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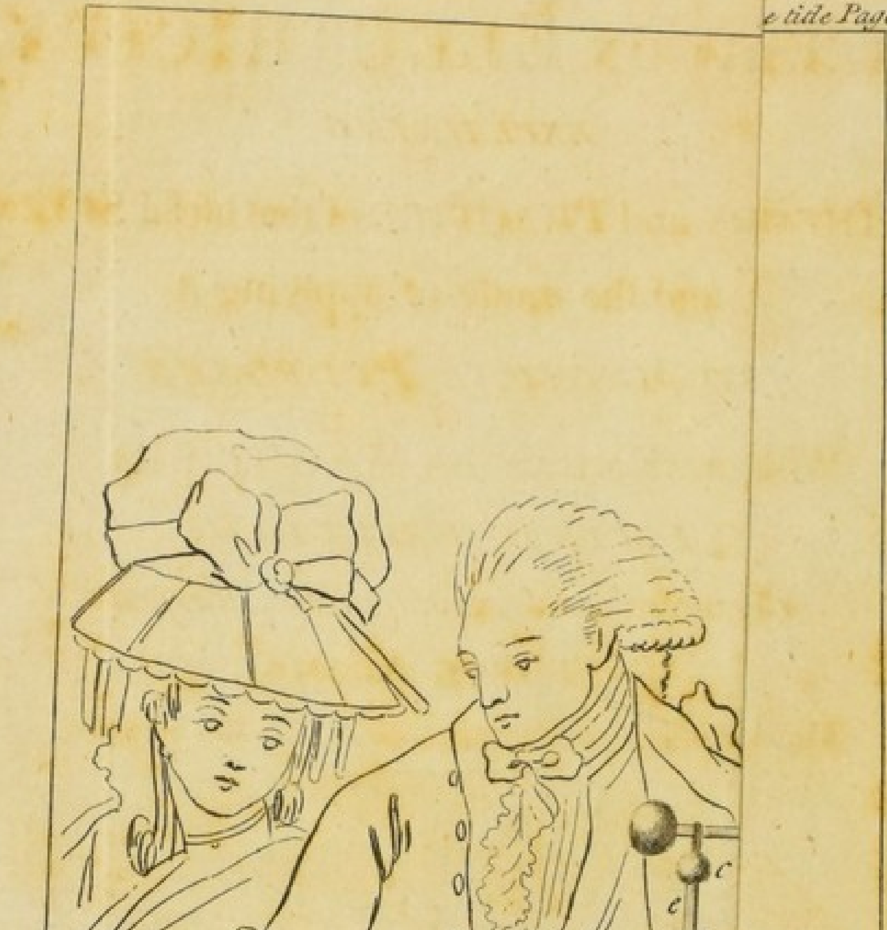

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AN

ESSAY ON ELECTRICITY,

EXPLAINING

The THEORY and PRACTICE of that useful SCIENCE;

and the mode of applying it

TO MEDICAL PURPOSES.

With an ESSAY on MAGNETISM.

THIRD EDITION

Corrected and considerably enlarged

By GEORGE ADAMS,

Mathematical Instrument Maker to His Majesty.

LONDON:

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PREFACE.

PREFACE.

IT may be eaſily perceived by the title of this work, that it is not offered to the public as a finiſhed piece on the ſubject. To treat of the theory and practice of electricity, in the fulleſt manner, would require a larger treatiſe, and employ more time than I can devote to a work of this kind.

The ſcience of electricity is now generally acknowledged to be uſeful and important; and there is great reaſon to think, that at a future period it will be looked up to as the ſource from whence the principles and properties of natural philoſophy muſt be derived. It's utility to man will not be inferior to it's dignity as a ſcience.

I have not attempted to trace electricity from it's firſt rude beginnings, or to follow the mind of man in it's various and irregular wanderings, in ſearch of the laws by which it acts, and the ſource from whence it is derived, as this has been ſo well executed by Dr. Prieſtley. Our view of things is ſo circumſcribed, and the myſteries of nature ſo profound, that it is not eaſy for us to determine, whether the received theory is founded on the baſis of truth, and conformable to nature, or whether we ſhall be conſidered, by future philoſophers, as mere children, amuſed and ſatisfied with imperfect opinions and ill-digeſted theories. When a variety of things are mixed together, which have little or no connection, they naturally create confuſion. It has been my endeavour, in the following eſſay, to collect and arrange, in a methodical and conciſe manner, the eſſential parts of electricity, by theſe means to render it's application eaſy, pleaſant, and obvious to the young practitioner; and by bringing together experiments of the ſame kind, make them mutually illuſtrate each other, and thus point out the ſtrength, or diſcover the weakneſs, of the theories that have been deduced from them. Though the nature and confined limits of my plan did not admit of much variety of obſervation, or a formal enumeration of every particular, yet few things, I hope, of uſe and importance have been omitted.

As I do not wiſh to incur the imputation of plagiariſm, I with pleaſure acknowledge the aſſiſtance I have received from the different authors who have written on this ſubject. I have uſed an unreſerved freedom, in ſelecting from their works whatever I found to anſwer my purpoſe. I am particularly obliged to Sir Joſeph Banks, for his politeneſs in lending me "Les Memoires de "l'Acal'Academie de Berlin," for 1780, at a time when I could not procure them elfewhere.

The various interruptions and avocations, from which, as a tradefman, I cannot be exempt, will, I hope, induce the reader to make fome favourable allowances for any errors which he may difcover, and kindly correct them for himfelf.

Being encouraged by the very rapid fale of the firft edition of this work, to offer another to the public, I have endeavoured to render it more perfect by fuch additions and alterations, as either occurred to my own mind, or were fuggefted to me by others. The reader will find moft of the chapters either enlarged by the addition of new matter, or improved by a different arrangement of the old; more particularly, the chapters on medical electricity and the Leyden phial.—The effay on magnetifm is alfo confiderably enlarged; for the prefent difpofition and order of treating it, I am indebted to the ingenious and kind hints of Dr. Lorimer. The additions are illuftrated by two new plates, and an engraved frontifpiece.

I have been engaged by my friends to prefix an introduction to this work, in order to render it more ufeful to thofe who are not already acquainted with the principles of this fcience, to which I have fubjoined an account of the principal discoveries that have been made in electricity, since the publication of these essays.

I beg leave to avail myself of this opportunity to inform the public, that I am engaged in arranging and preparing for the press different essays on the mechanical parts of mathematical and philosophical learning, and explaining the various uses of the different instruments in their present state of improvement; which, I trust, will greatly tend to facilitate the attainment of knowledge, and accelerate it's progress. For this purpose I have been at a considerable expence in collecting such materials as may enable me to offer to the public some essays on this subject, which I hope will not be found unworthy of it's patronage, and which I mean to publish with all convenient speed.

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A

SUMMARY VIEW

OF THE

GENERAL PRINCIPLES

OF

ELECTRICITY.

OF ELECTRICITY, OF ELECTRICS, AND NON-ELECTRICS.

THERE is a natural agent or power, generally called the electric fluid, which by friction, or other means, is excited, or brought into action.

This action is manifested to our senses by what are termed electric appearances.

These appearances are—the attraction and repulsion of light bodies.—pencils of light darting

ing from the electrified body, attended with a snapping noise on the approach of certain substances.

Experiment.—Take a glass tube of an inch and a half in diameter, and about three feet long, rub this tube from one end to the other, with the hand, or a piece of dry silk, and it will exhibit electric appearances, or be excited. The power thus brought into action will attract and then repel small light bodies; small pencils of light will also dart from the tube in a beautiful manner, attended with a crackling noise, if the finger, or any other metallic substance is brought near the tube.

Experiment.—Put your cylinder in good order, by the rules laid down in Chap. II. of the following Essay. Then turn the glass cylinder, and all the forementioned appearances may be observed; but as the action of the cylinder is stronger than that of the tube, the effects will be more visible in the former. In these two experiments the friction against the tube or cylinder has brought into action and rendered sensible an agent, which before was apparently dormant and invisible to us.

With respect to the electric matter, all substances may be divided into two classes, electrics, or non-electrics.

Electrics do not suffer the electric matter to pass readily over their surfaces; hence they are also called non-conductors.

Non-electrics permit the electric matter to pass readily over their surfaces; from whence they are termed conductors.

Experiment.—A metallic cylinder being fixed upon a glaſs ſupport, and placed near the electric machine, will receive the electric fluid from the glaſs cylinder, which will diffuſe itſelf over the whole ſurface of the metallic cylinder. It does not however readily paſs over the glaſs ſupport, but is detained by it on the metallic cylinder, from whence it may be conveyed by any metallic ſubſtance.

A metallic cylinder ſupported by glaſs, and furniſhed with ſharp-pointed wires to collect the electricity from the glaſs cylinder, is called the prime conductor.—It is ſaid to be inſulated by the glaſs ſupport, becauſe this obſtructs the paſſage, or cuts off the communication of the electric fluid with the earth.

This experiment will ſerve to give a general idea of the foundation of the general diviſion of all ſubſtances into electrics and non-electrics; but as it is a diſtinction which runs through the whole buſineſs of electricity, we ſhall endeavour to elucidate it further, by entering more fully into the properties by which theſe ſubſtances are diſtinguiſhed.

Electrics, or non-conductors, may have any part of their ſurface rendered electrical by friction, without diffuſing the ſame kind of electricity to any other part of their ſubſtance.

Non-electrics, or conductors, cannot be rendered electrical by friction, and when electrified by any other means, the electricity is diffuſed over the whole of their ſurface, and every part thereof exhibits the ſame kind of electricity.

The partial diſtribution of the electric fluid on non-con-

 ductors

ductors is easily shewn, by only exciting one part of a glass plane, or a glass tube.

The equal diffusion of this fluid is seen by the prime conductor when electrified.

A conductor electrified by communication, parts with the whole of it's electricity at once to any conducting substance, (that communicates with the earth) when brought in contact with it; or a conductor cannot be electrified while it communicates with the earth, because all the electricity is carried off by the communication. Whereas under the same circumstances an excited electric loses it's electricity only in those parts, which are near the conducting substance, or to which it is applied.

EXPERIMENT.—To illustrate this position, bring any conducting substance, that communicates with the earth, in contact with the prime conductor, and it will immediately deprive it of all the electricity it had acquired; but if the same conducting substance is brought near the excited glass cylinder, it will only take off a portion of the electric matter from that part to which it is applied.

Some conducting substances are more perfect than others.

EXPERIMENT.—The fluid will pass more readily over a metal rod, than one of wood.

Among conductors, metals are the most perfect; sealing-

wax,

wax, rosin, and glass, are amongst the best non-conductors. For a list of conducting substances, &c. see page 16.

The electric fluid may be excited by friction, by heating and cooling.

Experiment.—In working the electrical machine, this fluid is excited by friction. The Tourmalin stone is excited by increasing or diminishing it's heat. See Chap. I. of the following Essay, and also pages 339 and 368.

Of EXCITATION, and of the contrary STATES of the ELECTRIC FLUID.

The excitation produced by rubbing of electrics against each other is very small.

Experiment.—Rub two pieces of glass, or sealing-wax, together, and only a small degree of electricity will be obtained.

It is therefore necessary, that the rubber should be a conducting substance, and that it should not be insulated.

Only a small quantity of electricity can be produced, when the rubber and conductor of an electrical machine are both insulated.

Experiment.—Take off the chain, which is generally suspended from the cushion to the table; turn the machine, and you will find less electricity than when the cushion or rubber communicated with the earth.

If

If the rubber of an electrical machine be insulated, and the conductor uninsulated, or made to communicate with the earth, by hanging a chain from it; on turning the cylinder, the rubber will be strongly electrified, and will attract and repel light bodies, and exhibit the same general appearances as the prime conductor.

EXPERIMENT.—Connect an insulated conductor with the rubber, place another before the cylinder, and both will be electrified.

The conductor which is electrified by the cylinder will attract those bodies, which are repelled by the conductor that is connected with the cushion, and vice versa.

If these conductors are brought near each other, strong sparks will pass between them.

If they be brought into contact, (or if they are connected together by a chain) the electricity of one will destroy that of the other; and though the fluid may be seen to circulate round the cylinder, yet the two conductors, when thus conjoined, will exhibit few or no signs of electricity.—From these experiments it may be inferred,

That there are two powers in electricity, the one termed positive electricity, the other negative electricity; that these powers may be rendered evident to the senses when they are separated; and that they counteract each other when united, the one destroying the effects of the other.

To render this position more clear, we shall re-consider the foregoing experiments on the two conductors, comparing them with ſimilar experiments on two conductors electrified with the ſame power. Electrify two conductors equally, by placing them before the cylinder, (that is, electrify both poſitively) and the following obſervations may be made: 1. That what is attracted or repelled by the one, is alſo attracted and repelled by the other; whereas, in the foregoing inſtance, what the one attracted, the other repelled. 2. That no ſparks will paſs between two conductors equally electrified with the ſame power, though they will paſs continually between two electrified with different powers. 3. Connect the two conductors that are before the cylinder, and ſparks may be taken from them, which cannot be done from the others when they are united.

The conductor connected with the cuſhion, is ſaid to be negatively electrified.

The conductor placed before the glaſs cylinder is ſaid to be poſitively electrified. (*a*)

Theſe experiments may be eaſily exhibited by one conductor, if the rubber be inſulated; by means of the two directors with glaſs handles, that are deſcribed page 314.—

Take

(*a*) Hence every electrical machine, with an inſulated rubber, may be conſidered as acting in a threefold manner.

1. As a machine producing negative electricity; by connecting the prime conductor to the earth by a chain, and taking the fluid from the cuſhion or rubber.

2. As a machine producing poſitive electricity. To effect this, make the rubber communicate with the ground by a chain, and take the fluid from the conductor.

3. As communicating the action of both powers at once. In this caſe, the rubber and conductor muſt both be inſulated, and the ſubſtance to be electrified placed between two directors connected with them.

Take off the chain from the cushion, and connect a director with it by a wire or chain, and connect another director with the prime conductor; turn the cylinder, and on bringing the directors near to each other, sparks will pass from the one to the other; the one will also attract what the other repels, and when brought into contact, neither of them will exhibit any signs of electricity.

