happen to break upon the gun-barrel, it would all run down thereby to the ground.

As water is a conductor of lightning, a person, whose hat, wig, and clothes were well wetted, would be in less danger from lightning that broke upon his head; because much of it would run down by his wet clothes to the ground.

None ought to go near trees, or stand below their tops, in the time of thunder: for if it should happen to break upon the top of the tree under which a person then stood, the tree would conduct the lightning to his body.[23]

Persons in a room should always keep as far as they can from the walls, especially from that wall in which the chimney is; because, when the lightning comes down a chimney, it generally spreads about the adjoining wall. And it would be right for persons, in the time of thunder, to put the money out of their pockets and take the buckles out of their shoes. In short, they should then have no kind of metal about them if they can help it.

Note 23. The distance of ten or twelve yards from a tall tree is the most eligible situation that can be selected; for the tree will operate as a conductor, and thus carry the electric fluid to the earth, without producing any mischievous effects.

EXPERIMENT XXVIII.

Striking gold Leaf into Glass.

69. Take two slips of common window-glass, each about an inch broad and four inches long: then take a slip of gold or silver leaf, about the breadth of a straw, and six inches in length; and put it between the glasses lengthwise, in the middle, letting the ends of the leaf hang an inch without the glasses at each end. Tie the glasses close together, by wrapping a strong silk thread round them, and lay them down on the table, so that one end of the metal leaf may be in contact with the coating, at the bottom of a jar, placed so that it may be charged at the prime conductor. Then charge the jar, and having put one end of the discharger upon that part of the leaf that lies without the glass slips at their farthest end from the jar, apply the other end of the discharger to the ball on the top of the jar-wire; and all the fire in the jar will be discharged through the metal leaf. If the slips of glass remain whole, you will see that the leaf is missing in several places; and instead of it, a metallic stain upon both the glasses, exactly alike. When they are taken asunder, you will observe that the leaf has been melted by the electric lightning; and actually driven into the very substance of the glass, as neither *aqua fortis* nor *aqua regia* will take it off.

EXPERIMENT XXIX.

Giving a Person an Electric Shock.

70. Let the person put a finger of one hand to the coating of a charged jar near the bottom, and then put a finger of the other hand to the ball of the jar-wire. He will then act the part of the wire discharger, and receive a shock through his arms and breast. The whole fire in the jar running thence by the wire and his

finger, through that arm and his breast, the nearest way to the coating, by the other arm and finger that touched the outside. The person ought not to grasp the jar by the coating; much less to lift it up from the table: because, in the former case, the shock might make him inadvertently push down the jar; and in the latter, he must have very great resolution if he lets not the jar fall from his hand.

EXPERIMENT XXX.

Confining a Shock to any Part of the Body.

71. Suppose it were required to confine the whole of a shock to that part of the arm which is between the shoulder and elbow. Tie one end of a metal chain to the elbow by a ribbon, or piece of silk cord, and put the other end round the bottom of a jar set to be charged at the prime conductor. Then tie one end of another chain in the same manner to the shoulder, and desire an assistant to take hold of that chain, about a foot from the other end, holding it quite clear of the former chain, and so that he may conveniently strike the prime conductor with the loose end that hangs down from his hand. When the jar is charged, let the assistant strike any part of the prime conductor with the loose end of the chain; this will discharge the jar, and the person to whom the chains are tied will receive the shock, which will only go through the part of his arm between the chains, and he will feel it no where else. For the fire that flies from the jar by one chain will return to it by the other, as it always takes the nearest course that it can find, by the best conductor. And as metal conducts electric fire better than the human body does, the assistant who holds the chain will receive no shock.

If it were required to give a shock to any tooth, or part of the gum; take the machine described in § 33, and represented by Fig. 5, of Plate II. And holding it on the gum, with the tooth between the ends *c* and *f* of the wires *a b c* and *d e f*, hook the chains *g* and *h* on the other ends of their wires; put the other end of the chain *g* round the bottom of a coated jar, and cause an assistant to hold the chain *h*, hanging down from his hand, as in the above experiment; the chains not touching one another, and both of them clear of the table. Then, having charged the jar, desire the assistant to strike the prime conductor with the loose end of the chain *h*; this will discharge the jar, and give the person a shock, which will be felt only in the tooth and gum that is taken in between the wires at *c* and *f*.

EXPERIMENT XXXI.

Giving a Shock to any Number of Persons who desire it.

72. Let all the persons join hands, so as to form a sort of chain; and stand so, that the first person at either end of the chain may hold one end of a wire in the hand that joins not, the other end of that wire being below the bottom of the jar to be charged; and the person at the other end of the chain may touch the prime conductor (when desired) with the hand which the one next him has not hold of. Then charge the jar, and let the last person touch the conductor with his loose hand; which will discharge the jar, and give them all a shock at the same instant.

As all the persons are connected together, they form a complete discharger. The one who holds the wire on which the jar stands, acts the part of the end *b*. (Fig. 2, of Plate I.) of the discharging wire that touches the bottom of the jar: and the person who touches the prime conductor (which is the same in effect as if he had touched the ball *a* of the jar-wire) acts the part of the end *c* of the discharging wire that touches the ball *a*. The reason why all the persons feel the shock at tne same instant may be understood by reading the second, third, and fourth paragraph of the first section.

If a bason of water be placed between every two of the persons who desire to have a shock, they will have no occasion to join hands, nor even to touch one another, but only to dip the fingers of the hands in water that otherwise would have joined. And when the jar is discharged, they will all receive a shock.

And, if there were as many canals of water (each as long as that in St. James's Park) as there are persons who want to take the shock, and these canals so situated as to form a kind of circle, and their neighbouring ends had about three feet of solid ground betwixt them, and persons standing on these intervals of ground should put one of their hands in the water on the right side, and the other hand into the water on the left, it will answer as well as if they had stood close, and joined hands as above. Dr. Watson has given an electric shock to two persons who were two miles distant from each other;[24] and who, by having stop-watches in their hands, found that they felt the shock at the same instant.[25]

EXPERIMENT XXXII.

Giving a Shock by the Magic Picture.

73. Set the face of the picture (§ 27) to the ball *G* of the prime conductor, and turn the globe by the winch to electrify it. Then take it away, and holding it by the top of the frame, in a horizontal position, with the face upward, lay a small piece of gilt metal, made in the form of a crown, upon the head. This done, desire any per-

Note 24. A circuit of four miles in length, composed of a copper wire; has been employed; and yet the motion of the electric fluid has been so rapid, that it has not required any appreciable time for its passage through so great an extent.

Note 25. Phil. Trans. abridged, Vol. X, page 363.—Author.

son to take hold of the foot of the frame with one hand, and take off the crown with the other. In attempting to do this, he will fail of his design; for, the moment he touches the crown, he will receive a strong shock. You must continue to hold by the top of the frame all the while, and will have nothing to fear ; because none of the electric virtue with which the picture was charged can come to your hand. But if you quit your hold, and trust to him who holds by the foot of the frame, the shock will make him quit his hold ; and the picture may be broken by the fall.

The picture-glass being coated by the gilding on both its sides, as far as the pannel in the middle was cut out ; and a communication having been formed on the lower part of the back of the border, by a slip of gilding between that on the back of the glass and on the inside of the foot of the frame ; and the person who holds by that part of the frame touches the gilding there with his fingers, and the crown with his other hand ; he receives the shock after the same manner as if he had touched the coating of a charged jar with one hand, and the ball of the jar-wire with the other ; as in Experiment 28.

EXPERIMENT XXXIII.

The seemingly animated Spider.

74. Take away the crooked wire *d e* (Fig. 3, of Plate I.) from the ball *D*, and place the jar *A* so that its ball *C* may touch the prime conductor : then turn the winch to charge the jar. When it is charged, take hold of it by the coating, below the ring of the wire *B*, and place it so on the table that the cork-spider *E* (§ 24) may hang mid-way between the balls *C* and *D*. The spider will then begin to move from ball to ball, stretching out his legs towards each ball as he approaches

it, and grasping each ball with his legs when he touches it, as if he were really animated.

The inside of the jar is electrified *plus*, or positively, and so is its wire and ball *C*; but the outside of the jar, and the wire *B* with its ball, are electrified *minus*, or negatively. (See Exp. 23.) The positively electrified ball *C* attracts the unelectrified spider, and electrifies him when he touches it: he is then repelled from that ball to the negatively electrified ball *D*; and, by his linen legs, which are conductors, he deposites all the fire upon *D* that he had taken from *C*; and then, as the ball *D* has unelectrified him, he is again attracted by the ball *C*, which yet continues to be electrified positively, because he had carried off but very little fire from the inside of the jar. And thus he will continue to be alternately attracted and repelled, till he has carried all the surcharge of fire from the inside to the outside of the jar; and then, having restored the equilibrium between both sides, he will have done.

The silk thread *a b*, by which the spider is hung, being a non-conductor, makes him retain the electric virtue he received from *C* till he deposits it upon *D*. If he had been hung by a linen thread, he would have stuck by the ball *C*; and as fast as he received the electric virtue therefrom, it would have run off by the thread to the ceiling of the room, and returned gradually from thence by the walls, floor, and table, to the outside of the jar. And then the spider would have left that ball, and hung mid-way at rest between it and the other.

EXPERIMENT XXXIV.

The Use of pointed Metal Rods.

75. Every thing having been removed from the prime conductor, take a small lock of cotton, and draw out part of it into the form of a thread, about an inch long, and

fix the end thereof by a little bit of bees-wax to the undermost side of the conductor, so that it may hang down therefrom, as between *Q* and *X*; and, with both your hands, pull out the rest of the cotton till it be very thin, and hang together by little shreds. Then hold a needle in yonr left hand, keeping the point of it covered with the top of the fore-finger. This done, turn the globe of the electrical machine by the winch, to electrify the cotton, which will make all the parts of it repel each other, and swell out into a larger size than before. Continue turning the winch, and hold the tip of the finger, that covers the needle's point, upward, below the cotton, which will then stretch itself downward to meet your finger. But, withdraw the finger to shew the point of the needle towards the cotton, and the cotton will immediately shrink upward from the point towards the prime conductor. And thus, by alternately covering and uncovering the point of the needle, the cotton will stretch downward and shrink upward, as long as you keep turning the winch. *This is one of* DR. FRANKLIN'S *Experiments.*

When the cotton is replete with electric fire, it expands and stretches itself toward the earth, like a cloud filled with lightning and highly electrified therewith. The unelectrified finger attracts the cotton towards it; as the thunder-cloud, being more highly electrified than the earth below it, is attracted by the earth. The point of the needle draws off the electric virtue from the cotton, and then it naturally re-assumes its former state and figure: so the point of a metal knob draws off the lightning from a thunder cloud, by which the cloud was expanded, and the metal conducts the lightning silently from the clouds down to the ground, and then the cloud being divested of its repulsive lightning, shrinks into a less space by the mutual attraction of its particles which the lightning had left; and thus makes the distance greater between the cloud and building, and a stroke therefore less likely to happen. This shews, that a long metal rod, whose lower end goes down into the ground, and its upper end terminates in a sharp point at some height, (suppose five or six feet) about the top of the highest chimney of a house, will draw down the lightning from a thunder-cloud over the house, gradually and silently, into the earth, so as not to let the lightning accumulate in the cloud, to endanger the house by breaking thereon. Or, if such a cloud comes suddenly over the house, and breaks, the rod will attract all the lightning, and conduct it into the ground, where it will harmlessly disperse into the moist earth; and the house will receive no damage from it. This safety-rod may be bent at different places, to fit the wall and tiling, and may be fixed thereto with iron staples, which will be so far from endangering the wall, that if any lightning were in it, they would draw it out to the rod. I need not tell the public how much the world is indebted to Divine Providence for having inspired DR. FRANKLIN with this invention; and to him for communicating it. Experience has fully proved its utility, and no high building should be without it, especially such as have steeples or spires.

Had there been such a rod to St. Bride's church, it would have been preserved from the great damage it lately sustained by thunder. And, as the method was publicly known before that church was struck, future ages will hardly believe that it would have been repaired again and left without such a safeguard, as it yet continues to be.

These rods may be made of different pieces of metal, screwed into one another, but copper is better than iron, because it will not contract rust and decay in time, as iron does. Or they may be made of leaden bars, about two inches broad and half an inch thick, nailed together at the joinings ; and the top part, which is sharp pointed, may be about two or three feet long, and made of copper. Or, where there are leaden spouts on the sides of the building, the metal needs only to go from the point to any of these spouts, and a rod or bar go from the bottom of the spout into the ground, so that the whole may be done at a very small expence. The part of the metal that goes into the ground should be turned away from the foundation of the building and terminate in moist earth.[27]

It is amazing to think how great a flash of lightning may be accumulated into a small wire, and conducted thereby. In confirmation of this, I shall here take the liberty to transcribe an account from DR. FRANKLIN'S book of *Experiments and Observations on Electricity* ;[28] printed in London, A. D. 1769.

"Being, (says the Doctor) in the town of *Newbury* in *New England*, in *November*[29] last, I was shewn the effect of lightning on their church which had been struck a few months before. The steeple was a square tower of wood reaching seventy feet up from the ground to the place where the bell hung, over which rose a taper spire of wood likewise, reaching seventy feet higher, to the vane of the weathercock. Near the bell was fixed an iron hammer to strike the hours ; and from the tail of the hammer a wire went down through a small gimlet-hole in the floor that the bell stood upon, and through a second floor in like manner ; then, horizontally under and near the plastered ceiling of that second floor, till it came near a plastered wall ; then down by the side of that wall to a clock, which stood about twenty feet

Note 27. An improved metallic preserver has lately been suggested for the use of ships. It consists of thin metallic wire, wove into a cord, which, by its flexibility, allows the mariner to adapt it to any part of the rigging of the vessel.

Note 28. Pages 162, 163, 164.—AUTHOR.

Note 29. Meaning November, in the year 1754.—*Idem* below the bell. The wire was not bigger than a common knitting needle. The spire was split all to pieces by the lightning, and the parts flung in all directions over the square in which the church stood, so that nothing remained above the bell.

"The lightning passed between the hammer and the clock in the above-mentioned wire, without hurting either of the floors, or having any effect upon them, (except making the gimlet-holes, through which the wire passed, a little bigger,) and without hurting the plastered wall, or any of the building, so far as the above-said wire and the pendulum wire of the clock extended; which latter wire was about the thickness of a goose-quill. From the end of the pendulum, quite down to the ground, the building was exceedingly rent and damaged; and some stones in the foundation-wall torn out and thrown to the distance of twenty or thirty feet. No part of the aforesaid long thin wire, between the clock and the hammer could be found, except about two inches that hung to the tail of the hammer, and about as much that was fastened to the clock; the rest being exploded, and its particles dissipated in smoke and air, as gunpowder is by common fire; and had only left a black smutty track on the plastering three or four inches broad, darkest in the middle, and faintest about the edges, all along the ceiling under which it passed, and down the wall. These were the effects and appearances on which I would only make the few following remarks :

1. "That lightning, in its passage through a building, will leave wood, to pass as far as it can in metal, and not enter the wood again till the conductor of metal ceases. And the same I have observed in other instances, as to walls of bricks or stone.

2. "The quantity of lightning that passed through this steeple must have been very great, by its effects on

the lofty spire above the bell, and on the square tower all below the end of the clock pendulum.

3. " Great as this quantity was, it was conducted by a small wire and a clock pendulum, without the least damage to the building so far as they extended.

4. " The pendulum rod, being of a sufficient thickness, conducted the lightning without damage to itself; but the small wire was utterly destroyed.

5. " Though the small wire was itself destroyed, yet it had conducted the lightning with safety to the building.

6. " And from the whole, it seems probable, that if even such a small wire had been extended from the spindle of the vane to the earth before the storm, no damage would have been done to the steeple by that stroke of lightning, though the wire itself had been destroyed." So far DR. FRANKLIN.

EXPERIMENT XXXV.

The Thunder-house.

76. This is the grand electrical experiment. It confirms the truth of DR. FRANKLIN'S method of preserving houses from damage by lightning. And as any other experiment would make but a poor figure if shewn after it, we have reserved it for the last.

The whole of this part of the apparatus (Fig. 5, of Plate I.) being put together as represented by the figure, and as described in the 26th paragraph of the 3d section, with the diagonal wire *a N c* of the square piece of wood *a b c d* lying in the position as shewn in the figure, and the jar *M* set to the prime conductor; charge the jar, and continue turning the globe by the winch till the jar discharges itself with a flash. While the jar is charging, the feathers *H* being electrified, they repel each other, and expand like a thunder-cloud;

but the instant when the jar discharges itself, they shrink and come together, and the square piece *a b c d* is driven out by the flash of electric lightning to a good distance from the gable-board *A*.

The jar discharges itself along the metal chain *K I* and the crooked wire *E w F*; the fire snaps from the ball *F* to the ball *G*, and thence runs down the wire *g d* to *d*; where finding no further metal conductor to carry it onward, it spends its whole force on the square piece *a b c d*, and drives it out of the hole in the board *A*. This shews how dangerous weather-cocks are on the tops of buildings. For, when the thunder breaks upon them, the lightning is collected into the iron spindle of the weather-cock, runs down to the lower end thereof, and finding no further metal conductor, it spreads about, and spends its whole force on that part of the building. If there be iron clamps in the stones, near the foot of the spindle, and near to each other, and these clamps be not connected by wires, the lightning splits the building from clamp to clamp; as was the case at St. Bride's Church-steeple.

Put the square piece of wood *a b c d* into its place again, so that the diagonal wire *a N c* may be in the position *b N d*; and then its ends *a* and *c* will touch the ends *d* and *b* of the two wires *g d* and *b h*, and then the metal conductor *G g d N b h i k* will be complete. This done, turn the winch to charge the jar again; and continue turning till it discharges itself as before: and all the electric fire that it contained will go off with a flash, through the whole metal course *K I w F*, from *F* to *G*, and thence through *g d N b h i k* to the coating of the jar, (which fiery course may be seen in a darkened room) and the square board *a b c d* will remain in its place, without being moved in the least, even if it lies ever so easy in the hole. Which manifestly shews, that complete metal conductors will preserve houses from damage by lightning.

Take off the ball *G*, that the sharp end of the wire within it may point toward the ball *F*. Then charge the jar, and you will be hardly able to make it discharge itself, nor will the feathers *H* expand any thing like what they did before. For the sharp point draws off the electric fire gradually from *F*; and, in a darkened room, it will be seen like a quiescent durable spark on the point of the wire. Which shews, that if a thuder-cloud be over a house, where there is a complete metal conductor, the point will gradually draw down the lightning from the cloud, and so prevent its accumulating therein, sufficient in quantity to break.