The electricity produced by the excitation of glass, is called positive electricity.

The electricity produced by the excitation of sealing-wax, or rosin, is called negative.

OF ELECTRICAL ATTRACTION AND REPULSION.

If two bodies be electrified, both positively, or both negatively, they repel each other.

If one be electrified positively, the other negatively, they attract each other.

A body not at all electrified will be attracted by those which are electrified, either negatively or positively.

EXPERIMENT.—Electrify a pair of insulated pith balls positively, and they will repel each other. See page 54.

EXPERIMENT.—Electrify a pair of insulated pith balls negatively, and they will repel each other.

EXPERIMENT.—A pair of insulated pith balls electrified positively, will attract a pair that are electrified negatively.

EXPERIMENT,

Experiment.—A pair of insulated pith balls electrified negatively, are attracted by excited glass, and repelled by excited wax; and the contrary: for if the balls are electrified positively, they will be repelled by excited glass, and attracted by excited wax.

Experiment.—A pair of insulated balls in their natural state are attracted both by excited glass, and excited wax.

The repulsion of balls electrified positively is destroyed by the application of an equal degree of negative electricity.

Experiment.—Electrify two pair of pith balls equally, but one with positive electricity, the other with negative; bring the cylinders by which the balls are suspended in contact, and the balls will immediately close.

Experiment.—Electrify two pair of insulated pith balls equally with positive electricity, bring the cylinders by which they are suspended in contact, the balls will remain unaltered.

From these experiments it may be inferred, that in the natural state of electricity the two powers are always united; that they only become visible by their separation, and that when separated they manifest themselves by those appearances which we term electrical. It is highly probable, that the general phænomena of nature are carried on by these powers when united, and the more particular phænomena, or discordant notes in the great system of the universe, are occasioned by the action of these powers when separated, and their constant tendency to unite. Be this as it may, the foregoing positions will be found to illustrate all the experiments on electric attraction, from whichwe have selected the following, as some of the most pleasing.

Experiment.—Light feathers, hair, &c. connected with the conductor, are, when electrified, attracted by any non-electric body.

Experiment.—The hair of any person that is electrified becomesrepellent.

Experiment.—Down feathers, bits of leaf gold, paper images, and other light bodies brought near the conductor, are first attracted, and then repelled.

Experiment.—The two outside bells, fig. 17, communicate by a chain with the conductor ; the middle bells and the two clappers are suspended by silk, which is a non-conductor. The electric fluid passes from the conductor to the outside bells, these attract the clappers and impart electricity to them, which they in their turn communicate to the middle bell, from whence it is conveyed by a chain to the earth. The clappers, in receiving and communicating the fluid, are alternately attracted and repelled.

Those substances that are brought within the influence of electrified bodies, become possessed of a contrary electricity ; or, bodies, which are immerged in an electric atmosphere, always become possessed of an electricity contrary to that of the body in whose atmosphere they are immerged.

See Experiment xviii. xix. xx. xxi. xxiii. xxiv. xxv. of the following Essay.

Experiment.

Experiment. — Bring a conductor (without pointed wires) near to the glaſs cylinder, whilſt the machine is working. If the conductor be not inſulated, it will be negatively electrified, till it is brought ſo near as to receive ſparks from the cylinder. If the conductor be inſulated, it will, in the ſame ſituation, be electrified negatively in the parts neareſt the glaſs cylinder, and poſitively in the parts more remote; as may be ſeen by bringing a glaſs tube, which is poſitively electrified, near a ball which is ſuſpended from the conductor.

Of ELECTRIFIED POINTS.

The electic fluid appears as a diverging ſtream darting forwards into the air from a pointed body poſitively electrified.

It appears as a little globular ſtar on a point negatively electrified. (*a*)

Experiment.

(*a*) Mr. Nicholſon has ſhewn, that it is the property of all ſhort-pointed conductors riſing out of another ſurface nearly plane, to give a ſpark when poſitively electrified, but none when negatively; hence he contrived an inſtrument for diſtinguiſhing the two electricities, which is repreſented at fig. 10, in the plate facing the end of the ſupplement. A and B are two metallic balls, which may be placed at different diſtances from each other by means of the joint c; the two legs c A, c B, are of varniſhed glaſs; from one of the balls A proceeds a ſhort point towards the other ball B: a long ſpark will paſs from the ball A towards B, when

Experiment.—Theſe appearances are to be obſerved in a dark room on the extremity of a pointed wire fixed upon a conductor poſitively or negatively electrified; or on a wire held in the hand, and preſented to a poſitively or negatively electrified conductor.

Experiment.—Theſe phænomena are beautifully exhibited by the luminous conductor.

A current of air is occaſioned from an electrified point.

Experiment.—Place a pointed wire in the conductor, and hold the hand over it when the machine is in action, a very ſenſible wind will be felt by the hand.

Experiment—Stick ſeveral pieces of paper or card like vanes in a cork, through the center of which a needle or ſteel pin paſſes, ſuſpend the whole by a magnet, preſent one of the vanes to a pointed wire inſerted in the conductor, and they will be put in motion by the current occaſioned by the point, and will turn with rapidity. See alſo experiments lxxvii. lxxviii. lxxix. &c. of this Eſſay.

A pointed wire placed on or brought near to an electrified conductor, gradually and ſilently diſſipates the electric fluid.

It

it is poſitively electrified; but the electricity will paſs without ſparks, and ſcarce any noiſe, when it is electrified negatively.—Nicholſon's Introduction to Natural Philoſophy, 2d. edit. p. 320.

It is to be obferved here, that if the point is brought within certain limits, it will not difcharge the conductor in the manner expreffed in the foregoing pofition, but by a fucceffion of fmall explofions very quickly following each other, which leads to the following pofition.

If an electrified point be fituated in fuch circumftances as to caufe the fluid to accumulate on the conductor; or, in other words, if it is fo fituated, that the power of the fame name with that of the conductor cannot be readily difcharged from it, it will then receive the electricity from the conductor in the form of a ftrong fpark.

Experiment.—Place a pointed wire on the end of a fpiral tube, and it will take a fpark. See alfo experiment lxiii. clv. and clvii. of the following Effay.

Of the LEYDEN PHIAL.

A glafs jar or phial coated on both fides (except about two inches from the top) with tinfoil, or any other conducting fubftance, is called the Leyden jar or phial.

If one fide of this jar is electrified, while the other fide communicates with the earth, it is faid to be charged.

If a communication is formed from one fide of the jar to the other (by a conducting fubftance) after it has been charged, an explofion will be heard, and the jar is ſaid to be diſcharged.

A Leyden phial cannot be charged when it is inſulated; that is, when neither ſide communicates with the earth.

As the apparatus repreſented at fig. 49, pl. II. is the moſt ready, and beſt adapted for illuſtrating the phænomena of the Leyden phial, we ſhall confine ourſelves principally to it in this part of the preſent Summary.

Experiment.—Screw the phial with the belt on it's inſulated ſtand, as at fig. 48; bring the coating in contact with the conductor, turn the machine ſlowly, and after a few turns remove the phial from the conductor; then form a communication between the outſide and the inſide of the phial, by placing one end of the diſcharging rod firſt upon the coating, and then bringing the other end of the rod to the braſs ball of the bottle; there will be no exploſion, the bottle not being charged becauſe both ſides were inſulated.

Experiment.—Hang a chain from the braſs ball of the phial to the table, then bring the coating in contact with the conductor, and after a few turns of the machine remove the phial as before; then apply the diſcharger, an exploſion will be heard, and the bottle will be diſcharged; for in this caſe, the inſulation of the inſide is deſtroyed by the chain, and the phial becomes capable of receiving a charge.

As much of the electrical fluid is thrown off from one ſide of a jar when charging, as is communicated to the other.

Experiment.—Place the coating of the jar, fig. 48, in contact with the conductor, and the knob of another equal sized jar (as L, fig. 49) in contact with the knob of the first; turn the machine a few times, then remove the jars from each other, and from the conductor; apply a discharger, as before directed, first to the one, then to the other, and you will find them both equally charged; the inside of the second phial having received from the inside of the first, as much of the fluid as the outside thereof received from the machine. See also exper. lxxiv.

When a Leyden phial is charged, the two sides thereof are in contrary states; that is, the one is positively, the other negatively electrified.

Experiment.—Charge the jar, fig. 48, by bringing the coating in contact with the conductor, and letting a chain fall from the ball to the table. When it is charged, remove the jar from the conductor, and the chain from the knob. The coating of the jar will electrify a pair of insulated pith balls positively, and the knob will electrify a pair negatively; evincing that the inside and outside of the jar are in contrary states.

Reverse the foregoing experiment, by bringing the knob of the jar in contact with the conductor, and letting a chain fall from the outside coating to the table; charge the jar, and remove the chain, the coating will now electrify the insulated pith balls negatively, and the knob will electrify them positively.

Experiment.—Charge the jar, fig. 48, positively; connect a director with the chain from the coating, and bring the ball of the director towards the knob of the bottle; a

cork

cork ball, or an artificial ſpider, ſuſpended by a ſilk ſtring, will play between the two balls till the bottle is diſcharged, carrying the fluid from one to the other, till it has reſtored the equilibrium.

A jar is ſaid to be poſitively electrified, when the inſide receives the fluid from the conductor, and the outſide is connected with the earth.

It is ſaid to be negatively electrified, when the outſide receives the fluid from the conductor, and the inſide communicates with the earth. (*a*)

The contrary ſtates of the Leyden phial ſhewn by the charge and diſcharge thereof.

Experiment.—Take two bottles of the ſame ſize, as H and I, fig. 49, charge both poſitively, and connect the coatings of each, as in fig. 48, bring the two knobs together, and no exploſion will take place, and the bottles will not be diſcharged; becauſe the inſide and outſide of each bottle is in the ſame ſtate, or endued with a power of the ſame kind, and have therefore no tendency to unite. The ſame happens if both are charged negatively.

Experiment.—Charge one poſitively, the other negatively; then on bringing the knobs together as before, an exploſion will take place, and both bottles will be diſcharged; in this the powers on the inſide and outſide of each bottle were of different kinds, with a ſtrong tendency to unite.

In

(*a*) It is neceſſary that a jar charging negatively ſhould be inſulated, becauſe the fluid is, in the firſt inſtance, conveyed to the coating, and would, if uninſulated, be immediately carried to the earth.

In the foregoing experiments it will be found very convenient for the difcharge of the jars, to fcrew the wire K or L into the hole at the top of the infulating pillar; as the coating of the moveable jar may be placed on this wire, and it's knob be eafily brought to touch the infulated jar.

The contrary ftates of the fides of a Leyden phial may be exhibited by the appearance of the electric light, or pointed wires connected with the coating, or balls of the bottle; and alfo by the different appearance thereof in vacuo. But for thefe we fhall refer the reader to the following Effay, as the foregoing experiments are fufficient to prove the fact.

The charge of a coated jar refides in the glafs, and not in the coating.

Experiment.—Let a plate of glafs be placed between two metallic plates, about two inches in diameter, fmaller than the plate of glafs; charge the plate of glafs, and then remove the upper metallic plate by an infulated handle; take up the glafs plates, and place it between two other plates of metal unelectrified and infulated, and the plate of glafs thus coated afrefh will ftill be charged.

The paffing of the electric fluid from one fide of a charged jar to the other, is apparently inftantaneous, through whatever length of a metallic or other good conductor it is conveyed.

Experiment.—Let any number of perfons make a part of the circuit of communication, and the fluid will pafs inftantaneoufly through the whole.

The difcharge of a charged jar gives a painful fenfation, called the electric fhock, to any animal placed in the circuit of communication.

If the circuit be interrupted, the fluid will become vifible; and if refifted in it's paffage, will leave an impreffion upon the intermediate or refifting bodies. (*a*)

Experiment.—Let the fluid pafs through a chain, or through any metallic bodies, placed at fmall diftances from each other; the fluid, in a dark room, will be vifible between the links of the chain, or between the metallic bodies.

Experiment.—If the circuit be interrupted by feveral folds of paper, a perforation will be made through it, and each of the leaves will be protruded by the ftroke from the middle towards the outward leaves.

Experiment.—If fpirits of wine, or gun-powder, be made part of the circuit, it will be fired.

The force of an electric charge does not depend on the fhape of the charged furface.

Let the fame quantity of coating be placed upon a jar, and upon a plate of glafs, the effect will be found to be nearly the fame in each.

When the furfaces of an electric jar are charged with a certain quantity of the two powers, it is obferved, that no additional electricity can be communicated to them, however great an excitation is applied for that purpofe.

Or

(*a*) Enfield's Inftitutes of Natural Philofophy.

Of the ELECTRIC BATTERY.

The force of the electric charge may be increafed, by augmenting the furface of coated glafs.

The ufual method of effecting this, is to form a communication between the infide of a number of coated glafs jars, and another communication between the external coating; jars fo difpofed are called an electrical battery.

Fine metallic wire may be melted by a battery, fmall animals may be killed, thick pieces of glafs be fhattered to pieces, and other curious effects produced, the greater part of which are defcribed in Chap. viii. of the following Effay.

The electric fluid and lightning are the fame fubftance.

Their properties and effects are the fame; flafhes of lightning form irregular lines in the air; the electric fpark, when ftrong, has the fame appearance. Lightning ftrikes the higheft and moft pointed objects, takes in it's courfe the beft conductors, fets fire to bodies, melts metals; in which, and many other particulars, it agrees with the phænomena of the electric fluid. Laftly, the lightning being brought from the clouds to an electrical apparatus, will exhibit all the appearance of the electric fluid.

It is fuppofed that buildings may be fecured from the effects of lightning, by fixing a pointed metallic rod higher than any part of the building, and continuing it, without interruption, to the ground or neareſt water.

* See Chap. ix. of the following Eſſay. The experiment moſt generally uſed to illuſtrate this poſition, is that of the thunder-houſe, which is a board ſhaped like the gable end of a houſe, and fixed perpendicularly upon an horizontal board; in the perpendicular board a ſquare hole is made, into which a ſquare piece of wood is to be fitted, ſo that it may eaſily fall out of it's place; a wire is fixed diagonally into this ſquare piece; another wire, terminated with a braſs ball, is faſtened to the upper part of the perpendicular board, with it's ball above the board, and it's lower end in contact with the diagonal wire; in the ſquare piece of wood, a communication is continued from the other end of the diagonal wire, by a wire to the bottom of the perpendicular board. If the wires, in this ſtate, are made part of a circuit of communication, on diſcharging the jar, the ſquare piece of wood will not be diſplaced; but if the communication be interrupted, by changing the direction of the diagonal wire, the ſquare piece of wood will, on the diſcharge, be driven out of it's place. See fig. 68.

If, inſtead of the upper braſs ball, a pointed wire be placed above the perpendicular board, the diſcharge may be drawn off without an exploſion.

Of a PLATE of AIR.

As the air is an electric, it will receive a charge, and give a ſhock like any other electric ſubſtance.

This

This is effected by means of two large boards, covered with tin foil, the one connected with the conductor, the other placed parallel to it on an insulated stand; these boards may be considered as the coatings to a plate of air; and if a communication be formed between them by touching the uninsulated board with one hand, and applying the other hand to the conductor, the shock will be felt. See Chap. x. of this Essay, and Nicholson's Introduction to Natural Philosophy.

"A great part of the electric phænomena, are the consequence of the air being thus charged. Thus the prime conductor imparts it's electricity to the surface of air immediately contiguous to it, and when the spark is drawn, the discharge is made to the non-electrics in the room, which are in contact with the opposite surface.

"It is a consequence of the air being charged, that broad non-electric surfaces draw large sparks from the conductor, for the sparks are the discharges of a large plate of interposed air; a less surface will draw a less spark, because the same machine charges less surfaces higher than greater; the spontaneous discharge through the body of the electric air, will be made at a greater distance of the surfaces; that is to say, the sparks will be longer. If the surface of the presented plate be still smaller, the sparks will also be smaller, and emitted to a greater distance; and if the surface be indefinitely small, or in other words, if the non-electric be pointed, the spark may be so small as to be invisible, and the distance to which it can be emitted, may be unlimited."

Of MEDICAL ELECTRICITY.

The satisfactory experiments that have been made on this head,

head, by ſome of the firſt characters in the medical line, particularly at St. Thomas's Hoſpital, by Mr. Birch, have eſtabliſhed the reputation of electricity in medicine, as they have clearly proved, that when uſed by the ſkilful, it is as certain in it's effects as any medicine in the whole materia medica, and more extenſive in it's application.

In medicine, it has been very judiciouſly conſidered as acting under three forms.

1. The Fluid, which may be conſidered as a ſedative.

2. The Spark, or friction, which may be ranked under the title of a ſtimulant.

3. The Shock, which may be conſidered as a powerful deobſtruent.

The fluid may be thrown upon or extracted from the patient.

This is always beſt effected by a wooden point.

1. Inſulate the patient, and connect him with the poſitive conductor; then preſent the wooden point of the director towards him, and it will gradually draw the fluid from him.

2. Let the patient communicate with the ground, and connect the metal part of the director with the poſitive conductor, and the fluid will be gently thrown upon the patient.

3. Connect the inſulated patient with the cuſhion, then he will receive the fluid from the direction held in the hand.

4. Connect the director with the cuſhion, and the fluid will be extracted from the patient.

Of

Of the electric ſpark, or friction.

What has been ſaid with reſpect to the fluid, is equally applicable to the electric friction ; only here the point is to be unſcrewed from the director, and the braſs ball ſcrewed on in it's ſtead.

In the friction, the part ſhould be covered with woollen cloth or flannel, and the braſs ball is to be applied cloſe to the flannel ; but in taking ſparks, it is to be removed a little diſtance from the body.

To increaſe the denſity of the fluid, or ſpark.

Fix the medical bottle to the conductor, let a chain fall from the hook at the bottom thereof to the table, place the electrometer on the conductor, (as it is repreſented in the frontiſpiece to this work,) let the ball of the electrometer be placed at ſome little diſtance from the conductor, and then connect your director, by means of a wire, with the exterior ball of the electrometer; after this preparation, you may turn the machine, and when the fluid has attained ſufficient force to paſs from the conductor to the ball of the electrometer, you may apply the director to the patient, who will receive a denſe ſtream therefrom ; the machine to be kept turning during the operation. Or, connect an inſulated patient with the electrometer, and then, on applying the director to him, you will extract a denſe ſtream from him.

N. B. Whenever the director is uſed without being connected with the conductor or cuſhion, the hand ſhould communicate with the braſs part thereof.

To

To paſs a ſtream of the electric fluid through any part of the body, without giving the ſhock.

1. Connect one director with the cuſhion, and another with the conductor; place the part, through which you want the ſtream to paſs, between the directors.

N. B. The denſity of this ſtream is augmented, if the bottle is ſuſpended agreeable to the directions in the preceding article, and one director joined to the electrometer.

2. Inſulate the patient, and apply a director that communicates with the conductor, (or with the electrometer and bottle) to one part, and a braſs ball to the other.

To give the ſhock.

Suſpend the bottle from the conductor, put the electrometer in it's place, (ſee the plate that faces the title-page of this work) and remove the inner ball a ſmall diſtance from the conductor; then connect one director by a wire with the hook at the bottom of the bottle, and the other with the exterior ball of the electrometer; the part through which the ſhock is to paſs, muſt be placed between theſe balls; there will be a ſhock every time the fluid has acquired ſufficient force to paſs from the conductor to the electrometer.

To give a quick vibratory ſenſation, not ſo pungent as the ſhock, though ſtronger than the ſpark.

The directions in the preceding article apply immediately to the preſent, with only this difference, the ball of the electrometer may be removed further off, and the long wire is to be taken out of the tube of the bottle.

Of

OF ATMOSPHERIC ELECTRICITY.

The atmofphere is always electrified, fometimes negatively, but moft commonly with pofitive electricity. In ferene weather, the electricity is always pofitive, and the quantity is proportional to the quantity of moifture.

Hail is always accompanied with electricity.

Rain generally fo.

Low and thick fogs ftrongly electrical, though generally more fo after a froft.

In fummer, the electricity of the atmofphere is very weak; it grows ftronger at fun-rife, and increafes in ftrength with the elevation thereof; at fun-fet it again becomes weaker.

Impetuous winds generally leffen the force of the atmofpheric electricity.

A ftrong electricity often rifes with the dew, particularly if the feafon is cold, the fky clear, and very little wind.

OF A VACUUM.

Air rarified to a certain degree, permits the electric fluid to pafs eafily through it.

As the air is a non-conductor, it refifts the motion of the electric fluid; therefore, the removal of it facilitates the effort this fluid makes to efcape from the fubject on which it is thrown; at the fame time it is highly probable, that it is by means of the vapour which expands itfelf when the prefſure of the atmoſphere is taken off, that the electric fluid is conducted through the vacuum; for there is reaſon to think, that electricity always requires a conductor, to make it paſs from one body to another; and this is further confirmed by thoſe experiments, which ſhew that a more perfect vacuum of air is a non-conductor, which will be ſhewn in the Supplement.

EXPERIMENT.—Let a vacuum be made part of the circuit in diſcharging a Leyden phial.

EXPERIMENT.—Let a jar be charged in vacuo.

A SUP-

A SUPPLEMENT TO THE *ESSAY* ON ELECTRICITY.

Containing an Account of the PRINCIPAL DISCOVERIES made in that Science, ſince the Publication of the firſt Edition.

An Extract from Mr. *De Sauſſure*'s Inquiries and Obſervations on Atmoſpherical Electricity. (*a*)

THE electrometer uſed by Mr. De Sauſſure is nearly the ſame as that of Mr. Cavallo's, which is deſcribed in my Eſſay, at page 260, and at fig. 76. The following are the moſt material circumſtances in which they differ; firſt, the

(*a*) This electrometer may be uſed inſtead of the condenſer of M. Volta, by only placing it on a piece of oiled ſilk, ſomewhat larger than the baſe of the inſtrument; but in this caſe, it is the baſe, and not the top of the inſtrument, which muſt be brought into contact with the ſubſtance whoſe electricity is to be explored.

the fine wires, by which the balls are ſuſpended, ſhould not be long enough to reach the tinfoil which is paſted on the inſide of the glaſs, becauſe the electricity, when ſtrong, will cauſe them to touch this tinfoil twice conſecutively, and thus deprive them in a moment of their electricity. To prevent this defect, and yet give them a ſufficient degree of motion, it is neceſſary to uſe larger glaſſes than thoſe that are generally applied to Mr. Cavallo's electrometer; two or three inches diameter will be found to anſwer the purpoſe very well. But as it is neceſſary to carry off the electricity which may

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By this inſtrument, it is eaſy to aſcertain the degree of conducting power in any ſubſtance. For example, if it is placed on an imperfect conductor, as dry wood or marble, and if the inſtrument is electrified ſtrongly, and afterwards the top is touched, the electricity will appear to be deſtroyed; but on lifting up the inſtrument by the top, the balls will again open, becauſe the imperfect conductor formed with the baſe a kind of electrophorus, by which the electric fluid was condenſed, and loſt it's tenſion, till the perfect conductor was ſeparated from the imperfect one; whereas, if the conductor had been more perfect, it would have been deprived of it's electricity immediately on the application of the hand.

It is eaſy to diſcover alſo, by this inſtrument, the electricity of any ſubſtance, as of cloaths, hair of different animals, &c. For this purpoſe, it muſt be held by the baſe, and the ſubſtance rubbed briſkly (only once) by the ball of the electrometer; the kind of electricity may be aſcertained in the uſual manner. It is proper, however, to obſerve here, that as the top of the electrometer acts in this caſe as an inſulated rubber, the electricity it acquires is always contrary to that of the rubbed body.

may be communicated to the inſide of the glaſs, and thus be confounded with that which belongs to thoſe ſubſtances that are under examination ; four pieces of tinfoil ſhould be paſted on the inſide of the glaſs ; the balls ſhould not be more than 1-20th of an inch diameter, ſuſpended by ſilver wire, moving freely in holes nicely rounded. The bottom of the electrometer ſhould be of metal ; for this renders it more eaſy to deprive them of any acquired electricity, by touching the bottom and top at the ſame time. (*b*)

In order to collect a great quantity of electricity from the air, the electrometer is furniſhed with a pointed wire, 15 inches, or two feet long, which unſcrews in three or four pieces, to render the inſtrument more portable ; ſee fig. 4. When it rains or ſnows, the ſmall parapluie, fig. 5, is to be ſcrewed on the top of the inſtrument, as by this it's inſulation is preſerved, notwithſtanding the rain.

This inſtrument indicates not only the electricity of fogs, but that alſo of ſerene weather, and enables us to diſcover the kind of electricity which reigns in the atmoſphere ; and to a certain degree, to form an eſtimate of it's quantity, and that under two different points of view, the degree of intenſity, and the diſtance from the earth at which it firſt begins to be ſenſible.

A conductor (*c*) exhibits ſigns of electricity, only when the electric fluid is more or leſs condenſed in the air, than in the earth. Though the air reſiſts the paſſage of the electric fluid, it is not abſolutely impermeable to it ; it ſuffers it to paſs gradually, and generally with more eaſe in proportion as it's maſs or thickneſs is leſs. It is therefore interesting

(*b*) Voyage dans les Alpes par H. B. De Sauſſure, Tom. ſecond.

(*c*) A conductor raiſed for the purpoſe of making atmoſpherical experiments is meant here.

tereſting to diſcover at what height it is neceſſary to be elevated, in order to find a ſenſible difference between the electricity of the earth, and that of the air. A very ſenſible difference may be generally diſcovered by this inſtrument, at the diſtance of four or five feet from the ground; ſometimes it may be ſeen if the inſtrument is placed even on the ground, while at others, it muſt be raiſed ſeven or more feet before the balls will open; ſometimes, though ſeldom, this height is not ſufficient. This diſtance is generally greateſt when the electricity is ſtrongeſt, though neceſſarily modified by a variety of circumſtances, ſome of which are known, as the degree of dryneſs or humidity of the air, and others are unknown.

The degree of intenſity, at a given height, may be diſcovered thus; raiſe the electrometer, and judge by the diviſions which are placed on the edge thereof, the degree of their divergence. To find the relation between this degree of divergence, and the force of the electricity, M. De Sauſſure took the following method, as he could not with certainty double or triple a given quantity of electricity; yet, as a given force may be reduced one half, a fourth, or eighth, &c. by dividing it between two equal and ſimilar bodies, the electricity contained in one; he took two of his unarmed electrometers, which were as ſimilar as poſſible, and electrified one of them, ſo that the balls ſeparated preciſely 6 lines; he then touched the top thereof by the top of that which was not electrified; in an inſtant the electricity was equally divided between them, as was evident by the divergence of the balls, which was 4 lines in each; conſequently, a diminution of half the denſity had only leſſened the divergence one third. One of theſe electrometers was then deprived of it's electricity, and was afterwards brought in contact with the other, as before; the remaining electricity divided itſelf again between them, and the balls fell from 4 to 28 lines, nearly in the ſame proportion as before; in the third operation they fell to 19; in the fourth to one, where he was obliged to ſtop, as there was not now ſufficient force in the fluid to paſs from one electrometer to the other, and diſtribute itſelf uniformly between them. The ſame experiment repeated ſeveral times, gave very nearly the ſame reſults. Negative electricity decreaſed alſo in the ſame proportion as the poſitive. The following table may therefore be conſidered as giving a general, though not exact idea (*un aperçu*) of the increaſe in force, which correſponds to different degrees of divergence in the balls; it is only calculated to every fourth of a line; the force of electricity is always expreſſed by whole numbers, as it would be ridiculous to put a greater degree of exactneſs in the numbers, than is to be found in the experiments which form the baſis of the calculation. (*d*)

Diſtance of the balls in fourths of a line.			Correſponding forces of electricity.
1	——	——	1
2	——	——	2
3	——	——	3
4	——	——	4
5	——	——	5
6	——	——	6

Diſtance

(*d*) Mr. De Sauſſure, in a long note, anticipates the objections that may be made to the foregoing method of eſtimating the force of electricity; but as at the moſt they only ſhew that this ſcience is at preſent in a ſtate of conſiderable imperfection, it will be unneceſſary to take notice of them here.