The glass tube *C D* insulates the wire *D E w F*, and prevents the electric fire, 'discharged from the jar, from running down to the table in the direction *E D G*; so that it can take no other course than what is shewn in the experiment.[30]

SECTION VI

Medical Electricity

67. A girl, about seven years of age, belonging to the Foundling-hospital, was seized with a rigidity of all the muscles of her body, so as to be felt more like those of a dead corpse than of a living person; her jaws were quite locked up, and she was very much emaciated. After having continued in this dreadful condition for a month, and all the usual medicines had failed, Dr. Watson ordered her to be electrified, which was begun about the middle of November, 1762; and continued, by intervals, till the end of January following, when every muscle in her body was perfectly flexible

Note 30. An ingenious modification of this apparatus is sometimes employed called the *powder-house*. It is so contrived, that when the electric discharge occurs, a quantity of gunpowder is ignited, and the explosion shews the disastrous effects which would arise from the passage of the electric fluid through a magazine or powder-room.

and subservient to her will; so that she could stand, walk, and run, like other children of her age. I happened to be at the Royal Society when the whole account was read there, on the 10th of February, 1763; and it was afterwards published in the 53rd volume of the Philosophical Transactions.

78. Mr. Jallabert, Professor of Mathematics at Geneva, mentions the cure of a palsy that he had performed on the arm of a locksmith, which had continued fifteen years; and was occasioned by the blow of a hammer. The method was, by taking sparks frequently from the paralytic arm, and sometimes sending the electric shock through it.[31]

79. Mr. Wilson, by electricity, cured a woman of a deafness which had continued seventeen years. But he owns that he had tried the same experiment on six other deaf persons without any success.[32]

80. Mr. Lovet, lay-clerk of the cathedral church at Worcester,[33] says, that electricity is almost a specific in all cases of violent pains, of however long continuance in any part of the body; as in obstinate headachs, the toothach, sciatica, and disorders resembling the gout. As it would be unfair in me to transcribe too much of his Essay, I shall refer the reader to the work itself; which appears to be written with candour.

81. The Rev. Mr. Wesley has followed Mr. Lovet's method, and often quotes him. He says, he has scarce known any instance in which electrical shocks over all the body have failed to cure a quotidian or tertian ague.[34] He mentions a case of blindness cured by it, and even of its giving hearing to a man who was born deaf. He further says, it has cured bruises, running sores, a palsy in the tongue, and has brought away

Note 31. Histoire, pt. 3. p. 36.---AUTHOR.

Note 32. Wilson's Treatise on Electricity, p. 207.---*Id.*

Note 33. Lovet's Essay.---*Id.* *Note* 34. Wesley's Desideratum.---*Id.*

gravel from the kidneys. In deep hysterical cases, he advises that the patients be simply electrified, sitting on cakes of rosin, at least half an hour, morning and evening: then begin to take small sparks from them, and afterwards give them shocks, more or less strong, as their cases require; always beginning with gentle shocks. This method seems very rational; and the Rev. Dr. Priestley very justly observes, that as electricity has done so much good in the hands of those who are not physicians, and consequently cannot be supposed always to distinguish between cases where it might be advantageously applied, and where it might not, it is pity but that it were in the hands of able physicians.[35]

82. Dr. Antonius de Haen, in his Ratio Medendi (quoted by Dr. Priestley[36]) one of the most eminent physicians of the present age, says, that a paralysis and trembling of the limbs, from whatever cause it arose, never failed of being relieved by electricity; and he relates one instance of a particular case of this nature, where a person was cured after having received ten shocks. And he assures us, that it has never failed to cure the St. Vitus's dance; but it entirely failed in its application to a gutta serena, and to a strumous neck. He says, that it ought not to be administered to women with child; and Veratti advises, that it be by all means avoided in the venereal disease.

For my own part, being but a young electrician, I can have very little to say with respect to the medical part But, as far as I have had experience, I shall here relate the facts.

83. A woman, who complained much of a pain in her stomach, came to be electrified. I gave her only one shock across the stomach, and the pain immediately

Note 35. Priestley's History of Electricity, page 419 and 422.---AUTHOR.
Note 36. *Idem.*

left her. But, on the next day, she came and told me, I had driven the pain from her stomach into one of her teeth, so that she was almost mad with the toothach. I then gave her a strong shock through her teeth and gums (as described in the 18th experiment) on which the toothach directly left her. I saw her about a week afterward, and she told me that she was quite well, and had no return of her late cause of complaint. I have tried the like experiment on many others since, who were afflicted with the toothach, and it failed only with three; in one of whom I observed the tooth was much spoiled and decayed.

83. A poor woman brought her daughter (who was about eight years of age) to be electrified for the rheumatism, which (as the woman said) had settled upon the child's left knee, and so far taken away all the use of her left leg, that she had been quite lame for a month. I drew several sparks from the knee, which the child told me at first she did not feel; but then she began to feel them more and more acute. I desired her mother to bring her on the next day, which accordingly she did. I drew sparks from the knee for about a quarter of an hour, and from two or three inches both above and below it, till the skin became red and full of pimples; when the child told me she felt it very warm, and could no longer endure the pain that the sparks gave. I then sent a gentle shock through her knee, after that a somewhat greater one, and lastly a pretty strong one, which made the child cry. I gave her twopence for her good courage, and she told me I had now made her quite a gentlewoman, and that she would never cry out again when she was brought to be electrified. On the next day the woman came alone, and told me she had been very agreeably surprised; for her daughter came down stairs[37] to breakfast without any help; but had got a

Note 37. The woman lodged in a garret, but dressed her victuals in the kitchen.—AUTHOR.

sad pain in her stomach, which must have been the rheumatism driven into it from her knee. I desired her to bring the child directly, which she did, and I sent a tolerably strong shock through the child's stomach; on which the pain ceased, and I heard nothing afterwards of any return.

85. A man, whose left shoulder had been dislocated by a fall from his horse, and his arm very much bruised all from the shoulder to the elbow, came about a year after to be electrified. He told me that a surgeon had replaced the bone very well, (as indeed it appeared to be, but the muscles had been so much bruised ,that he had never since been able to move his left hand a foot from his side, without the assistance of the right. I told him, there was but very little reason to hope for any cure by electricity; however, I would try; and so gave him three shocks from the shoulder to the elbow, at the last of which, he held his arm out almost half way into a horizontal position. I desired him to come again the next day, which he did, and I gave him a couple of strong shocks: then he held his arm directly right out; and without the assistance of his right hand, he unbuttoned and buttoned the collar of his shirt with the left. Whether the use of his arm continued or not, I cannot tell; for he went away, and I never saw him nor heard of him again.

86. A woman, who had a hard swelling in her left cheek, which she told me had come on in a very few days, came to be electrified. I had hopes of success, as the complaint was of so short standing. I first drew many sparks from the cheek, and then sent a couple of gentle shocks through it; desiring her to keep it warm afterward by covering it well with a double flannel cloth. She came again on the next day: I found the swelling was then much less and soft. I drew off many sparks again, and gave three shocks, the last of which was pretty strong. She

put on the flannel, went away, and returned the next day; when I found the swelling was so nearly gone, that I thought it needless to repeat the operation.

87. I was once, at Bristol, seized with a sore throat, so that I could not swallow any thing. Mr. Adlam of that city, who is a fine electrician, came and drew many electric sparks from my throat, and in about half an hour after, he did the same again. He staid with me about an hour longer, and before he went away, I could both eat and drink without pain; and had no return of that disorder. I have relieved several persons in such cases, but never in so short a time as Mr. Adlam cured me.

88. A young man, who had well nigh lost his hearing, so that those who spoke to him were obliged to speak very loud, came twice to be electrified. I only drew sparks from his ears, and at the second time he heard very well, and continued to do so afterward. But, since that time, I have tried the experiment on three persons, without the least success; although, after finding no good from the sparks, I sent gentle shocks through each ear alternately, to the opposite side of the throat.

89. In rheumatic cases, I have generally found electricity successful; only by continuing to take sparks from the pained places, till the skin has been red and pimpled, and the patient felt a glowing warmth where the sparks were drawn off. And I have found the same method efficacious in old sprains

90. I was once deceived by a man who had the venereal distemper, (as I afterward found out) who came several times to be electrified, as he said, for the rheumatism; but, on finding him grow worse and worse, I suspected the cause, and questioned him. He strongly denied the fact, even though I told him that if he had that complaint, electrifying would not only hurt him greatly, but might even kill him: and so I sent him away, telling him that he need not come any more.

He then thought proper to apply to a surgeon, who cured him, and told me afterwards what his real case was.

91. I have never tried electricity in paralytic cases, nor in the gout. In the last of these, I never intend to try it until I find that others have done it with success.

92. The ingenious Mr. William Swift, a turner at Greenwich (who makes good electrical machines) has lately cured Mrs. Allmey, a baker's wife in that town, of a hemiphlegia or dead palsy in one side, in which she was so far gone, that boiling water might have been applied from her hand to her shoulder, and from her shoulder to her foot, on that side, without being felt by her. Dr. Green who attended her, ordered Mr. Swift to electrify her, which he accordingly did, sometimes drawing sparks for a whole hour together, and sometimes for two hours, all over where the palsy was, and then giving shocks. Her feeling is now quite restored, she walks very well, and I saw her name, which was well written by the hand of which she had quite lost the use. As this is a very remarkable case, I shall set down the different times of electrifying, and the number of shocks given each time, from the account sent by Mr. Swift, with whom I am very well acquainted. He first gave strong shocks till she began to feel them, and then moderate ones.