Distance of the balls in fourths of a line.			Corresponding forces of electricity.
7	——	——	8
8	——	——	10
9	——	——	12
10	——	——	14
11	——	——	17
12	——	——	20
13	——	——	23
14	——	——	26
15	——	——	29
16	——	——	32
17	——	——	36
18	——	——	40
19	——	——	44
20	——	——	48
21	——	——	52
22	——	——	56
23	——	——	60
24	——	——	64

Those who are desirous to carry this measure of the electric force further, may do it by having similar electrometers constructed, but made upon a larger scale, and with heavier balls, which would only separate one line, with the degree of electricity that makes the smaller ones diverge 6 lines; these would consequently measure a force 1024 times greater than that which forms the unity of the preceding table, and thus by degrees we may be enabled to discover the ratio of the strongest discharge of a great battery, or perhaps even of thunder itself, to that of a piece of amber, which only attracts a bit of straw. (*e*)

Of

(*e*) The consideration of the repulsive force is not sufficient to discover the absolute force of an explosion, or electrical discharge.

Of the manner of obſerving the electricity of the atmoſphere with the electrometer.

The firſt thing is to bring the electric fluid contained in the electrometer, to the ſame degree of denſity with that at the ſurface of the earth; this is eaſily done by letting the bottom and top touch the ground at the ſame time; ſee fig. 6; then

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diſcharge. For Mr. Volta has ſhewn, that the force of a diſcharge depends principally on the quantity of the electric fluid which paſſes from one body to another. Now the repulſive force of the electrometer only indicates the ratio of this quantity, in equal and ſimilar bodies, and which are alſo ſimilarly ſituated. If equal quantities of the electric fluid were imparted to two unequal and ſeparate conductors, the electric fluid being leſs condenſed on the largeſt, would act with the leaſt force on the electrometer; though it is probable, the force of the diſcharge in the two conductors would be equal. The repulſive force ſerves, however, to ſhew what Mr. Volta calls the *electrical capacity* of a body, the quantity of the electric fluid it actually contains, or is capable of containing. To effect this, and have points of compariſon, we ſhould uſe light metallic balls, of different ſizes, ſuſpended by ſilk thread. One of theſe balls, unelectrified, being brought into contact with the ſubſtance whoſe electricity is to be explored, will diminiſh the tenſion, or repulſive force of this ſubſtance; and the quantity diminiſhed by the contact of the ball, will give the ratio of the capacity of this ſubſtance with that of the ball. Let us ſuppoſe a Leyden phial uninſulated, but ſo concealed, that only the knob is viſible, and we are therefore ignorant of it's ſize, and the ſtrength of the ſhock it will give. Let the then raiſe the point, keeping the bottom ſtill in contact with the ground, from whence it may be lifted up in a vertical poſition, till the balls are level with the eye.

The ſecond circumſtance is to render the divergence of the balls, which is occaſioned by the electricity of the air, permanent. This is effected by touching the top of the electrometer with the finger; but here the acquired electricity becomes contrary to that of the body, by which they are electrified. Let us ſuppoſe, for example, that the electrometer is at five feet from the ground, and the balls diverging; touch the top of the electrometer with the finger, and the balls will cloſe; but they will again open, if the electrometer is withdrawn from the influence of the electricity of the air, by being brought nearer the ground, or into the houſe. Mr. De Sauſſure only employed this method, when the electricity was ſo weak, that he could not perceive any until the electrometer was raiſed conſiderably above his eye; as in this caſe, he could not perceive the divergence of the balls, he always endeavoured to obtain a permanent electricity in the foregoing manner.

To

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top of M. De Sauſſure's electrometer be in contact with the knob of the bottle, and the balls of the electrometer ſeparate 6 lines,—from this ſolitary fact, we ſhall gain no information relative to the force of the ſhock; becauſe, if the jar is very large, this degree of tenſion will give a very painful ſenſation; when, if it is very ſmall, with the ſame indicated tenſion, the ſenſation may be almoſt imperceptible. But if I bring a ball, of a foot diameter, in contact with the knob of the bottle, and after having thus taken a part of the fluid therefrom, the electrometer is again put in contact with the knob thereof, the remaining quantity of repulſive force will ſhew the relation between it's contents and that of the globe of metal, and by this means the intenſity of it's charge.

To know whether the balls ſeparate with poſitive or negative electricity, bring a piece of excited wax gradually near the top of the electrometer; if the balls ſeparate further on the approach of the wax, they are negatively electrified, or of the ſame nature with the electricity of the wax; if on the other hand they come nearer together, on the approach of the wax, then the electricity is poſitive, or in a contrary ſtate to that of the wax. If glaſs is uſed, the reſults will be exactly the reverſe of the preceding.

The following example will render the uſe of the foregoing obſervations more familiar. Chooſe an open ſituation, free from trees and houſes, ſcrew the conductor on the top of the electrometer, lay hold of it by it's baſe, and place it ſo that the baſe and conductor may touch the ground at the ſame time, then elevate it to the height of the eye, and obſerve the quantity of lines, or fourths of a line, that the balls have diverged; now lower it till the balls almoſt touch each other, and obſerve at what diſtance the top of the conductor is from the ground; and this is the height from the ground, at which the electricity of the air begins to be ſenſible. If the electricity of the air is ſufficiently ſtrong to make the balls diverge when it ſtands upon the ground, one of the lengths of the electrometer muſt be unſcrewed from it. If the balls however ſtill diverge, the other parts of the conductor ſhould alſo be unſcrewed, and you may mark down, that the electricity is ſenſible at zero, or on the ſurface of the earth. If, on the contrary, the electricity is ſo weak, as not to cauſe the balls to diverge, when they are even with the eye, and conſequently when the conductor is two feet higher, or 7 feet from the ground, you ſhould then raiſe it a foot higher; while it is thus elevated, touch the top with the other hand; when this hand is taken away, lower the electrometer, and if it is electrified, you may ſay the electricity is ſenſible at 8 feet; if it is not, raiſe it as high as the arm can reach, and repeat the ſame operation; if any electricity is found, write down electricity ſenſible at 9 feet; if not, mark 0, or no electricity relative to this inſtrument, and this mode of employing it; for ſigns of electricity may ſtill be obtained, by throwing a metallic ball 50 or 60 feet into the air, which is at the ſame time connected with the electrometer by a metallic thread.

One advantage of this inſtrument is, that it will often exhibit ſigns of electricity, when none can be obtained from a conductor of a hundred feet in height, becauſe it can more eaſily be preſerved from humidity, &c. which deſtroy the inſulation of the large conductors.

Aerial electricity varies according to the ſituation; it is generally ſtrongeſt in elevated and inſulated ſituations, not to be obſerved under trees, in ſtreets, in houſes, or any incloſed places; though it is ſometimes to be found pretty ſtrong on quays and bridges. It is alſo not ſo much the abſolute height of the places, as their ſituation; thus a projecting angle of a high hill will often exhibit a ſtronger electricity than the plain at the top of the hill, as there are fewer points in the former to deprive the air of it's electricity.

The intenſity of the atmoſpheric electricity is varied by a great many circumſtances, ſome of which may be accounted for, others cannot. When the weather is not ſerene, it is impoſſible to aſſign any rule for their variation, as no regular correſpondence can then be perceived with the different hours of the day, nor with the various modifications of the air. The reaſon is evident; when contrary and variable winds reign at different heights, when clouds are rolling over clouds, theſe winds and clouds, which we cannot perceive by any exterior ſign, influence however the

ſtrata

ſtrata of air in which we make our experiments, produce theſe changes of which we only ſee the reſult, without being able to aſſign either the cauſe, or it's relation. Thus, in ſtormy weather, we ſee the electricity ſtrong, then null, and in a moment after ariſe to it's former force; one inſtant poſitive, the next negative, without being able to aſſign any reaſon for theſe changes. Mr. De Sauſſure ſays, that he has ſeen theſe changes ſucceed with ſuch rapidity, that he had not time to note them down.

When rain falls without a ſtorm, theſe changes are not ſo ſudden; they are however very irregular, particularly with reſpect to the intenſity of force; the quality thereof is more conſtant. Rain, or ſnow, almoſt uniformly gives poſitive electricity.

In cloudy weather, without rain or ſtorms, the electricity follows generally the ſame laws as in ſerene weather.

Strong winds generally diminiſh it's intenſity, they mix together the different ſtrata of the atmoſphere, and make them paſs ſucceſſively towards the ground, and thus diſtribute the electricity uniformly between the earth and the air; Mr. De Sauſſure has obſerved a ſtrong electricity with a ſtrong north wind (*la biſe*).

The ſtate of the air, in which the electricity is ſtrongeſt, is foggy weather; this is always accompanied with electricity, except when the fog is going to reſolve into rain.

The moſt intereſting obſervations, and thoſe which throw the greateſt light upon the various modifications of electricity in our atmoſphere, are thoſe that are made in ſerene weather. In winter, (during which moſt of Mr. De Sauſſure's obſervations were made) and in ſerene weather, the electricity was generally weakeſt in an evening, when the dew had fallen, until the moment of the ſun's riſing; it's intenſity afterwards augmented by degrees, ſometimes ſooner, and ſometimes later; but generally before noon, it attained

tained a certain maximum, from whence it again declined, till the fall of the dew, when it would be ſometimes ſtronger than it had been during the whole day; after which, it would again gradually diminiſh during the whole night; but is never quite deſtroyed, if the weather is perfectly ſerene.

Atmoſpherical electricity ſeems, therefore, like the ſea, to be ſubject to a flux and reflux, which cauſes it to increaſe and diminiſh twice in 24 hours. The moments of it's greateſt force are ſome hours after the riſing and ſetting of the ſun; thoſe when it is weakeſt, precede the riſing and ſetting thereof. This will be further explained in the following pages.

Mr. De Sauſſure has given an inſtance of this periodic flux in electricity, on the 22d of February, 1785, (one of the coldeſt days ever remembered at Geneva;) the hygrometer and thermometer were ſuſpended in the open air, on a terrace expoſed to the ſouth-weſt; the electrometer, from it's ſituation, indicated an electricity equal to what it would have ſhewn if it had been placed on an open plain. The height of the barometer is reduced to what it would have been if the mercury had been conſtantly at the temperature of 10 degrees of Reaumur's thermometer. The place of obſervation was elevated 60 feet above the level of the lake. The obſervations of the day preceding and following this great cold, are inſerted in the following table; becauſe it is pleaſing to have the obſervations which precede and follow any ſingular phænomena. There was a weak S. W. wind during the whole three days; and it is rather remarkable, that moſt of the great colds, which have been obſerved at Geneva, were preceded by, or at leaſt accompanied with, a little S. W. breeze.

T A B L E.

d.	h.	m.	Barometer, feet in height.	Thermometer.	Hygrom.	Electrom.	
21	9	15 M	26 6 7	— 8 3	89 3	2 0	Pale ſun, cloudy
	11	10 M	26 6 5	— 4 3	83 9	1 6	Bright ſun
	2	10 E	26 6 1	— 0 2	69 6	1 1	The ſame
	5	E	26 6 1	— 2 3	77 2	1 1	Setting ſun
	6	E	26 6 0	— 5 2	85	1 0	Cloudy in the S. W.
	7	E	26 6 2	— 6 8	89	1 8	Perfectly clear
	8	E	26 6 3	—10 0	95	2 0	Idem
	9	E	26 6 3	—10 6	97 5	1 8	Idem
	10	E	26 6 1	— 9 9	95	1 2	Little cl. at horiz. S.
	11	E	26 6 0	—12 3	99 1	1 5	Id. more to S. W.
	12	E	26 5 15	—12 5	Hoar froſt	1 2	Idem
22	1	M	26 6 0	—14 3	Idem	0 9	Idem
	2	M	26 6 8	—14 5	Id.	1 2	Clo. incr. & approa.
	6	15 M	26 5 7	—15 0	Id.	0 8	Clear
	7	30 M	26 5 4	—14 7	Id.	1 2	Light fog
	8	10 M	26 5 2	—14 2	Id.	1 1	Idem
	9	10 M	26 4 15	—10 7	Id.	1 6	Idem
	10	10 M	26 4 13	— 8 2	Id.	2 2	Thicker fog
	11	10 M	26 4 3	— 4 8	Id.	1 8	Idem
	1	10 E	26 4 0	— 4 9	Id.	1 7	Idem
	2	20 E	26 3 14	+ 0 6	82	1 4	Weak fog, pale ſun
	3	30 E	26 3 13	— 0 9	81 9	1 1	Cloudy pale ſun
	5	E	26 3 13	— 4 3	89	1 2	Leſs cloudy
	6	E	26 3 14	— 4 4	91 2	2 2	More ſo
	7	E	26 3 14	— 6 1	94	1 7	Idem
	8	E	26 3 13	— 5 9	Id.	3 7	Clou. fog. in S. W.
23	0	45 M		— 4 1	Id.	1 0	Clou. with more fog
	8	5 M	26 5 0	— 1 0	81 3	1 2	Idem
	10	7 M	26 5 5	— 0 0	76	0 8	Idem
	3	45 E	26 6 8	+ 0 5	76	Id.	Cloudy pale ſun
	5	E	26 6 14	— 0 3	75 3	1 0	Cloudy
	6	E	26 7 3	— 0 7	74	0 8	Idem
	7	E	26 7 9	— 1 7	79 7	2 2	Very clear
	8	E	26 7 14	— 3 7	87 3	1 7	Cloudy
	12	E	26 9 1	— 3 0	.92	0 5	More ſo

M for Morning, E for Evening.

From

From the firſt 18 obſervations of this table, when the ſky was quite ſerene, we ſee that the electricity was pretty ſtrong at 9 in the morning, that from thence it gradually diminiſhed till towards 6 in the evening, which was it's firſt minimum; after which it increaſed again till 8, it's ſecond maximum, from whence it again gradually declined till 6 the next morning, which was the time of it's ſecond minimum; after which, it again increaſed till ten in the morning, which was the firſt maximum of the following day; as this was cloudy, the electric periods were not ſo regular.