Times of electrifying.			Shocks.
Sept. 3, 1769,	for 1	hour	4
5,	1		6
7,	2	hours	12
8,	2		12
9,	1½	hour	12
11,	2	hours	9
12,	2		12
13,	2		12

Times of Electrifying.			Shocks.
Sept. 16	2		9
19	1½	hour	6
23	1½	hour	8
24	2	hours	7
Oct. 3	1½	hour	6
4	1½		6
6	2	hours	5
9	2		7
16	2		4
18	2		4
In all, 18 times,	31½	hours	141 shocks.

94. I lately, by desire, tried electricity for a lady who had a stiffness in the principal muscle on one side of her neck, and a small hard swelling thereon, not so big as a hazel-nut. Her head was turned toward one side, and she could not without pain turn it toward the other. I continued to draw sparks from her neck, a quarter of an hour each day, for a week; but she did not receive the least benefit thereby.

95. I have often drawn sparks from chilblains, and always found they were cured thereby.

96. One time my wife happened to scald her wrist with boiling water I set her upon the glass-footed stool directly, and took sparks from the wrist. In a short time I found the redness of the skin (occasioned by the scald) begin to disappear, and she felt immediate relief. A linen bandage was then put round her wrist, and, in a few hours after, I repeated the operation, which entirely cured her, and there was not the least blister on the skin, nor any difference in its colour from what it had before the accident. If it had not been taken immediately, and before a blister had risen, perhaps electrifying would have been of little or no service.

97. In cases where shocks are given, I should always think it advisable to begin with gentle ones; and, if the disorder will not yield to these, increase them gradually. The shocks may be made as small as the operator pleases; for if he charges the jar but a very little, they will be little accordingly.[38]

Note 38. This branch of the subject is still but in its infancy, though the Editor believes that the application of electricity to the purposes of medicine, will ultimately be found of the greatest importance;—unfortunately, however, the emperical operators who were the first to direct the public attention to the matter, ascribed an almost miraculous effect to its agency; and the medical world, in order to atone for their former credulity, would rob it of that merit which it really possesses.

APPENDIX.

MISCELLANEOUS ELECTRICAL EXPERIMENTS.

To produce Flashes of Electric Light.

If two persons, one standing upon an insulated stool, and communicating with the prime conductor, while the other stands upon the floor, hold in their hands plates of metal, in such a manner that the flat sides of the plates shall be opposite each other at the distance of about two inches; on strongly electrifying the insulated person, dense and frequent flashes of light will be observed between the plates, forming a kind of artificial lightning.

Attraction and Repulsion.

Electric attraction and repulsion may be agreeably shewn by means of a glass tube and feather. When the tube is excited, by being drawn through the hand, or a flannel rubber, the feather, when brought near it, will be attracted, and jump to the tube; then, after taking some time to get fully saturated with the electric matter, (because, being a bad conductor, it can receive it but very slowly,) it will suddenly jump from it, and fly towards the next conductor, to which it will impart the redundant electricity it has acquired. If no other body happen to be in the way, it will tend towards the ground; but by holding under it the electrified tube, it will still be repelled, and therefore suspended, and may be driven to any part of the room, as it will always avoid the tube until it has touched some conducting substance. To continue this experiment for some time, the air should be tolerably dry.

A remarkable circumstance, in performing this experiment, is, that the feather always presents the same side to the glass tube, because, being a bad conductor, as just observed, it is only that side of it which it presents to the tube, that is possessed of the same electricity as the tube.

Insulate two bodies, and charge one of them plus, the other minus. Then suspend between them, by a silken string, an artificial spider, of which the body may be cork and the legs the fibres of feathers; the spider will move from one of the insulated bodies to the other till their charge is equalized.

Place a cap or covering of metal upon the two extremities of a glass tube four or five inches long, and inclose in the tube some saw-dust or pith-balls: then charge one of the plates plus and the other minus, when, as glass is a non-conductor, the equilibrium can only be restored by the saw-dust or balls, which will accordingly jump up and down till the charge of each plate is the same.

Electric Battery.

The electric battery is formed by combining a number of jars in such a way that they may be charged or discharged simultaneously. When a battery is always intended to be used entire, the best construction is, to have a ball at the top of every vertical wire as in a single jar, and to let the horizontal wires pass through these balls both across the length and breadth of the battery, so that they will form squares, at the corners of which are the balls. By this arrangement, the passage of the electric fluid is less interrupted than in the former. The vertical wires may either be supported by corks fixed within the jar, or by a wooden cover.

To render more complete the communication of the outside coatings of the jars with the earth, the compartments of the box are entirely lined with tin-foil; and on one side of the box is a hole, through which passes a metallic hook, which is in contact with the lining of the box, and consequently with outside coatings of the jars. With this hook may be connected a wire communicating with the earth, also any substances through which the charge of the battery is desired to pass.—A brass handle is usually fixed on each side of the wooden box, for the purpose of conveniently moving the battery.

In electrical experiments, it is a general rule to avoid moisture, yet by blowing into jars from the mouth, which is best done through a tube, they are not only less liable to break than before, but they will bear a charge one-third stronger than they would otherwise admit.

A powerful battery may be formed of common green glass bottles, such as are used for wine, porter, &c. They must be coated and furnished with a wire in the same manner as ordinary jars, with this difference, however, that brass fillings must be substituted for the inner coating.

When any difference is known to exist in the strength of the jars employed to form a battery, the weakest jars should be placed on the side furthest from that where the discharge is made. By observing this rule, the late Mr. Brookes found that he could use cracked jars, after having repaired them with the following composition: Take of Spanish white eight ounces; heat it very hot in an iron ladle, to evaporate all the moisture: and when cool, sift it through a lawn sieve; and three ounces of pitch, three-quarters of an ounce of rosin, and half an ounce of bees-wax; combine these ingredients over a gentle fire, stirring them frequently for nearly an hour; then take the composition off the fire, and continue the stirring till it is cold.

Plates or squares of glass, coated on both sides with tin-foil to within about half an inch of the edge, will form a good battery, but they do not retain the charge so long as jars.

The power of a battery is estimated according to the number of square feet which it contains of coated surface.

When a battery is not found to take a charge in the manner expected, it may be suspected that one or more of the jars is cracked, in which case no charge can be given until the accident is repaired. No method has yet been discovered which so effectually prevents jars from being struck through by the electric discharge, as that discovered by Mr. Brookes, whose recipe for mending jars has just been given. His plan consists in placing writing-paper between the tin-foil coating and the jar. The tin-foil is first pasted on the paper, and then the latter upon the glass. After adopting this experiment, he never had a jar struck through, although some that he employed were so large as to contain three gallons each. On the contrary, he found that jars coated with brass filings, mixed up with a cement composed of pitch, rosin, and wax, were struck through with a very low charge. Paper, which answered so well, is neither a good insulator nor conductor: the cement which produced so many disasters is composed of electrics; these facts point to the probable effects of other substances appliedto this purpose.

In discharging electrical jars or batteries, the electric fluid passes in the greatest quantity through the best conductors, and by the shortest course. Thus, if a chain and a wire, communicating with the outward coating, be presented to the knob of a jar, the greater part of the charge will pass by the wire, because the chain is the worse conductor, from want of perfect continuity in the links. When the discharge is made by the chain only, sparks are seen at every link, which would not happen if they were in contact: and as it requires considerable force in stretching the chain, before the sparks cease to be seen, a proof is thus obtained that a strong power of repulsion is to be overcome, before the contact of bodies ensues.

Effects of a Shock sent over the Surface of a Card or Glass.

Put the extremities of two wires upon the surface of a card, so that they may be opposite each other, at the distance of about an inch, then, by connecting one of the wires with the outside of a charged jar, and the other wire with the knob of the jar, the shock will be made to pass over the card; upon which, if very dry, a lucid tract will be observed for some time after the explosion. If a piece of common writing paper be used instead of the card, it will be torn to pieces by the discharge.

The card is an imperfect conductor, and the body over which the discharge is sent, should of course always be an imperfect conductor, or a proper electric. If instead of a card, the discharge be sent over the surface of a piece of glass, this substance will be marked by an indelible track, which generally reaches from the extremity of one of the wires to the extremity of the other. By this process, the glass is very seldom broken by the explosion; but Henley discovered a method of increasing the effect of the explosion upon the glass, which consists in pressing with weights that part of the glass which lies between the two wires, and which will be the path of the shock. He puts first a thick piece of ivory upon the glass, and places upon that ivory a weight at pleasure, from one quarter of an ounce to six pounds. The glass, under this management, is generally shivered into small pieces, and some of it is reduced into an impalpable powder. If it be so thick as to resist the force of the explosion, it is indelibly marked with the most lively prismatic colours. The weight laid upon the glass is always shaken by the explosion, and sometimes thrown quite off the ivory.

To strike Metals into Glass, Stain Paper, &c.

Take two slips of common window-glass, about three inches long, and half an inch wide; put a small slip of gold, silver or brass leaf between them, and tie them together, or press them between the boards of a press, belonging to the universal discharger, leaving out a little of the metallic leaf between the glasses at each end; then send a shock through this metallic leaf, and the force of the explosion will drive part of the metal into so close a contact with the glass, that it cannot be wiped off, or even affected by the menstrua, which otherwise would dissolve it. In this experiment the glasses are often shattered to pieces; but whether they are broken or not, the tinge from the metal will be found in several places, and sometimes through the whole length of both glasses.

If a chain which forms part of a circuit between the two sides of a charged jar, rest upon white paper, after the discharge has been made, the paper will be found stained with a blackish tinge at the juncture of the links. If the charge be considerable, the paper will be burnt through. If the chain repose upon glass, instead of paper, the glass will be stained, though only slightly.