The electricity of ſerene weather is much weaker in ſummer than in winter, which renders it more difficult to obſerve theſe gradations in ſummer than in winter; beſides a variety of accidental cauſes, which at the ſame time render them more uncertain. In general, in ſummer, if the ground has been dry for ſome days, and the air is dry alſo, the electricity generally increaſes, from the riſing of the ſun till 3 or 4 in the afternoon, when it is ſtrongeſt; it then diminiſhes till the dew begins to fall, which again reanimates it; though after this it declines, and is almoſt extinguiſhed during the night.

But the ſerene days that ſucceed rainy weather in ſummer, generally exhibit the ſame diurnal periods or ſtates of electricity, as are to be obſerved in winter.

The air is invariably poſitive in ſerene weather, both in winter and ſummer, day and night, in the ſun or in the dew. It would ſeem, therefore, that the electricity of the air is eſſentially poſitive, and that whenever it appears to be negative, in certain rains or in ſtorms, it probably ariſes from ſome clouds, which have been expoſed to the preſſure of the electric fluid contained in the upper part of the atmoſphere, or to more elevated clouds, that have diſcharged a part of their fluid upon the earth, or upon other clouds.

In order to find out the caufe of thefe phænomena, Mr. De Sauffure inftituted a fet of experiments on evaporation, avoiding the ufe of Mr. de Volta's condenfer.

To produce a ftrong evaporation, he threw a mafs of red hot iron into a fmall quantity of water, which was contained in a coffee pot, with a large mouth, and fufpended by filk ftrings; by this he obtained a ftrong pofitive electricity, though, according to Mr. Volta's fyftem, it ought to have been negative; the experiment was repeated feveral times, varying fome of the circumftances, but the refult was always the fame.

As it was not eafy to think fo able a philofopher as Mr. Volta was deceived, it was neceffary to try the experiment in a manner more analagous to that of Mr. Volta. A fmall chafing-difh was therefore infulated by filk cords, and the coffee-pot, with a fmall quantity of water, placed on it; one electrometer was connected with the coffee-pot, and another with the chafing-difh; the fire was raifed by a pair of bellows; when the water had boiled ftrongly for a few minutes, both electrometers exhibited figns of electricity, which, on examination, was found to be negative; proving the truth of Mr. Volta's experiment. The evaporation produced by the effervefcence of iron in the vitriolic acid, and by that of chalk in the fame acid, gave alfo negative electricity.

It was now neceffary to inquire, why the vapour, excited by the heated iron, produced pofitive electricity; while that from boiling water, in any other way, produced a negative electricity.

Mr. De Sauffure fufpected, that the intenfity of heat to which the water is expofed, by the contact of a body in a ftate of incandefcence, was the caufe of the electricity produced by it's evaporation, and that a combination was then formed, by which a new quantity of the electric fluid was produced. This conjecture may at firſt ſight ſeem improbable; but the quantity of electricity produced by this experiment, will aſtoniſh thoſe that repeat it; and this quantity is the more ſurprizing, becauſe, if it is true, according to the ſyſtem of Mr. Volta, that the vapours abſorb, while they are forming, a quantity of the electric fluid, there muſt, therefore, be enough developed in this experiment, for the formation of the great quantity of vapours produced by the heated iron, and afterwards a ſufficient quantity to electrify ſtrongly the apparatus, and all theſe vapours.

This experiment ſhews clearly the cauſe of that prodigious quantity of electricity, which is unfolded in the eruption of volcanos; as it is probable, that the water in theſe, from many circumſtances, acquires a much greater degree of heat than is given to it in our experiments.

To verify this conjecture, that it was in ſome meaſure the combuſtion of the water, or the iron, that produced the poſitive electricity, it was proper to try whether, by a regular moderation of the heat of the iron, poſitive electricity would always be obtained. This was eſſayed in the following manner: A large iron crucible, 5 inches high, 4 in diameter, and 6 lines thick, was heated red hot, then inſulated; after which, ſmall quantities of water were thrown into it, each projection of the water cooling more and more the crucible; thus deſcending by degrees, till there was only ſufficient heat to boil the water; carefully obſerving, and then deſtroying the electricity produced at each projection. The electricity was always poſitive or null; at the firſt projections it was very ſtrong; it gradually diminiſhed to the twelfth, when it was ſcarce ſenſible, though always with a tendency to be poſitive.

On repeating this experiment, and varying it in different ways, a remarkable circumſtance was obſerved: When a ſmall quantity of water was thrown into the crucible, the moment it was taken from the fire, while it was of a pale red, approaching what is called the white heat, no electricity was obtained.

This fact ſeemed to have ſome connection with another mentioned by Muſſchembrock, that water evaporates more ſlowly on a metal, or any other incandeſcent body, than on the ſame body, heated only a ſmall degree above boiling water. To examine this relation, and to find whether there was any between the periods of evaporation, and the production of electricity, Mr. De Sauſſure made a great number of experiments, which are moſt accurately deſcribed in his excellent work ; but as the detail would be much too long to be introduced in this Supplement, I muſt content myſelf with preſenting the reader with the heads thereof, and a deſcription of the apparatus.

The apparatus conſiſted of a pot of clay, well baked or annealed, 15 lines thick, and 4 inches diameter; this was inſulated by a dry glaſs goblet; upon this pot was placed the crucible, or any other heated ſubſtance, on which the water was to be thrown, in order to be reduced into vapours; the crucible was contiguous to a wire connected with an electrometer; a meaſure, containing 54 grains weight of diſtilled water, was thrown upon the heated crucible; the time employed in the evaporation thereof was obſerved by a ſecond watch; the electricity produced by this evaporation was noted. When this meaſure of water was reduced into vapour, the electricity of the apparatus is deſtroyed, and a freſh meaſure of water is thrown into the crucible, proceeding in the ſame manner till the crucible is almoſt cold.

The firſt experiment was with an iron crucible, from which it was found, that Muſſchembrock was not right, in ſaying that the evaporation was ſloweſt when the iron was hotteſt; for at the inſtant it was taken from the fire, it required 19 ſeconds to evaporate the water, and took more time till the third projection, when it took 35 ſeconds, though from that period it employed leſs time, or in other words, the evaporation accelerated in proportion as the iron cooled.

With reſpect to the electricity, it was at firſt 0, then poſitive, afterwards negative, then 0, and afterwards poſitive to the end of the experiment. The vapour was not viſible till the 7th projection.

In the ſecond experiment with the ſame crucible, though every endeavour was made uſe of to render them as ſimilar as poſſible, the electricity was conſtantly poſitive.

The third experiment was with a copper crucible; here alſo the electricity was poſitive, and the longeſt time employed in evaporation was not the inſtant of the greateſt heat. It was very curious to ſee the water endeavouring to gather itſelf into a globule, like mercury on glaſs, to be ſometimes immoveable, and then to turn on itſelf horizontally, with great rapidity; ſometimes throwing from ſome of it's points a little jet, accompanied with an hiſſing noiſe.

The fourth experiment was with the ſame crucible; the electricity was at firſt negative, then conſtantly poſitive.

The fifth was with a crucible of pure ſilver; a conſiderable time was employed here in evaporating the ſame quantity of water; even in the inſtant of the greateſt heat it took 5 minutes, 6 ſeconds; the electricity was weak, three times no electricity was perceived, five times negative electricity was diſcovered.

In a ſixth experiment with the ſame crucible, a poſitive electricity was obtained, at the ſecond projection, after which none of any kind was perceived.

The ſeventh with the ſame, gave at firſt a ſtrong negative electricity,

electricity, the second and third projection gave a weak positive electricity.

The eighth was made with a porcelain cup; here the evaporation was slower at the second, than the first projection; but from this it took longer time till it was cold, contrary to what happened with the metals; the electricity was always negative.

The ninth and tenth experiments with the same cup, produced similar effects.

The eleventh experiment was with spirits of wine in a silver crucible; here there was no electricity produced at the two first projections, and what was afterwards obtained was negative.

Twelfth experiment with ether; here the electricity was also negative. These two inflammable fluids, in evaporating, followed the same laws as water, being dissipated at first most rapidly in the greatest heat, afterwards taking a longer and longer time before they were evaporated, to a certain period, then employing less time, or evaporating quicker, till the crucible was nearly cold.

Now as china and silver always produced negative electricity, while iron and copper have generally given positive electricity, we may conclude, that electricity is positive with those bodies that are capable of decomposing water, or of being decomposed themselves by their contact with the water; and negative with those which are not at all decomposed or altered.

From hence Mr. De Saussure conjectures, that the electric fluid may be looked upon, as formed by the union of fire with some unknown principle, perhaps a fluid analogous to inflammable air, but exceedingly more subtil. This analogy seems to him sufficiently proved by the inflammation of the electric fluid, and by the diminution of the air in which this inflammation is made. Though many

doubts

doubts have been attempted to be thrown on this inflmmation, there seems to be one reason which forces us to admit it, which is the loss of a quantity of this fluid at every spark; we may diminish at pleasure any quantity of this fluid, (*en le faisant et inceler*) by taking a number of sparks from it. From whence also it may be inferred, that a considerable quantity is destroyed every day by thunder.

According to this system, when the operation, which converts water into vapour, produces at the same time a decomposition, it then generates the electric fluid. A part of this fluid combines itself immediately with these vapours, and serves even to form them. The vessel, in which this operation is performed, will acquire a positive electricity, none at all, or a negative; according as the quantity of the fluid generated is superior, equal, or inferior to that which the formation of the vapours consumes. When no decomposition accompanies the evaporation, the electricity ought to be constantly negative, because there is nothing to replace the quantity of this fluid, which is employed in forming the vapour.

If in the foregoing experiments, those substances which were susceptible of calcination had constantly given a positive electricity, and those which do not calcine had always given the negative; every thing would have been explained by these principles, and they would thence have acquired a greater degree of probability. But the phænomena have not always followed this law. We have seen iron and copper sometimes give a negative electricity, and silver the positive. The first case is not difficult to account for; it is well known with what facility iron and copper calcine in a brisk fire; they become covered with a scaly crust, which is not susceptible of any further alteration with the same heat. If the bottom of the crucible acquires this crusty coating, the drop of water placed thereon will be no

longer

longer in contaƈt with a calcinable ſubſtance; there will be no further decompoſition, no generation of the electric fluid: the vapours, however, which are ſtill formed, will abſorb a part of the fluid naturally contained in the apparatus, and this will therefore be electrified negatively. If ſome of the ſcales ſhould be ſo far detached, that the water may gain ſome points of contact, the quantity thus generated may compenſate for what is abſorbed by the vapours, and thus the electricity will be null. If more are detached, it will ſuper-abound and be poſitive. From the ſame reaſons, a large maſs of water, by attacking the iron in a greater number of points, always gives poſitive electricity; and hence, alſo, a ſtrong poſitive electricity is obtained, by throwing a piece of red-hot iron into a maſs of water.

It is not ſo eaſy to explain why ſilver gives ſometimes a poſitive electricity, but by ſuppoſing it to have been mixed with ſome ſubſtances, capable of calcination; and this the more, as the white porcelain always gave negative electricity. This ſuppoſition was verified by ſome ſubſequent experiments, in which the ſame ſilver, when purified, always gave a negative electricity.

Mr. De Sauſſure owns himſelf incapable of explaining why heated charcoal always gives negative electricity; unleſs it can be attributed to the promptitude with which ſo rare a ſubſtance loſes it's heat, by the contact of water.

One fact aſtoniſhed him, namely, that by combuſtion properly ſo called, although it is an evaporation, nay, the higheſt degree of evaporation, he never obtained any ſigns of electricity; though he tried to obtain it in a variety of ways. Probably, the current produced by the flame, diſperſes and diſſipates the electricity as ſoon as it is formed. The caſe, however, muſt not be looked upon as general, becauſe Mr. Volta obtained ſigns of electricity from bodies in combuſtion, by means of his condenſer.

Another ſingular fact was, his not being able to obtain electricity without ebullition, though he endeavoured to compenſate by the quantity of ſurface for the quantity of vapours that were elevated by boiling water; and indeed, the ſame quantity of water, if extended over too large a ſurface, will not give any electricity.

Notwithſtanding the uncertainty theſe experiments throw upon the ſyſtem, it does not at preſent ſeem poſſible to find another reaſon, which ſo ſatisfactorily accounts for the poſitive electricity which reigns in the air. The prodigious quantity of this fluid, which continually deſcends from the upper part of the atmoſphere, filtrating through the air to penetrate the interior parts of the earth, muſt neceſſarily be brought back again by ſome means; for otherwiſe, the air would be exhauſted of it's fluid, or the earth would be ſaturated. The perpetual circulation of this fluid, which is carried on by means of vapours, is a ſtriking circumſtance; it riſes inviſible and inactive, concealed in their boſom, but diſplaying afterwards it's energy. When the vapours have changed their form, it deſcends active, animated with a penetrating and expanſive force; the tops of trees, the points of leaves, the beards of different grains, attract and force it to paſs through the vegetables, of which it becomes, (perhaps) when decompoſed, the moſt active and ſavoury part. This alſo may be one of the reaſons, why exerciſe in the open air is much more conducive to health than that which is taken in covered or cloſe places; for it ſeems evident, that the ſoft and gentle electrization, which every one muſt partake of in the open air, muſt have an influence upon our organs, on the circulation of the blood, the ſecretion of the humours, and inſenſible tranſpiration.

In further purſuing this ſubject, we muſt conſider, that vapour ſometimes acts as the producing cauſe of aerial electricity; at other times, as a conductor of this ſame fluid;

and ſometimes, both together. Towards the end of the night, the electricity of the air is very weak, either becauſe there is no evaporation, or becauſe the humidity of the preceding evening, and that of the fore part of the night, have tranſmitted to the earth the electricity that was accumulated in the air : but as ſoon as the ſun warms the earth, and in proportion as he riſes above the horizon, the aerial electricity augments ; becauſe the vapours which then riſe, carry this fluid into the air. But when the ſun has attained the meridian, the heat increaſes in a greater proportion than the evaporation, the air becomes dry, and hardly tranſmits the fluid which is accumulated in the upper part of the atmoſphere ; the electrometer, therefore, exhibits leſs ſigns of electricity, though it is ſtill accumulating in the upper part of the atmoſphere. Laſtly, when the ſun is near ſetting, the air grows cool, becomes humid, and tranſmits more abundantly to the earth the electric fluid that was accumulated in the higher regions ; the electrometer, therefore, riſes again with the dew, till two or three hours after ſun-ſet, when the air is exhauſted, and the electricity again diminiſhes till the next day.