The electric fluid, while passing through a perfect conductor, is invisible; but as the links of a chain are never in perfect contact, unless stretched to an extraordinary degree, in passing through a chain the light appears at every link, and if the links be very small, the shock sent through the chain, will appear in the dark like a continuous line of fire.

Influence of Points on the Electric fluid.

The influence of points, in drawing off the electric fluid has frequently been alluded to in the course of the preceding pages, but to render the fact more conspicuous, we shall notice it among these experiments.

Place one hand upon the outside coating of a charged jar capable of giving a violent shock, and with the other hand hold a sharp-pointed needle, and keeping the point directed towards the knob of the jar, advance it gradually, until the point of the needle touches the knob. This operation discharges the jar ; the pointed conductor employed has therefore had the effect of silently and gradually drawing off the redundant fluid it contained.

The more acute the point of the conductor made use of, the more powerful is its effect. A prime conductor, in which a needle is fastened, or held at a little distance from it, will afford but a feeble spark ; for the electricity communicated to it passes rapidly off into the air.

The extremity of a point receiving the electric fluid, always assumes the appearance of a small globe or star ; when imparting electricity, the appearance from it is that of a stream or pencil.

To pierce a Card, &c. by Electricity.

Take a card, a quire of paper, or any similar material, and place it against the outside coating of a charged jar : keep the card in its situation by pressing against it one knob of the discharging rod, and with the other knob of the rod touch that of the jar. The discharge which will immediately follow, to restore the equilibrium of the two sides of the jar, will be found to have made one or more holes entirely through the card; and each hole will have a bur or raised edge on both sides, unless pressed rather hard against the sides of the jar. This double bur shews that the card is not perforated in the direction of the passage of the fluid, but by the expansion of its substance in every direction.

If, instead of paper, a very thin plate of glass, sealing-wax, rosin, or the like, be interposed between the knob of the discharging rod and the outside coating of the jar, the discharge will break these substances to pieces.

To fire Gunpowder.

Take a small cartridge of paper, or the tube of a quill, and fill either of them with gunpowder; in each end of the cartridge or quill insert a wire, and let the extremities of the wire be about the fifth of an inch from each other. Then send the charge of a jar through the wire, and the gunpowder will take fire. If the gunpowder be mixed with steel filings, it may be fired by a less shock than would otherwise be required.

If gunpowder be placed loosely upon a stand, and the interruption of the wire circuit be in other respects the same, on discharging the jar, the spark will merely scatter without firing it; but even in its loose state, the gunpowder will be fired, if the discharge be made through imperfect conductors. For this reason, water is commonly made part of the circuit, and the electric fluid then strikes the gunpowder with more force. The experiment may be conducted thus: a glass tube, (suppose eight or ten inches long) filled with water, must be corked at each extremity: through one cork, so as to reach a very little way within the water, is inserted the wire communicating with the inside of the jar, through the other cork is inserted another wire, also just reaching into the water, and projecting a little externally above the cork. The jar being placed upon a table on which some gunpowder is laid, and the glass tube held vertically, at a little distance from the jar, with its lower wire among the gunpowder, on making the discharge, the electric fluid has to pass to the outside of the jar through the water and along the table, and the water and table being both imperfect conductors, the gunpowder lying between them is fired by the force of the stream.

To melt Wires.

To melt wire by means of electricity, the wire should be attached by one end of the hook communicating with the inside coating of a battery, and the other end fastened to one limb of the discharging rod; then when the battery is charged, the circuit may be completed with safety and convenience. Thirty square feet of coated surface will fuse the greater part of two feet of wire one-fiftieth of an inch in diameter. If the power of the battery be very considerable, the melted metal will be dispersed and totally lost.

If a wire be kept stretched, while it receives a shock just sufficient to make it red-hot, it will be lengthened by the operation; but when the wire is not stretched, and the power of the battery is insufficient for its fusion, it is often shortened by the explosion. Van Marum shortened a wire eighteen inches long, and one fifty-third of an inch in diameter, a quarter of an inch at a single discharge.

The facility with which metals are fused by electricity is not the same as that of their fusibility by fire. Van Marum caused wires of different metals to be drawn through the same hole, of one thirty-eighth of an inch in diameter, and observed how many inches of each could be melted by the explosion of his battery, which contained 225 feet of coated surface : taking care, in all these experiments, to charge it to the same degree, as ascertained by his electrometer. The results were as follow :

		Inches.		
Of Lead	the discharge melted	120 ;	the same metal melts by fire at	612°Fah.
Tin		120		442° .
Iron		5		21637° .
Gold		3½		5237° .
Silver	not quite	0¼		4717° .
Copper		do.		4587° .
Brass		do.		3807° .

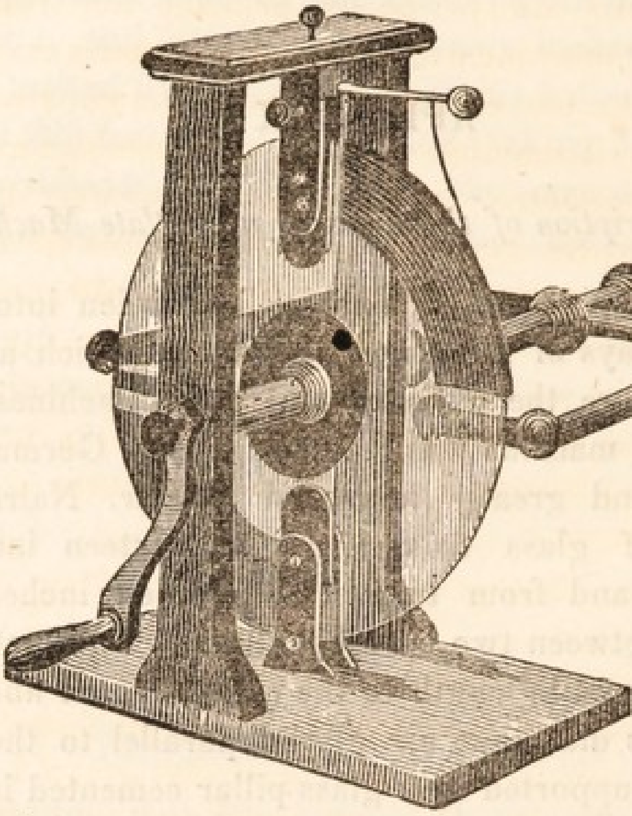
The Electrical Earthquake.

Van Marum, with the battery above mentioned, in order to imitate the phenomena of earthquakes, followed Dr. Priestley's method of making the electrical explosion pass over a board, floating on water, on which several columns of wood were erected ; but this succeeded only once. Reflecting that the electric explosion exerts the greatest lateral force when it passes through imperfect conductors, and that water is probably its principal subterranean conductor, he laid two smooth boards upon each other, moistening with water the sides which were in contact : upon the uppermost he placed pieces of wood in imitation of buildings, the bases of which were three inches long, and 1½ broad. When the charge of the battery was transmitted between the boards, all these were thrown down by the tremulous and undulatory motion of the board on which they stood

APPENDIX B.

A Description of the Cylinder and Plate Machines.

The globe electrical machine has fallen into disuse since the days of Ferguson; the forms which are now employed are the cylinder and plate machines. The cylindrical machine was invented by the German electricians, and greatly improved by Mr. Nairne. A cylinder of glass from eight to sixteen inches in diameter, and from twelve to fourteen inches long, revolves between two upright pillars. Two metal conductors, equal in length to the cylinder, and about one third of its diameter, are placed parallel to the cylinder, each supported by a glass pillar cemented into two transverse pieces of mahogany, which slide in the base of the machine in such a manner, that the conductors still remain parallel to the cylinder, while they are set at any required distance from its surface. To one of the conductors a cushion is fastened: it may be from eight to ten inches long, and from one inch and a quarter to one and three quarters wide. To the upper side of the cushion a flap of oiled silk is attached: it should reach from the cushion over the glass cylinder to within about an inch from the points which are fixed to the opposite conductor. The conductor which carries the rubber is called the negative conductor; and the opposite one to which the points are attached is termed the positive conductor. The sliding base of the negative conductor is fixed in the bottom of the machine by means of an adjusting screw, which regulates also the pressure of the cushion against the cylinder



The plate electrical machine was invented by Dr. Ingenhouz, but greatly improved, indeed first rendered efficient by Mr. Cuthbertson; it consists of a circular plate of glass revolving on an axis which passes through its centre; the excitation is effected by two pairs of cushions placed at opposite parts of the circumference of the plate. The cushions are loosely attached to thin pieces of mahogany, and the pressure upon the plate is adjusted by screws, which pass through the opposite pieces. A brass conductor, supported by a glass arm, is fixed to one pillar, or in large ones to the bottom of the frame of the machine, carrying two branches expanding beyond the periphery of the plate. The extremities of the conductors are furnished with points in order to collect the electricity from the excited surface.

On the comparative merits of these two machines little need be said. It is probable that for experiments of philosophical research, in which convenience and facility must always be of primary importance, the cylindrical machine will be found to possess the greatest advantages; the ease with which the two electricities are produced simultaneously in this machine gives it a decided superiority, in many instances, over the plate machine, where the exhibition of negative electricity is a matter of considerable difficulty. On the other hand, in experiments which require great quantity of the electric fluid, or where, as in public lectures, the loss of power is of less importance than the effect to be produced, the plate machine may be safely said to possess the superiority.

Electrometers.