In ſummer, the electricity of a ſerene atmoſphere is much weaker than in winter, and that, becauſe the air is then warm and dry, to a greater height, and therefore reſiſts more powerfully the tranſmiſſion of this fluid, that is accumulated in the higher regions of the atmoſphere. This uninterrupted accumulation accounts at the ſame time, very naturally, for the violence and frequency of ſtorms at this ſeaſon. But the increaſe of electricity, from the heat of the ſun, in the dry and hot days of ſummer, from it's riſing, till four or five in the afternoon, is not ſo eaſily accounted for. It is not improbable, that the dry exhalations from the earth, which are occaſioned by the heat, may produce this augmentation of electricity, and favour the deſcent thereof from the upper part of the atmofphere. It appears, however, in general, both in winter and fummer, that when the air is perfectly tranfparent, the aerial electricity always diminifhes in the hotteft part of the day. It is known, that the air is generally moft tranfparent and difengaged from vapours, in the ferene weather that follows great or heavy rains.—Mr. De Sauffure defires that this fyftem may be only looked upon as fo many conjectures, propofed with a view to animate other philofophers to the obfervation of thefe phænomena, and the inveftigation of their caufe.

The author refers alfo to his " Effais fur l' Hygrometrie " for the proofs, That the electric fluid is only neceffary to form or fufpend the grofs veficular vapours. Thofe which are diffolved, or are elaftic, fupport themfelves by the expanfive force, which they acquire from the element of fire combined with them, without the affiftance of any other agent. And thefe grofs vapours, which require the electric fluid for their formation, part with it, if they are refolved into water, or into an elaftic fluid. Thus the grofs vapours that are formed in the morning of a fine day, and which difturb a little the tranfparency of the inferior ftrata of air, carry this fluid with them, but part with it when they come into a more pure and dry air, where they are diffolved, taking the form of an elaftic fluid.

This explains the diminution of the aerial electricity, when clouds are forming in an atmofphere that was ferene; for the electric fluid, which was diffeminated in the air, combines with the vapours when they take the veficular form; the ftrata, or ftriated appearance that is then feen among the clouds, which is one of the moft fure indications of rain, feem to announce the prefence of the electric fluid, endeavouring to reftore an equilibrium, and re-place that which has been employed in the formation of the veficles, of which the clouds confift. Many experiments fhew, that this fluid, condenfed by art, difpofes in parallel and converging lines, like the clouds, thofe particles of duft through which it is made to pafs; while on the other hand, the increafe of aerial electricity, which is obferved when the air is getting clear and ferene after rain, arifes from this fluid, which the veficular vapours part with when diffolved in air.

Many other curious obfervations are to be found in Mr. De Sauffure's work, which are too long to be inferted here. My intention is, at a future period, to give a fecond volume of Effays on Electricity; in which I fhall endeavour to digeft all the obfervations and experiments which have been made fince the publication of the firft edition of this work.

Fig. 3, of the plate at the end of this Supplement, reprefents an improvement of the atmofpherical electrometer, by Mr. Abraham Bennett, of Wirkfworth, Derbyfhire; it was tranfmitted to me by a very ingenious friend. The principal advantage of this little inftrument, is the delicacy of the materials of which it is compofed.

It confifts of two flips of leaf gold, which are pafted to the fides of a peg, which fits into a fmall tube, in the under fide of the cap. The cap, or cover, is flat, in order that plates, books, or other articles, on which experiments are to be made, may be placed upon it. It has alfo a rim to keep off the rain, and maintain the infulation, when it is ufed in the open air. There is a fmall tube on one fide of the cap, to fix wire or any other occafional fubftance to; the pieces of leaf gold are about 3 inches long, and 1-5th of an inch broad. The cover may be taken off at pleafure, to repair any accident happening to the leaf gold. The glafs prevents the leaf gold from being agitated; two pieces of tin foil are faſtened on oppoſite ſides of the internal ſurface of the glaſs, to prevent the glaſs from being charged, and thus interfering with the repulſion of the electrometer; therefore the cover ſhould be ſo turned, that the leaf gold may ſtrike againſt the tin foil.

The following experiments ſhew the great ſenſibility of this little inſtrument.

1. Powdered chalk was put into a bellows, and blown upon the cap; it was electrified poſitively by the ſtream of chalk, when the nozzle of the bellows was only 6 inches diſtant from the cap; but the ſame ſtream electrified it negatively at the diſtance of three feet. In this experiment, the quality of the electricity is changed from poſitive to negative, by diſperſing or widening the ſtream, and making it paſs through a longer tract of air; it is alſo changed by paſſing the ſtream through a bunch of fine wires, ſilks, or feathers placed upon the nozzle of the bellows; it is negative when blown from a pair of bellows, the iron pipe being taken off to enlarge the ſtream. This laſt experiment ſeems to anſwer beſt in damp weather. The poſitive electricity generally remains, but in the negative the leaf gold collapſes as ſoon as the cloud of chalk is paſſed.

2. A piece of chalk drawn over a bruſh, or powdered chalk put into a bruſh and projected on the cover, electrified it negatively. The electricity was not permanent.

3. Powdered chalk blown (with the mouth, or a pair of bellows,) from a plate placed upon the cover, gave a permanent poſitive electricity. If a bruſh is placed upon the cover, and a piece of chalk is drawn over it, when the hand is withdrawn, the leaf gold gradually expands with poſitive electricity, as the cloud of chalk diſperſes.

4. Pow-

4. Powdered chalk falling from one plate to another, placed on the inftrument, electrified it negatively. Many other experiments have been tried, as projecting it from a goofe wing, chalking the edges of a book, &c. The inftrument being placed in a dufty road, the duft ftruck up with a ftick near it, electrified it pofitively; wheat flour and red lead gave a ftrong negative electricity, in all cafes where the chalk gave pofitive.

5. Place a metal cup upon the cap with a red hot coal in it, a fpoonful of water thrown upon the coal electrifies the cup negatively. If a bent wire be placed upon the cover, with a piece of paper faftened to it, to increafe it's furface, it will exhibit the pofitive electricity of the afcending vapour, when introduced into it. The electricity of rain may probably be illuftrated by pouring water on hot coals placed in an infulated cullender; the afcending vapour is pofitive, the defcending drops are negative.

6. The fenfibility of this inftrument may be increafed, by placing a candle upon the cap; by this means a cloud of chalk, which would but juft open the leaf gold before, will caufe them to ftrike the fides for a long time together, and the electricity is now communicated fo ftrong, that the leaves will be repelled by a ftick of excited wax at 10 or 12 inches diftance. A cloud of chalk made in one room will electrify this inftrument, brought from another room, and at a confiderable diftance.

A thunder cloud paffing over the inftrument, caufed the leaf gold to ftrike the fides at every flafh of lightning. No fenfible electricity has been difcovered by it on the explofion of gun-powder, or the projection of fmoke, or flame over it.

Excited fealing-wax will often make the leaf gold ftrike the fides of the glafs more than 12 times; when the fealing-wax recedes, it will ſtrike it again, nearly the ſame number of times; but if the approach is quicker than the receſſion, the number of times will ſometimes be greater. The quantity of electricity neceſſary to cauſe a repulſion of the leaf gold is ſo ſmall, that the ſharpeſt points or edges do not draw it off, unleſs they are brought in contact with it: hence it is unneceſſary to avoid points or edges in the conſtruction of this inſtrument.

This electrometer may alſo be conveniently united with Mr. Volta's condenſer, by making the cap ſerve as the upper plate of the condenſer, and by applying a marble or varniſhed wooden plate upon it, with a metallic handle for the lower plate. In ſome experiments, a candle may be connected at the ſame time by a wire with the upper part of the electrometer; and thus increaſe the advantages to be obtained from it. When this apparatus is uſed, the operator muſt touch the metallic handle, and the electricity will enter by the candle, between the cap and upper plate; this being lifted up, the inſtrument will exhibit the electricity.

N. B. This is an inverted condenſer, the under plate being inſulated inſtead of the upper one.

A Deſcription of a very large Electrical Machine placed in Teyler's Muſeum, in Haarlem.

This machine was conſtructed by Mr. John Cuthbertſon, an Engliſh mathematical inſtrument maker, in Amſterdam; it conſiſts of two circular plates of glaſs, each of 65 inches diameter, which are made to turn upon the ſame horizontal axis, at the diſtance of 7 $\frac{1}{2}$ inches from each other. Theſe plates

plates are excited by eight rubbers, each 15 ½ inches in length; and to the diſtance of 16 ½ inches from the center, they are covered on both ſides with a reſinous compoſition, which is deſigned to prevent their breaking, and to hinder the excited electricity from being carried off by the axis. The prime conductor, which conſiſts of ſeveral pieces, is very large, and is ſupported by three glaſs pillars, each 57 inches high. The plates are made of French glaſs; as this is found to ſucceed better than any other kind, except the Engliſh flint, which could not be procured of ſo large a ſize. This machine is furniſhed with nine electrical batteries, each containing fifteen jars, and each jar having about a ſquare foot of coated glaſs; ſo that the grand battery, in which all theſe are combined, conſiſts of above 130 ſquare feet of coated glaſs.

This machine, when thus completed, was aſtoniſhingly powerful. From the prime conductor, ſparks have been taken 24 inches long; theſe, when ſeen in the dark, appeared of the ſize of a common gooſe-quill, ſeemed to dart in ſerpentine lines, and emitted many collateral rays, ſome of which were ſix, ſeven, and even eight inches in length. Even upon the ſharpeſt ſteel points that could be made, ſparks of half an inch have been received from the conductor.

Another proof of the extraordinary power of this machine is, that from a braſs ball, 4 ½ inches in diameter, and projecting 5 inches from the end of the conductor, a pencil or plume of electrical fire was emitted, which extended 16 inches in length and breadth.

By the ſpark from the prime conductor alone, without uſing any coated glaſs, gunpowder has been fired, and tinder, roſin, and match been lighted; being at different times made to paſs through oil of turpentine, and oil of olives, they caught fire from it; and it entirely melted a piece of gold leaf, 20 inches long, and half a line in breadth.

When

When this machine was ſtrongly excited, ſpectators have been affected, at the diſtance of five, ſix, and ſometimes of eight feet from the prime conductor, with that ſenſation which is uſually compared to a cobweb playing on the face and hands; and the air in the muſeum was ſo powerfully electrified, that at the further extremity of the apartment, which is 40 feet from the conductor, the balls of Mr. Cavallo's electrometer diverged half an inch.

Experiments on Electric Light, by Mr. William Morgan.

1. There is no fluid or ſolid body, in it's paſſage through which the electric fluid may not be made luminous; in water, ſpirits, oil, animal fluids of all kinds, the diſcharge of a Leyden phial, of almoſt any ſize, will appear very ſplendid, provided we take care to place them in the circuit, ſo that the fluid may not paſs through too great a quantity of them. The general method is, to place the fluid, on which the experiment is to be made, in a tube three quarters of an inch in diameter, and four inches long; ſtop up the orifices of the tube with two corks, through which puſh two pointed wires, ſo that the points may approach within one-eighth of an inch to each other; the fluid, in paſſing through the interval which ſeparates the wires, is always luminous, if a force be uſed ſufficiently ſtrong; the glaſs tube, if not very thick, always breaks when this experiment ſucceeds. To make the paſſage of the fluid luminous in the acids, they muſt be placed in capillary tubes, and two wires introduced, as in the preceding experiment, whoſe points ſhall be very near each other. It is a well-known fact, that the diſcharge

of

of a ſmall Leyden phial, in paſſing over a ſtrip of gold, ſilver, or Dutch metal leaf, will appear very luminous. By conveying the contents of a jar, meaſuring two gallons, over a ſtrip of gold leaf, one-eighth of an inch in diameter, and a yard long, it will frequently give the whole a dazzling brightneſs. We may give this experiment a curious diverſity, by laying the gold or ſilver leaf on a piece of glaſs, and then placing the glaſs in water; for the whole gold leaf will appear moſt brilliantly luminous in the water, by expoſing it, thus circumſtanced, to the exploſion of a battery.

II. The difficulty of making any quantity of the electrical fluid luminous in any body, increaſes as the conducting power of that body increaſes.

Experiment i.—In order to make the contents of a jar luminous in boiling water, a much higher charge is neceſſary, than would be ſufficient to make it luminous in cold water, which is univerſally allowed to be the worſt conductor.

Experiment ii.—There are various reaſons for believing the acids to be very good conductors; if, therefore, into a tube filled with water, and circumſtanced as has been already deſcribed, a few drops of either of the mineral acids are poured, it will be almoſt impoſſible to make the fluid luminous in it's paſſage through the tube.

Experiment iii.—If a ſtring, whoſe diameter is one-eighth of an inch, and whoſe length is ſix or eight inches, is moiſtened with water, the contents of a jar will paſs through it luminouſly; but no ſuch appearance can be produced by any charge of the ſame jar, provided the ſame ſtring be moiſtened with one of the mineral acids. To the preceding inſtance we may add the various inſtances of metals which will conduct the electrical fluid, without any appearance of light, in circumſtances the ſame with thoſe in which the ſame force would have appeared luminous in paſſing through other bodies, whoſe conducting power is leſs.

III. That the eaſe with which the electrical fluid is rendered luminous in any particular body, is increaſed by increaſing the rarity of the body. The appearance of a ſpark, or of the diſcharge of a Leyden phial, in rarefied air, is well known. But we need not reſt the truth of the preceding obſervation on the ſeveral varieties of this fact; ſimilar phænomena attend the rarefaction of ether, of ſpirits of wine, and of water.

Experiment iv.—Into the orifice of a tube, 48 inches long, and two-thirds of an inch in diameter, cement an iron ball, ſo as to bear the weight which preſſes upon it when the tube is filled with quickſilver, leaving only an interval at the open end, which contained a few drops of water. Having inverted the tube, and plunged the open end of it into a baſon of mercury, the mercury in the tube ſtood nearly half an inch lower than it did in a barometer at the ſame inſtant, owing to the vapour which was formed by the water. But through this rarefied water, the electrical ſpark paſſed as luminouſly as it does through air equally rarefied.

Experiment v.—If, inſtead of water, a few drops of ſpirits of wine are placed on the ſurface of the mercury, phænomena, ſimilar to thoſe of the preceding experiment, will be diſcovered, with this difference only, that as the vapour in this caſe is more denſe, the electrical ſpark, in it's paſſage through it, is not quite ſo luminous as it is in the vapour of water.

EXPERIMENT VI.—Good ether, fubftituted in the room of the fpirits of wine, will prefs the mercury down fo low as the height of 16 or 17 inches. The electrical fluid, in paffing through this vapour, (unlefs the force be very great indeed,) is fcarcely luminous; but if the preffure on the furface of the mercury in the bafon, be gradually leffened by the aid of an air-pump, the vapour will become more and more rare, and the electric fpark, in paffing through it, more and more luminous.

EXPERIMENT VII.—It has not been difcovered, that any vapour does efcape from the mineral acids when expofed in vacuo. To give them, therefore, greater rarity or tenuity, different methods are found neceffary. With a fine camel-hair pencil, dipped in the vitriolic, the nitrous, or the marine acid, draw upon a piece of glafs a line, about one-eighth of an inch broad. In fome inftances, you muft extend this line to the length of 27 inches, and you will find that the contents of an electric battery, confifting of ten pint phials coated, will pafs over the whole length of this line with the greateft brilliancy. If, by widening the line, or by laying on a drop of the acid, it's quantity be increafed in any particular part, the charge, in paffing through that part, will not appear luminous. Water, fpirits of wine, circumftanced fimilarly to the acids in the preceding experiments, will be attended with fimilar, but not equal effects; becaufe, in confequence of the inferiority of their conducting power, it will be neceffary to make the line, through which the charge paffes, confiderably fhorter.

IV. The brilliancy or fplendor of the electric fluid, in it's paffage through any body, is always increafed by leffening the dimenfions of that body; that is, a fpark, or the difcharge of a battery, which we might fuppofe equal to a

fphere

ſphere one quarter of an inch in diameter, will appear much more brilliant, if the ſame quantity of fluid is compreſſed into a ſphere one-eighth of an inch in diameter. This obſervation is the obvious conſequence of many known facts; if the machine be large enough to afford a ſpark, whoſe length is nine or ten inches, this ſpark may be ſeen ſometimes forming itſelf into a bruſh, in which ſtate it occupies more room, but appears very faintly luminous; at other times, the ſame ſpark may be ſeen dividing itſelf into a variety of ramifications, which ſhoot into the ſurrounding air. In this caſe, likewiſe, the fluid is diffuſed over a large ſurface, and in proportion to the extent of that ſurface, ſo is the faintneſs of the appearance. A ſpark, which in the open air cannot exceed one quarter of an inch in diameter, will appear to fill the whole of an exhauſted receiver, four inches wide and eight inches long: but in the former caſe it is brilliant, and in the latter it grows fainter and fainter, as the ſize of the receiver increaſes. This obſervation is further proved by the following experiments.

Experiment viii.—To an inſulated ball, four inches in diameter, fix a ſilver thread, about four yards long. This thread, at the end which is remoteſt from the ball, muſt be fixed to another inſulated ſubſtance. Bring the ball within the ſtriking diſtance of a conductor, and the ſpark, in paſſing from the conductor to the ball, will appear very brilliant; the whole length of the ſilver thread will appear faintly luminous at the ſame inſtant. When the ſpark is confined within the dimenſions of a ſphere, one-eighth of an inch in diameter, it will be bright; but when diffuſed over the ſurface of air which received it from the thread, it's light will be ſo faint as to be ſeen only in a dark room. If you leſſen the ſurface of air which receives the ſpark, by ſhortening the

the thread, it will not fail to increaſe the brightneſs of the appearance.

Experiment ix.—To prove that the faintneſs of the electric light in vacuo, depends on the enlarged dimenſions of the ſpace through which it is diffuſed; we have nothing more to do than to introduce two pointed wires into the vacuum, ſo that the fluid may paſs from the point of the one, to the point of the other; when the diſtance between them is not more than the one tenth of an inch, in this caſe we ſhall find a brilliancy as great as in the open air.

Experiment x.—Into a Torricellian vacuum, 36 inches long, convey as much air as will fill two inches only of the exhauſted tube if it were inverted in water; this quantity of air will afford reſiſtance enough to condenſe the fluid as it paſſes through the tube into a ſpark, 38 inches in length. The brilliancy of the ſpark in condenſed air, in water, and in all ſubſtances through which it paſſes with difficulty, depends on principles ſimilar to thoſe which account for the preceding facts.

V. That in the appearances of electricity, as well as in thoſe of burning bodies, there are caſes in which all the rays of light do not eſcape; and that the moſt refrangible rays are thoſe which eſcape firſt or moſt eaſily. The electrical bruſh is always of a purple or bluiſh hue. If you convey a ſpark through a Torricellian vacuum, made without boiling the mercury in the tube, the bruſh will diſplay the indigo rays. The ſpark, however, may be divided and weakened, even in the open air, ſo as to yield the moſt refrangible rays only.

Experiment xi.—To an inſulated metallic ball, four inches in diameter, fix a wire a foot and a half long; this wire

wire ſhould terminate in four ramifications, each of which muſt be fixed to a metallic ball half an inch in diameter, and placed at an equal diſtance from a metallic plate, which muſt be communicated by metallic conductors with the ground. A powerful ſpark, after falling on the large ball at one extremity of the wire, will be divided in it's paſſage from the four ſmall balls to the metallic plate. When you examine the diviſion of the fluid in a dark room, you will diſcover ſome little ramifications, which will yield the indigo rays only: indeed at the edges of all weak ſparks, the ſame purple appearance may be diſcovered. You may likewiſe obſerve, that the nearer you approach the center of the ſpark, the greater is the brilliancy of it's colour.

VI. That the influence of different media on electrical light, is analogous to their influence on ſolar light, and will help us to account for ſome very ſingular appearances.

Experiment xii.—Let a pointed wire, having a metallic ball fixed to one of it's extremities, be forced obliquely into a piece of wood, ſo as to make a ſmall angle with the ſurface of the wood, and to make the point lie about one eighth of an inch below the ſurface. Let another pointed wire, which communicates with the ground, be forced in the ſame manner into the ſame wood, ſo that it's point likewiſe may lie about one eighth of an inch below the ſurface, and about two inches diſtant from the point of the firſt wire. Let the wood be inſulated, and a ſtrong ſpark, which ſtrikes on the metallic ball, will force it's paſſage through the interval of wood which lies between the points, and appear as red as blood. To prove that this appearance depends on the wood's abſorption of all the rays but the red; when theſe points were deepeſt below the ſurface, the red only came to the eye through a

priſm;

prifm; when they were raifed a little nearer the furface, the red and orange appeared; when nearer ftill, the yellow; and fo on, till, by making the fpark pafs through the wood very near it's furface, all the rays were at length able to reach the eye. If the points be only one eighth of an inch below the furface of foft deal wood, the red, the orange, and the yellow rays will appear as the fpark paffes through it; but when the points are at an equal depth in a harder piece of wood, (fuch as box) the yellow, and perhaps the orange, will difappear. As a farther proof that the phænomena, thus defcribed, are owing to the interpofition of the wood, as a medium which abforbs fome of the rays, and fuffers others to efcape; it may be obferved, that when the fpark ftrikes very brilliantly on one fide of the piece of deal, on the other fide it will appear very red. In like manner, a red appearance may be given to a fpark which ftrikes brilliantly over the infide of a tube, merely by fpreading fome pitch very thinly over the outfide of the fame tube.

Experiment xiii.—If into a Torricellian vacuum, of any length, a few drops of ether are conveyed, and both ends of the vacuum are ftopped up with metallic conductors, fo that a fpark may pafs through it; the fpark in it's paffage will affume the following appearances. When the eye is placed clofe to the tube, the fpark will appear perfectly white; if the eye is removed to the diftance of fix or feven yards, the colour of the fpark will be reddifh. Thefe changes evidently depend on the quantity of medium through which the light paffes, and the red light of a diftant candle, or a beclouded fun.

Experiment xiv.—Dr. Prieftley long ago obferved the red appearance of the fpark when paffing through inflammable

flammable air; but this appearance is very much diversified by the quantity of medium, through which you look at the spark. When at a very considerable distance, the red comes to the eye unmixed; but if the eye is placed close to the tube, the spark appears white and brilliant. In confirmation, however, of some of these conclusions, you must observe, that by increasing the quantity of fluid which is conveyed through any portion of inflammable air, or by condensing that air, the spark may be entirely deprived of it's red appearance, and made perfectly brilliant. All weak explosions and sparks, when viewed at a distance, bear a reddish hue. Such are the explosions which have passed through water, spirits of wine, or any bad conductor, when confined in a tube whose diameter is not more than an inch. The reason of these appearances seems to be, that the weaker the spark or explosion is, the less is the light which escapes; and the more visible the effect of any medium, which has a power to absorb some of that light.

Chalk, oyster-shells, together with those phosphoric bodies, whose goodness has been very much impaired by long keeping, when finely powdered, and placed within the circuit of an electrical battery, will exhibit, by their scattered particles, a shower of light; but these particles will appear reddish, or their phosphoric power will be sufficient only to detain the yellow, orange, and red rays. When spirits of wine are in a similar manner brought within the circuit of a battery, a similar effect may be discovered; it's particles diverge in several directions, displaying a most beautiful golden appearance. The metallic calces are, of all bodies, those which are rendered phosphoric with the greatest difficulty; but even these may be scattered into a shower of red luminous particles by the electric stroke.

Electrical experiments made in order to ascertain the non-conducting power of a perfect vacuum, &c. by Mr. William Morgan.

The non-conducting power of a perfect vacuum, is a fact in electricity which has been much controverted among philosophers. The experiments made by Mr. Walsh, F. R. S. in the double barometer tube, clearly demonstrated the impermeability of the electric light through a vacuum; nor was it, I think, precipitate to conclude from them the impermeability of the electric fluid itself. But this conclusion has not been universally admitted, and the following experiments were made with the view of determining it's truth or fallacy.

A mercurial gage B, fig. 1, about 15 inches long, carefully and accurately boiled, till every particle of air was expelled from the inside, was coated with tin-foil, 5 inches down from it's sealed end (A), and being inverted into mercury through a perforation D, in the brass cap E, which covered the mouth of the cistern H; the whole was cemented together, and the air was exhausted from the inside of the cistern through a valve C, in the brass cap E just mentioned; which producing a perfect vacuum in the gage B, afforded an instrument peculiarly well adapted for experiments of this kind. Things being thus adjusted, a small wire, F, having been previously fixed on the inside of the cistern, to form a communication between the brass cap E, and the mercury G, into which the gage was inverted; the coated end A was applied to the conductor of an electrical machine; and, notwithstanding every effort, neither the smallest ray of light, nor the slightest charge, could ever be procured in this exhausted gage. It is well known, that if a glass tube be exhausted by an air-pump, and coated on the outſide, both light and a charge may very readily be procured. If the mercury in the gage be imperfectly boiled, the experiment will not ſucceed; but the colour of the electric light, which, in air rarefied by an exhauſter, is always violet or purple, appears in this caſe of a beautiful green; and what is very curious, the degree of the air's rarefaction may be nearly determined by this means. There have been inſtances known, in a courſe of experiments, where a ſmall particle of air having found it's way into the tube B, the electric light became viſible, and as uſual of a green colour; but the charge being often repeated, the gage has at length cracked at it's ſealed end, and in conſequence the external air, by being admitted into the inſide, has gradually produced a change in the electric light, from green to blue, from blue to indigo, and ſo on to violet and purple, till the medium has at laſt become ſo denſe, as no longer to be a conductor of electricity. There can be little doubt, from the above experiments, of the non-conducting power of a perfect vacuum; and this fact is ſtill more ſtrongly confirmed by the phænomena which appear upon the admiſſion of a very minute particle of air into the inſide of the gage. In this caſe, the whole becomes immediately luminous, upon the ſlighteſt application of electricity, and a charge takes place, which continues to grow more and more powerful, in proportion as freſh air is admitted, till the denſity of the conducting medium arrives at it's maximum, which it always does when the colour of the electric light is indigo or violet. Under theſe circumſtances, the charge may be ſo far increaſed, as frequently to break the glaſs. In ſome tubes, which have not been completely boiled, they will not conduct the electric fluid, when the mercury is fallen very low in them; yet upon letting in air into the ciſtern H, ſo that the mercury ſhall riſe in the gage B, the electric fluid, which was before latent in the inſide, ſhall now become

come vifible, and as the mercury continues to rife, and of confequence the medium is rendered lefs rare, the light fhall grow more and more vifible, and the gage fhall at laft be charged, notwithftanding it has not been near an electrical machine for two or three days. This feems to prove, that there is a limit even in the rarefaction of air, which fets bounds to it's conducting power; or, in other words, that the particles of air may be fo far feparated from each other, as no longer to be able to tranfmit the electric fluid; that if they are brought within a certain diftance of each other, their conducting power begins, and continually increafes, till their approach alfo arrives at it's limit, when the particles again become fo near, as to refift the paffage of the fluid entirely, without employing violence, which is the cafe in common and condenfed air, but more particularly in the latter.

It is furprifing to obferve, how readily an exhaufted tube is charged with electricity. By placing it at ten or twelve inches from the conductor, the light may be feen pervading it's infide, and as ftrong a charge may fometimes be procured, as if it were in contact with the conductor. Nor does it fignify how narrow the bore of the glafs may be; for even a thermometer tube, having the minuteft perforation poffible, will charge with the utmoft facility; and in this experiment, the phænomena are peculiarly beautiful.