Instruments for detecting the presence of the electric fluid, and estimating its intensity, are called *electrometers.* They are of great service in almost every branch of electrical enquiry: the most useful and most usual form is the gold-leaf electrometer. Two slips of gold-leaf are suspended from the cap of a glass cylinder, hanging parallel and contiguous when unelectrified, but separating from each other when electrified. Small balls turned from the pith of elder, and suspended by fine threads or silver wire, are sometimes used instead of the slips of gold-leaf. Their susceptibility is not so great, but they are less liable to injury. The most approved and certain method of insulation for electrometers, as well as for other electrical apparatus, was invented by Mr. Singer, and will be found in the Supplement devoted to atmospherical electricity. We proceed to give an account of some experiments relative to minute excitations of the electric fluid, which require the gold-leaf electrometer for their exhibition.

Sulphur being melted and poured into a conical wine-glass, contracts and produces signs of electricity in cooling. A glass rod should be introduced into the sulphur before it has become solid, in order to serve as an insulating handle: when it is cold it may be lifted out of the glass by the rod, and it will be found to communicate signs of electricity to the electrometer. If kept in the glass in which it was originally formed, it will preserve its electrical power for years, and evince its continuance whenever the glass and sulphur are separated.

If powdered chalk be projected from a pair of bellows upon the plate of a gold-leaf electrometer, electrical signs will be produced.

The stone called the tourmalin when heated becomes electrical, and produces very perceptible effects upon the gold-leaf electrometer.

If a small metallic cup containing water is placed upon the plate of the electrometer, and a hot cinder is dropped into the cup, the leaves immediately diverge. The condensation of vapour is also a source of electricity.

In order to determine whether the electricity indicated by the electrometer is positive or negative, it is only necessary to bring an excited glass tube near the plate of the electrometer: if the divergence is increased the electricity indicated is positive, if it is diminished, negative. A stick of sealing-wax may also be used instead of a glass rod, but the phenomena will then, of course, be reversed. Whichever substance is used, care must be taken that it is not too much excited, as when that is the case it will not only neutralize the electricity with which the electrometer is charged, if it be of the opposite kind, but also charge it at the same instant with its own electricity; in this case, the conclusion drawn from the supposition, that the electricity of the electrometer was increased by the approach of the electrified body, would be erroneous.

The luminous phenomena of the electric fluid are considerably diversified, according to the circumstances under which they are produced. It will, therefore, be necessary to examine these circumstances with attention, and to compare them with the general principles of electric action.

Light does not always accompany the excitation of electricity: but when that process is carried on with activity it always appears, and it is brilliant according to the intensity of the excited electricity.

From the nature of the electric fluid no means can be contrived to bring it into comparison with material existencies, from which our notions of quantity and magnitude are entirely derived; our only means of understanding its circumstances are the effects which it produces. In the following pages it will be necessary to speak of the agency by which these effects are produced. As these then are material, it is allowable to suppose the agency which produces them to be itself material. By *fluid*, however, it cannot be intended to convey the same idea as is usually attached to the term: but by the term *electric fluid* we shall understand those particles of matter which produce electrical effects. Nor can it be objected to this definition, that electrical phenomena are probably produced by the vibrations of a fluid which expands itself through all space: if such indeed be the fact, no erroneous conclusions can be drawn from the above definition, as the particles actually vibrating would be the only particles which could be concerned in producing the immediate phenomena, and we might consequently reason respecting them, as though they existed separately and independently. We shall, therefore, consider the electric fluid as possessing both quantity and intensity—terms which have been used by almost every writer on electricity, and which can only be understood upon the supposition, that the electric fluid is material.

Let us now take an insulated conductor, which can be divided into two equal parts without the insulation being destroyed, and electrify it: upon being brought near the gold-leaf electrometer a certain divergence of the leaves will ensue. Having now separated the two portions of the insulated conductor, and applied both of them in succession to the electrometer, the same degree of divergence will take place, as when the two parts were united.

From this it is deduced, that the electric fluid is equally distributed over every part of an insulated conductor. And this deduction also appears evident, from the obvious tendency of the electric fluid to an equilibrium in different conductors when brought near to each other: from which we may infer, that it will spread itself equally in the same conductor.

Let us now investigate the effects produced, when the conducting *surface* is increased or diminished, whilst the electricity remains the same. For this purpose, insulate a smooth metal cup with rounded edges, and in the cup place a smooth metallic chain free from sharp edges or points: let a silk thread, passing over a pulley fixed above the cap, be attached to one end of the chain, so that the chain may be raised out of the cup without destroying the insulation. Attach a pith ball electrometer to the cup and electrify it: then it will be found that when the chain is raised from the cup, the balls will approach each other: when the chain is lowered into the cup the balls will assume their original position.

In this experiment the solidity of the cup and chain remained the same, the surface exposed to the atmosphere was altered. We may therefore infer, that a change of electrical intensity accompanies a change of surface.

Now, if two cylinders of equal surface, the one of solid metal, the other of metallic plate, be electrified by the same number of turns of the same machine, their effects upon the electrometer, the intensity of the sparks taken from them, and all the phenomena which they exhibit, will be nearly equal : but if the metal of the solid cylinder be beaten out into plates, and a large cylinder made from them, the effects produced by the machine upon the large and small hollow cylinders will be found to be very different. The spark will be much stronger, and the effect upon the electrometer more considerable, from the small than from the large cylinder, after an equal number of turns of the machine.

From these experiments we may fairly infer, that the electrical fluid spreads itself only upon the surfaces of insulated conductors. Whether it penetrates the substance whilst actually in its passage through a conductor, is not so easily determined. The fact now deduced will be sufficient for our present purpose. In the following illustrations the quantity of electricity will be supposed to be proportionate to the surface of the insulated conductor, and consequently, the intensity inversely proportionate to the surface. This law, although not strictly demonstrated, appears to agree very nearly with the phenomena of electrified bodies. This hypothesis was maintained by Mr. Cavendish.

If two spheres be connected together by a conducting substance and electrified, they will of course have the same intensity ; but if the spheres be of unequal size, the atmosphere of the smallest will extend the farthest ; and it is probably for this reason that a longer spark can be drawn from a small ball annexed to the side of the conductor, than from the conductor itself. For this reason also, a point allows of the rapid dispersion of the electric fluid, and the smaller its dimensions the more rapidly will it receive or transmit electricity. From the probable law of electric distribution, stated above, it follows, that the larger any insulated conductor is, the higher must be the charge given to it, in order to make a spark drawn from it pass through a given distance.

The following experiments will illustrate the changes produced in electric light by alterations in the size and shape of the conductors, between which the fluid passes.

EXPERIMENT I.

Present a brass ball, of three inches diameter, to the positive conductor of a powerful electrical machine: brilliant sparks of white light will be observed to pass between them, accompanied with a loud snapping noise.

EXPERIMENT II.

Fix a ball of an inch and a half diameter, to the conductor, so as to project three or four inches from it: present the large ball to it, and much larger sparks will be obtained than from the conductor itself; but they will be much less brilliant, and of a zig-zag form.

EXPERIMENT III.

Substitute a small ball for that fixed to the conductor in the last experiment: the electric fluid will now pass to a greater distance, but in the form of a divided brush of rays faintly luminous, and producing little noise: this brush will even occur with larger balls if the machine is very powerful.

In order to make experiments on the influence of gaseous mediums upon electrical light, a simple apparatus is required: a globe of glass about four inches in diameter, having two necks capped with brass; to one of the necks is screwed a stop-cock with a wire and ball projecting into the globe; another ball is attached to a wire which slides through a collar of leathers screwed to the other cap. The apparatus may be exhausted by connecting the stop-cock with an air pump, and the different gases introduced into it, or the air which it contains may be condensed: in this manner the effect of every modification of gaseous medium upon the electric spark taken between the two balls may be observed. In condensed air, the light is white and brilliant; in uncondensed air, divided and faint; in rarefied air, of a dilute red or purple colour. The effect of gases appears to be proportionate to their density; in carbonic acid gas, the spark is white and vivid; in hydrogen gas, it is red and faint.

Metallic conductors transmit electricity without any luminous appearance, provided they are of sufficient size, and perfectly continuous. But if there is the slightest separation in any part of their length, at that point where the disunion takes place a spark will be perceived, upon the electric fluid being directed through them. On this principle various devices are formed, by pasting a narrow band of tin-foil on glass in the required form, and cutting it across with a pen-knife, where it is intended that sparks should appear. If an interrupted conductor of this kind be pasted round a glass tube, in a spiral direction, and one end of the tube be held in the hand, and the other presented to the conductor of the machine, a spiral line of brilliant sparks will be seen to surround the tube. On the same principle luminous words are formed; but the strips are then generally pasted parallel to each other, upon a flat surface of glass. Where great extent is required, *pasteboard* may be substituted for glass, without at all injuring the effect. On this principle an ingenious electrician has invented a plan for representing the various constellations with great brilliancy. The positions of the stars are to be laid down upon pasteboard, and strips of tin-foil pasted down in such a manner as to form a long conductor, covering the situations of all the stars to be represented: at these points the tin-foil is cut away, as in the preceding experiment: in order to give the appearance of the different *magnitudes* of the stars, thin pieces of paper are to be pasted over the points of disjunction; for a star of the second magnitude, one fold might be applied, for one of the third two folds, &c.

APPENDIX D.

On the Electrical Battery.

The most usual form in which accumulated electricity is employed, is that obtained by the use of the Leyden phial: it therefore becomes necessary to have a variety of coated jars; for although the same intensity may be obtained from every jar of equal thickness, the quantity will depend upon the extent of the surface, and the quantity is, in many electrical experiments, a consideration of great importance.

Very large jars cannot be obtained: the largest which are ever manufactured, expose a surface of little more than six square feet. This is quite inadequate to many purposes, when great electric power is required; it becomes therefore necessary to combine several jars together, so that they may be charged or discharged at once as a single jar. Such a combination is called an electric battery; and it is obvious, that by increasing the number of jars any extent of coated surface may be obtained.

The structure of an electric battery should be simple, for its parts are liable to derangement: a jar sometimes breaks by a spontaneous explosion, and until it is removed, and replaced by another, the battery is useless. The jars are usually placed in a box with thin partitions, to prevent their coming in contact with each other. The bottom of the box inside is lined with tin-foil; the outer coatings of the jars are therefore kept in conducting communication with each other. If there are twelve jars, they may be placed in three rows of four each: every jar having its charging wire terminated by a brass ring instead of a ball, as in a jar intended to be used separately. A brass rod, with balls at its extremities, is to be passed through the rings in each row, in order to connect the inner coatings together: two shorter rods being laid across these, the whole inner coating will be connected: as the short rods are moveable, either four jars, eight jars, or the whole battery may be employed, according to the nature of the experiment.

A battery is charged and discharged in the same manner as a single jar: it is charged by bringing the wire of its internal coating in contact with the positive conductor of the electrical machine, whilst the outer coating is connected with the earth: it is discharged by connecting the outer and inner coatings with the discharging rod, or any other conductor.

The height of the uncoated rim of the jar should be proportionate to its size: with a small jar two, or two and a half inches are sufficient, the coated surfaces being then separated by an interval of five inches: with larger jars a rim of about three and a half inches is usually adequate.

After having described the modes of obtaining accumulations of the electric fluid, it is necessary to obtain some mode of measuring the intensity thus produced. The *quadrant electrometer* is frequently applied with advantage to this purpose: it consists of a brass stem, which can be fixed into small holes made in the conductor of the electrical machine, and in various parts of electrical apparatus; this stem carries a *graduated quadrant* of ivory; at the centre of the quadrant is fixed a pivot upon which revolves a thin slip of cane, serving as an index, and having at its other extremity a pith-ball. When the electrometer is unelectrified, the index hangs parallel to the stem and cuts the quadrant at zero. When the apparatus is electrified, the light ball recedes from the stem, and the intensity is inferred from the degree of the quadrant cut by the index. It is also termed Henley's electrometer, from the name of its inventor.

It is evident that this electrometer is applicable as well to the battery, as to the conductor of a machine, as the intensity alone is required to be indicated in each case.

Lane's discharging electrometer consists of two balls of equal size, one connected with the inside of the jar, the other insulated opposite to the first, but capable of being placed at any distance from it. The insulated ball is connected by means of a conductor with the outer coating; the intensity of the discharge is, therefore determined by the distance at which these balls are placed. The principal inconvenience in the use of this electrometer arises from the circumstance of small particles of dust intervening between the two balls, by which the charge is imperceptibly carried off, and the indications of the instrument rendered fallacious.

The most useful and accurate electrometer for batteries is that invented by Mr. Cuthbertson: it consists of a metal rod, about thirteen inches long, terminated by balls at each extremity, and balanced upon a knife-edge in the manner of a scale-beam. One arm of the rod is graduated, and has a brass slider upon it which loads the arm, according to the division to which it is set, from one grain to sixty. The ball of the graduated arm rests upon a similar ball which is supported by a bent metal tube from the same insulating stand; and at four inches distance below the opposite extremity another insulated ball is placed, which is to be connected with the outside of the jar or battery. Now when the metallic stand is connected with an electrified conductor, or the inside of a charged jar, there will be an attraction between the extremity of the balance and the lower insulated ball, since they will be in different electrical states : when this force of attraction exceeds the weight with which the opposite arm is loaded, the attracted arm of the balance will descend, and discharge its electricity upon the lower ball. This instrument is frequently surmounted by a quadrant electrometer, in order to indicate the *progress* of the charge, as that is not shewn by the action of the balance electrometer itself.

It must be remarked, that all these electrometers indicate only the *intensity* of the accumulated electricity : its quantity must be estimated from the comparative *extent* of the coated surface, or from an examination of the effects produced by different batteries, and is therefore not to be accurately appreciated.

To transmit a charge from a battery with certainty and precision, an ingenious apparatus has been contrived ; it is well known by the name of the universal discharger : it was invented by Mr. Henley. It consists of a mahogany board, fourteen inches long, and four wide, having a socket in the centre, to which may be adapted either a small table with a slip of ivory let into the sur face, or a mahogany press. Two glass pillars are cemented into the mahogany base at equal distances from the central socket. They are each surmounted with a universal joint, carrying a spring tube, through which two sliding wires are passed. The body through which the charge is to be passed is placed on the table, or screwed in the press, which is then fixed into the socket. The sliding wires are then brought into contact with its opposite sides : one is connected with the exterior coating of the battery, and the other with the discharging rod, or a discharging electrometer. In this manner the charge is directed through the substance with great precision.

APPENDIX E.

On the Chemical Effects of Electricity.

The agency of electricity in producing chemical changes, is very remarkable, and extended in its operations. The most obvious and simple are the production of light and heat: these may possibly arise from the rapid motions of the electric fluid through particles of other matter; for both these phenomena are observed during the sudden mechanical compression of all elastic bodies. The simple motion of electricity through air is accompanied by a rise of temperature, as may be observed by placing a thermometer between two balls of wood, and passing sparks from the prime conductor between them. In its concentrated state, electricity is capable of inflaming almost all combustible bodies, if it is passed through a stratum of air in contact with them in the form of a spark; and any idea of the direct agency of caloric in the production of these effects, may be obviated by the transmitting conductors being formed of substances which would absorb it.

EXPERIMENT I.

Dry the outside of a wine glass nearly filled with cold water, so that its stem may serve as an insulating stand; on the surface of the water pour a stratum of ether, connect the water by means of a wire with the conductor of the electrical machine: when the handle is turned, a spark may be taken from the ether by a brass ball held in the hand, and the ether will be inflamed.

The same effect will take place, if a series of glasses, filled with freezing mixtures, and connected by wires are employed to transmit the electric fluid from the machine to the water: so that it is evident that the absorbing power of the intervening conductor does not destroy the power of the spark in producing heat.

EXPERIMENT II.

Fill a flat porcelain dish with water, and strew over the surface a quantity of powdered resin : place two wires at the opposite sides of the dish at about five inches distance from each other : pass the charge of a jar from one wire to the other, and the resin in the track of the explosion will be inflamed.

This experiment may be varied by strewing powdered resin upon a small quantity of cotton wool tied round the knob of the discharging rod ; when the discharge is made, the resin and cotton will be inflamed.

The most remarkable effects of combustion produced by electricity are, the results of its action upon metal. These effects were first observed by Dr. Franklin : his experiments were followed by those of Mr. Kimmersly and Beccaria, and have since been investigated and extended with great success by Mr. Brook, Dr. Van Marum, and Mr. Cuthbertson. Some of these effects have already been noticed by Ferguson, which it will not now be necessary to recapitulate. We therefore proceed to give those experiments which appear to throw most light upon this part of the subject. In all of the following experiments, Cuthbertson's electrometer should be employed to regulate the charge.

EXPERIMENT III.

Arrange two inches of pendulum wire in the circuit between the lower insulated ball of the electrometer and the external coating of the jar. Set the slider on the graduated arm of the electrometer to fifteen grains. The machine is then to be put in motion, and when the intensity of the charge exceeds the resistance of fifteen grains, the beam of the electrometer will descend, and the charge passing through the two inches of wire, will render it red hot and melt it into balls.

EXPERIMENT IV.

The arrangements in this experiment are to be the same as in the last: in order, however, to avoid the danger of fracturing the jar, adapt a paper rim to the inside, in such a manner as to reach about an inch above the internal coating. Eight inches of wire being placed in the circuit, the slider is to be set at thirty grains, and the turning of the machine resumed. When the charge is sufficiently intense, the beam of the electrometer will descend, and the charge will melt the eight inches of wire with the same appearances as the two inches in the last experiment.

EXPERIMENT V.

Arrange eight inches of wire in the circuit as in the last experiment; but instead of one jar charged to thirty grains, now employ two charges to fifteen grains. The wire will be melted in exactly the same manner as before: it therefore appears that the effect is equally increased by doubling the *extent of coated surface*, or the *intensity of the charge*.

From many experiments of this kind, it has been concluded by Mr. Brook and Mr. Cuthbertson, that the action of electricity on wires increases as the square of increased power; since *two* jars charged to any degree will melt four times the length of wire melted by *one* jar charged to the same degree.

This law is not applicable when any considerable difference exists between the thicknesses of the jars employed: as thick jars display the same intensity with a comparatively small quantity of electricity, and consequently have less power in melting wires. Mr. Singer mentions the circumstance of a very large jar in his possession, which, from the extent of its coated surface, should have melted three feet of wire, with a charge of thirty grains: but from its limited electrical capacity in consequence of extreme thickness, it will melt only eighteen inches. This is correspondent to the conclusion drawn by Mr. Cavendish, that the quantities of electricity required to charge different jars of the same extent of coated surface, will be in the inverse proportion of their thickness.

The conversion of metallic bodies into oxides, is a circumstance of considerable interest: these combinations are always produced when the quantity of electricity passed through a metallic body is sufficient for its ignition. The most perfect series of experiments which has been made upon this subject is that of Mr. Cuthbertson. His apparatus consisted of an air tight glass cylinder, which was furnished with brass caps at each extremity; at one end, within the cylinder, is fixed a small roller, upon which a quantity of the wire to be deflagrated, attached to a pack-thread, is coiled. A brass tube, about three inches long, is screwed into the upper cap, and through this tube the wire and pack-thread are passed by means of a long needle. The tube is filled with hogs'-lard secured by cork, so that the pack-thread and wire pass through it air-tight. The wire is by this means extended in the centre of the receiver, and when one length is exploded, another may be drawn forwards by means of the pack-thread to which the wire is attached at intervals of four inches: and thus many lengths of wire may be successively drawn forwards without opening the receiver. In order to examine the quantity of air absorbed during the deflagration of a certain length of wire, a glass tube about ten inches long may be screwed on to the lower end of the stop-cock, the open end being immersed in a basin of mercury and the stop-cock turned, the rise of the quicksilver in the tube will determine the quantity of air absorbed.

If the air remaining in the receiver be examined after a sufficient number of explosions, it will be found to have lost a portion of its oxygen: and if the receiver be filled with hydrogen or nitrogen, instead of atmospheric air, no chemical change in the metal will take place; but it will simply be fused and very minutely subdivided.

In order to oxidize wires, a more powerful battery is required than for their fusion; and the quantities of electricity required are not the same for each metal. The following table is given by Mr. Singer of the charges necessary for the fusion of given lengths of various metals. The oxides were received upon paper or glass fixed at about an eighth of an inch distance from the wire.

The length of the wire exploded in each experiment was five inches.

	Diameter of the wire in parts of an inch.	Charge of the electrometer.	Colours of the figures on paper.
Gold wire	$\frac{1}{180}$	18	Purple and brown.
Silver wire	$\frac{1}{180}$	18	Grey, brown, and green.
Platina wire	$\frac{1}{180}$	13	Grey and light brown.
Copper wire	$\frac{1}{180}$	12	Green, yellow, and brown.
Iron wire	$\frac{1}{180}$	12	Light brown.
Tin wire	$\frac{1}{180}$	11	Yellow and grey.
Zinc wire	$\frac{1}{180}$	17	Dark brown.
Lead wire	$\frac{1}{180}$	10	Brown, blue, and grey.
Brass wire	$\frac{1}{180}$	12	Purple and brown.

Brass wire is sometimes decomposed by the discharge, the copper and zinc being separated from each other, and appearing in their distinct metallic colours when the explosion is made over a strip of glass. The figures of all the metallic oxides are usually more beautiful when impressed on glass, than paper, but their colours are less permanent.

The same electrical agency which affects these compositions, is also able to restore the oxides to their natural states: for this purpose a very simple apparatus is sufficient.

EXPERIMENT VI.

Place in a glass tube some oxide of tin, so that when the tube is laid horizontally, the oxide may cover about half an inch of its lower internal surface. Place the tube on the table of the universal discharger, and introduce the pointed wires into its opposite ends, so that the portion of oxide may remain between them. Pass several strong charges in succession through the tube, replacing the oxide, should it be disturbed by the explosions. If the charges are sufficiently powerful, a part of the tube will soon become stained with metallic tin, which has been revived by the action of the transmitted electricity.

Other metallic oxides may be revived in the same way: vermillion, which consists of sulphur and mercury, will be decomposed with much facility: the charge of a very moderate sized jar being sufficient to separate the mercury.

Various fluids are decomposed by the electric spark. Water is resolved into oxygen and hydrogen, in the proportion of two measures of the latter to one of the former. The experiment was first made by a society of Dutch chemists, assisted by Mr. Cuthbertson: as then performed it was very laborious and tedious, but it has been much facilitated by an arrangement of Dr. Wollaston's. Two very fine wires of gold and platina are inserted into capillary tubes; and the glass is softened by heat until it adheres to the point and covers it. The glass is then ground away, until the point of wire becomes visible through a microscope. A series of sparks, being passed under water between two wires prepared in this manner, a series of minute bubbles arise from the points of the wires which may be collected in a small inverted receiver, and afterwards exploded: it is to be observed, however, that a considerable length of time is necessary in order to produce a sufficient quantity for this purpose. Dr. Wollaston found that the rapidity of the decomposition was inversely, as the size of the point exposed.

With less perfect conductors, as oils, alcohol, and ether, this precaution is unnecessary: they may be decomposed in a glass tube standing in a metal dish, the sparks being taken from the bottom of the dish to a platina wire passed through the upper end of the tube; the gas produced will rise into the tube which serves as a receiver.

APPENDIX F.

On Atmospherical Electricity.

Little progress having been made in the theory of the electrical phenomena of the atmosphere since the time of our Author, it only remains here to describe the apparatus which is most accurate and useful for making meterological experiments. In all these instruments good insulation is absolutely indispensable; by far the most perfect method of obtaining this, is that proposed by Mr. Singer, and of which we shall give his own description.

"Reflecting that the perfection of insulators is constantly diminished by the deposition of moisture on their surfaces, and that this moisture exists therein diffused as one gas mixed with another, it seemed to follow, that if the contact of the atmosphere with the insulators was less free, their insulation would be longer preserved, as the transition of moisture from it to them would be necessarily retarded. It was obvious that this might be effected by inclosing the insulator within a narrow channel, as the air in contact with it would be then limited in quantity, and little disposed to motion; for all gases communicate slowly with each other when separated by narrow tubes, and slower in proportion as these are less in diameter, and of greater extent.

The application of this principle to the perfection of the gold-leaf electrometer, was the first trial of its excellence, and the result was the most satisfactory demonstration of its utility.

The instrument is constructed as usual, with a glass cylinder surmounted by a wooden or a metal cap. The insulation is made to depend on a glass tube of four inches long, and one-fourth of an inch internal diameter, covered both on the inside and outside with sealing-wax, and having a brass wire of a sixteenth or twelfth of an inch thick and five inches long, passing through its axis so as to be perfectly free from contact with any part of the tube, and at the same time defending its inside from dust. To the lower part of the wire the gold leaves are fastened. The glass tube passes through the centre of the usual cap of the electrometer, and is cemented into it at about the middle of its length. When this construction is considered, it will be evident that the insulation of the wires, and consequently of the gold-leaves will be preserved, until the *inside* as well as the *outside* of the glass tube is coated with moisture; but so effectually does the arrangement preclude this, that some of the electrometers which were constructed in 1810, and have never yet been warmed or wiped, have still apparently the same insulating power as at first.

THE END.

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CONTENTS.

Amber, electrical properties of, 5.
Amalgam, how to make, 23.
Animated spider, 52.
Attraction, electric, 26.
Attraction and repulsion illustrated, 69.
Atmospherical electricity, 98.
Aurora Borealis, 36.

Battery, electric, 70—74, 88.
Beatification, diadem of, 41.
Buildings, how to preserve them from lightning, 25.
Brookes, Mr. cracked jars employed by, 71.

Card, how to perforate, 45.
Chemical effects of electricity, 92.
Chime, electrical, 13, 29.
Charging and discharging jars, 42.
Cohesion, electrical, 8.
Clock, electrical, 19, 34.
Cuthbertson's electrometer described, 90.
Cushion, its use, 11, 80.
Cures by electricity, 61, 68.
Cup, water electrified in, 33.

Diadem of beatification, 41.
Du Fay, hypothesis of, 5.

Earthquake, electrical, 78.
Electrical machine, 11, 80, 81.
Electrometers, how to construct, 81.
Electricity, origin of the word defined, 5.
Electrics, what, 7.

Feather electrified, 33.
Fire, electric, what, 6.
Flame, electrical, 40.
Fly, electrical, 28.
Flashes of electrical light, how to produce, 69.

Gilbert, Dr. the first who possessed any electrical apparatus, 5.
Gold leaf, how to strike into glass, 48.
Gunpowder, how to fire, 76.
Guns, liable to attract lightning, 47.

Henley's universal discharger, 91.
Hole through a card, how to strike, 45.
Human body, sparks from, 38.

Jallabert, Mr. cure of palsy by, 61.
Jones, Messrs. their improved apparatus, 11.

Lane's discharging electrometer, 90.
Leyden jar, 14.
Lind, Dr. James, conducting rod by, 46.
Luminous glass, 36.

Machine, electrical, examined, 11, 80, 81.
——— plate, mode of constructing, 80.
Magical picture, 17, 51.
Metal rods, their use, 53.
Minus, its meaning with reference to electricity explained, 8.
Medical electricity, 60.
Mill, electrical, 21.

Newbury, church at, damaged by lightning, 56.
Northern lights, 37.
Non-electrics, their nature explained, 7.

Oxides formed by electricity, 95.
Orrery, electrical, 20, 35.

Picture, magical, 17.
Pith balls, 32.
Plate machine described, 79;—its construction, 80.
Plus, the word defined, 7.
Points, metal, their peculiar electrical property, 10.
——, their influence on the electric fluid, 75.
Prime conductor, its use, 12.

Repulsion, electric, 27.

Spirits of wine, how to fire, 40.
Spider, animated, 52.
Stool, electrical, 18, 38.
Streams of electric fire, mode of drawing, 31.
Stockings electrified, 8.
St. Bride's Church, accident from lightning at, 55.
Symmer, phœnomenon alluded to by, 8.

Teeth, mode of communicating a shock to, 41.
Thales, the Milesian, experiment by, 5.
Theophrastus, electrical discovery by, 5.
Thunder-house, 16, 58.
Tooth-ache, instrument to cure, 22.
Trees, dangerous in a thunder-storm, 47.

Universal discharger, 91.

Water electrified in a cup, 33.
Water wheel, electrical, 18, 36.
Wine, spirits of, how to fire, 40.
Wire, how to melt by electricity, 77.
Wollaston, Dr. apparatus for decomposing water by electricity, 97.