Let one end of a thermometer tube be fealed hermetically; let the other end be cemented into a brafs cap with a valve, or into a brafs cock, fo that it may be fitted to the plate of an air-pump. When it is exhaufted, let the fealed end be applied to the conductor of an electrical machine, while the other end is either held in the hand, or connected to the floor. Upon the flighteft excitation, the electric fluid will accumulate at the fealed end, and be difcharged through the infide in the form of a fpark; and this accumulation and difcharge may be inceffantly repeated, till the tube is broken. By this means, a fpark 42 inches long may be procured; and if a proper tube could be found, we might have a fpark three or four times that length: if, inftead of the fealed end, a bulb be blown at that extremity of the tube, the electric light will fill the whole of that bulb, and then pafs through the tube in the form of a brilliant fpark, as in the foregoing experiment; though in this cafe, the charge, after a few trials, will make a fmall perforation in the bulb. If, again, a thermometer, filled with mercury, be inverted into a ciftern, and the air exhaufted in the manner before defcribed for making the experiment with the gage, a Torricellian vacuum will be produced; and now the electric light in the bulb, as well as the fpark in the tube, will be of a vivid green; but the bulb will not bear a frequent repetition of charges, before it is perforated in like manner as when it has been exhaufted by an air-pump. It can hardly be neceffary to obferve, that in thefe cafes the electric fluid affumes the appearance of a fpark,* from the narrownefs of the paffage through which it forces it's way. If a tube, 40 inches long, be fixed into a globe, 8 or 9 inches in diameter, and the whole be exhaufted, the electric fluid, after paffing in the form of a brilliant fpark throughout the length of the tube, will, when it gets into the infide of the globe, expand itfelf in all directions, entirely filling it with a violet and purple light, and exhibiting a ftriking inftance of the vaft elafticity of the electric fluid.

Mr. Brook's method of making mercurial gages is nearly as follows. Let a glafs tube L, fig 2, fealed hermetically at one end,

* By cementing the ftring of a guittar into one end of a thermometer tube, a fpark may be obtained, as well as if the tube had been fealed hermetically.

end, be bent into a right angle within two or three inches of the other end; at the diſtance of about an inch or leſs from the angle, let a bulb K, of about ¾ of an inch in diameter, be blown in the curved end, and let the remainder of this part of the tube be drawn out as to I, ſo as to be ſufficiently long to take hold of, when the mercury is boiling. The bulb K is deſigned as a receptacle for the mercury, to prevent it's boiling over, and the bent figure of the tube is adapted for it's inverſion into the ciſtern; for by breaking off the tube at M, within ⅛ or ¼ of an inch of the angle, the open end of the gage may be held perpendicular to the horizon, when it is dipped into the mercury in the ciſtern, without obliging us to bring our finger, or any other ſubſtance, into contact with the mercury in the gage, which never fails to render the inſtrument imperfect. It is neceſſary to obſerve, that if the tube be fourteen or fifteen inches long, it will be neceſſary to boil it for three or four hours; nor will it even then ſucceed, unleſs the greateſt attention be paid that no bubbles of air lurk behind, which will frequently happen, if the tube is not made very dry before the mercury is put into it. If this caution be not obſerved, the inſtrument can never be made perfect.

Experiments on air, by Henry Cavendish, Eſq.

The apparatus uſed in making the experiments was as follows. The air, through which the ſpark was intended to be paſſed, was confined in a glaſs tube M bent to an angle, as in fig. 7, which, after being filled with quickſilver, was inverted into two glaſſes of the ſame fluid, as in the figure. The air to be tried, was then introduced by means of of a ſmall tube, ſuch as is uſed for thermometers, bent in the manner repreſented by A B C, fig. 8, the bent end of which, after being previouſly filled with quickſilver, was introduced, as in the figure, under the glaſs D E F, inverted into water, and filled with the proper kind of air, the end C of the tube being kept ſtopped by the finger; then, on removing the finger from C, the quickſilver in the tube deſcended in the leg B C, and it's place was ſupplied with air from the glaſs D E F. Having thus got the proper quantity of air into the tube A B C, it was held with the end C uppermoſt, and ſtopped with the finger; and the end A, made ſmaller for that purpoſe, being introduced into one end of the bent tube M, fig. 7, the air, on removing the finger from C, was forced into that tube by the preſſure of the quickſilver in the leg B C. By theſe means he was enabled to introduce the exact quantity he pleaſed of any kind of air into the tube M; and by the ſame means, could let up any quantity of ſoap-lees, or any other liquor which he wanted to be in contact with the air.

In one caſe, however, in which he wanted to introduce air into the tube many times in the ſame experiment, he uſed the apparatus repreſented in fig. 9, conſiſting of a tube A B of a ſmall bore, a ball C, and a tube D E of a larger bore. This apparatus was firſt filled with quickſilver, and then the ball C and the tube A B were filled with air, by introducing the end A under a glaſs inverted into water, which contained the proper kind of air, and drawing out the quickſilver from the leg E D by a ſyphon. After being thus furniſhed with air, the apparatus was weighed, and the end A introduced into one end of the tube M, and kept there during the experiment; the way of forcing air out of this apparatus into the tube, being by thruſting down the tube E D a wooden cylinder, of ſuch a ſize as almoſt to fill up the whole bore, and by occaſion-
ally

ally pouring quickſilver into the ſame tube, to ſupply the place of that puſhed into the ball C. After the experiment was finiſhed, the apparatus was weighed again, which ſhewed exactly how much air had been forced into the tube M, during the whole experiment; it being equal in bulk to a quantity of quickſilver, whoſe weight was equal to the increaſe of weight of the apparatus.

The bore of the tube M uſed in moſt of the following experiments, was about one tenth of an inch; and the length of the column of air, occupying the upper part of the tube, was in general from 1 $\frac{1}{2}$ to $\frac{3}{4}$ of an inch.

It is ſcarcely neceſſary to inform any one uſed to electrical experiments, that in order to force an electrical ſpark through the tube, it was neceſſary, not to make a communication between the tube and the conductor, but to place an inſulated ball at ſuch a diſtance from the conductor, as to receive a ſpark from it, and to make a communication between that ball and the quickſilver in one of the glaſſes, while the quickſilver in the other glaſs communicated with the ground.

When the electric ſpark was made to paſs through common air, included between ſhort columns of a ſolution of litmus, the ſolution acquired a red colour, and the air was diminiſhed conformably to what was obſerved by Dr. Prieſtley. When lime-water was uſed inſtead of the ſolution of litmus, and the ſpark was continued till the air could be no farther diminiſhed, not the leaſt cloud could be perceived in the lime-water; but the air was reduced to two thirds of it's original bulk; which is a greater diminution than it could have ſuffered by mere phlogiſtication, as that is very little more than one-fifth of the whole.

The experiment was next repeated with ſome impure dephlogiſticated air. The air was very much diminiſhed, but without the leaſt cloud being produced in the lime-

water;

water; neither was any cloud produced when fixed air was let up to it; but on the further addition of a little cauftic volatile alkali, a brown fediment was immediately perceived.

Hence we may conclude, that the lime-water was faturated by fome acid formed during the operation; as in this cafe it is evident, that no earth could be precipitated by the fixed air alone, but that cauftic volatile alkali, on being added, would abforb the fixed air, and thus becoming mild, would immediately precipitate the earth; whereas, if the earth in the lime-water had not been faturated with an acid, it would have been precipitated by the fixed air. As to the brown colour of the fediment, it moft likely proceeded from fome of the quickfilver having been diffolved.

It muft be obferved, that if any fixed air, as well as acid, had been generated in thefe two experiments with the lime-water, a cloud muft have been at firft perceived in it, though that cloud would afterwards difappear, by the earth being re-diffolved by the acid; for till the acid produced was fufficient to diffolve the whole of the earth, fome of the remainder would be precipitated by the fixed air; fo that we may fafely conclude, that no fixed air was generated in the operation.

When the air is confined by foap-lees, the diminution proceeds rather fafter than when it is confined by lime-water; for which reafon, as well as on account of their containing fo much more alkaline matter in proportion to their bulk, foap-lees feemed better adapted for experiments defigned to inveftigate the nature of this acid, than lime-water. Accordingly fome experiments were made, to determine what degree of purity the air fhould be of, in order to be diminifhed moft readily and to the greateft degree; and it was found, that when good dephlogifticated air was ufed, the diminution was but fmall; when perfectly phlogifticated air was ufed, no fenfible diminution took place; but when

 five

five parts of pure dephlogiſticated air were mixed with three parts of common air, almoſt the whole of the air was made to diſappear. It muſt be conſidered, that common air conſiſts of one part of dephlogiſticated air, mixed with four of phlogiſticated; ſo that a mixture of five parts of pure dephlogiſticated air, and three of common air, is the ſame thing as a mixture of ſeven parts of dephlogiſticated air with three of phlogiſticated.

Having made theſe previous trials, introduce into the tube a little ſoap-lees, and then let up ſome dephlogiſticated and common air, mixed in the above-mentioned proportions, which riſing to the top of the tube M, divided the ſoap-lees into it's two legs, as faſt as the air was diminiſhed by the electric ſpark; continue adding more of the ſame kind, till no further diminution takes place; after which, a little pure dephlogiſticated air, and after that a little common air, were added, in order to ſee whether the ceſſation of diminution was not owing to ſome imperfection in the proportion of the two kinds of air to each other, but without effect. The ſoap-lees being then poured out of the tube, and ſeparated from the quickſilver, ſeemed to be perfectly neutralized, as they did not at all diſcolour paper, tinged with the juice of blue flowers. Being evaporated to dryneſs, they left a ſmall quantity of ſalt, which was evidently nitre, as appeared by the manner in which paper, impregnated with a ſolution of it, burned.

For more ſatisfaction, he tried this experiment over again, on a larger ſcale. About five times the former quantity of ſoap-lees were now let up into a tube of a larger bore; and a mixture of dephlogiſticated and common air, in the ſame proportions as before, being introduced by the apparatus repreſented in fig. 9, the ſpark was continued till no more air could be made to diſappear. The liquor, when poured out of the tube, ſmelled evidently of phlogiſticated nitrous acid.

This salt was found, by the manner in which paper, dipped into a solution of it, burned, to be true nitre. It appeared, by the test of terra ponderosa salita, to contain not more vitriolic acid than the soap-lees themselves contained, which was excessively little; and there is no reason to think, that any other acid entered into it, except the nitrous.

A circumstance, however, occurred, which at first seemed to shew, that this salt contained some marine acid; namely, an evident precipitation took place, when a solution of silver was added to some of it dissolved in water; though the soap-lees used in it's formation were perfectly free from marine acid, and though, to prevent all danger of any precipitate being formed by an excess of alkali in it, some purified nitrous acid had been added to it, previous to the addition of the solution of silver. On consideration, however, he suspected, that this precipitation might arise from the nitrous acid in it being phlogisticated; and therefore tried, whether nitre, much phlogisticated, would precipitate silver from it's solution. For this purpose, he exposed some nitre to the fire, in an earthen retort, till it had yielded a good deal of dephlogisticated air; and then having dissolved it in water, and added to it some well purified spirit of nitre, till it was sensibly acid, in order to be certain that the alkali did not predominate, he dropped into it some solution of silver, which immediately made a very copious precipitate. This solution, however, being deprived of some of it's phlogiston by evaporation to dryness, and exposure for a few weeks to the air, lost the property of precipitating silver from it's solution; a proof that this property depended only on it's phlogistication, and not on it's having absorbed sea salt from the retort, or by any other means.

Hence it is certain, that nitre, when much phlogisticated, is capable of making a precipitate with a solution of silver; and therefore there is no reason to think, that the precipitate, which our ſalt occaſioned with a ſolution of ſilver, proceeded from any other cauſe than that of it's being phlogiſticated; eſpecially as it appeared by the ſmell, both on firſt taking it out of the tube, and on the addition of the ſpirit of nitre, previous to dropping in the ſolution of ſilver, that the acid in it was much phlogiſticated. This property of phlogiſticated nitre is worth the attention of chemiſts; as otherwiſe they may ſometimes be led into miſtakes, in inveſtigating the preſence of marine acid by a ſolution of ſilver.

In a former paper Mr. Cavendiſh has aſſerted, that when nitre is detonated with charcoal, the acid is converted into phlogiſticated air; that is, into a ſubſtance which, as far as he could perceive, poſſeſſes all the properties of the phlogiſticated air of our atmoſphere: from which he concluded, that phlogiſticated air is nothing elſe than nitrous acid united to phlogiſton. According to this concluſion, phlogiſticated air ought to be reduced to nitrous acid by being deprived of it's phlogiſton; but as dephlogiſticated air is only water deprived of phlogiſton, it is plain, that adding dephlogiſticated air to a body, is equivalent to depriving it of phlogiſton, and adding water to it; and therefore phlogiſticated air ought alſo to be reduced to nitrous acid, by being made to unite to, or form a chemical combination with dephlogiſticated air; only the acid formed this way will be more dilute, than if the phlogiſticated air was ſimply deprived of phlogiſton.

This being premiſed, we may ſafely conclude, that in the preſent experiments the phlogiſticated air was enabled, by means of the electrical ſpark, to unite to, or form a chemical combination with the dephlogiſticated air, and was thereby reduced to nitrous acid, which united to the ſoap-lees, and formed a ſolution of nitre; for in theſe experiments thoſe two airs actually diſappeared, and nitrous acid was actually formed in their room; and as, moreover, it has juſt been ſhewn, from other circumſtances, that phlogiſticated air muſt form nitrous acid when combined with dephlogiſticated air, the above-mentioned opinion ſeems to be ſufficiently eſtabliſhed. A further confirmation of it is, that as far as we can perceive, no diminution of air is produced when the electric ſpark is paſſed, either through pure dephlogiſticated air, or through perfectly phlogiſticated air; which indicates the neceſſity of a combination of theſe two airs to produce the acid. Moreover, it was found in the laſt experiment, that the quantity of nitre procured, was the ſame that the ſoap-lees would have produced, if ſaturated with nitrous acid; which ſhews, that the production of the nitre was not owing to any decompoſition of the ſoap-lees.

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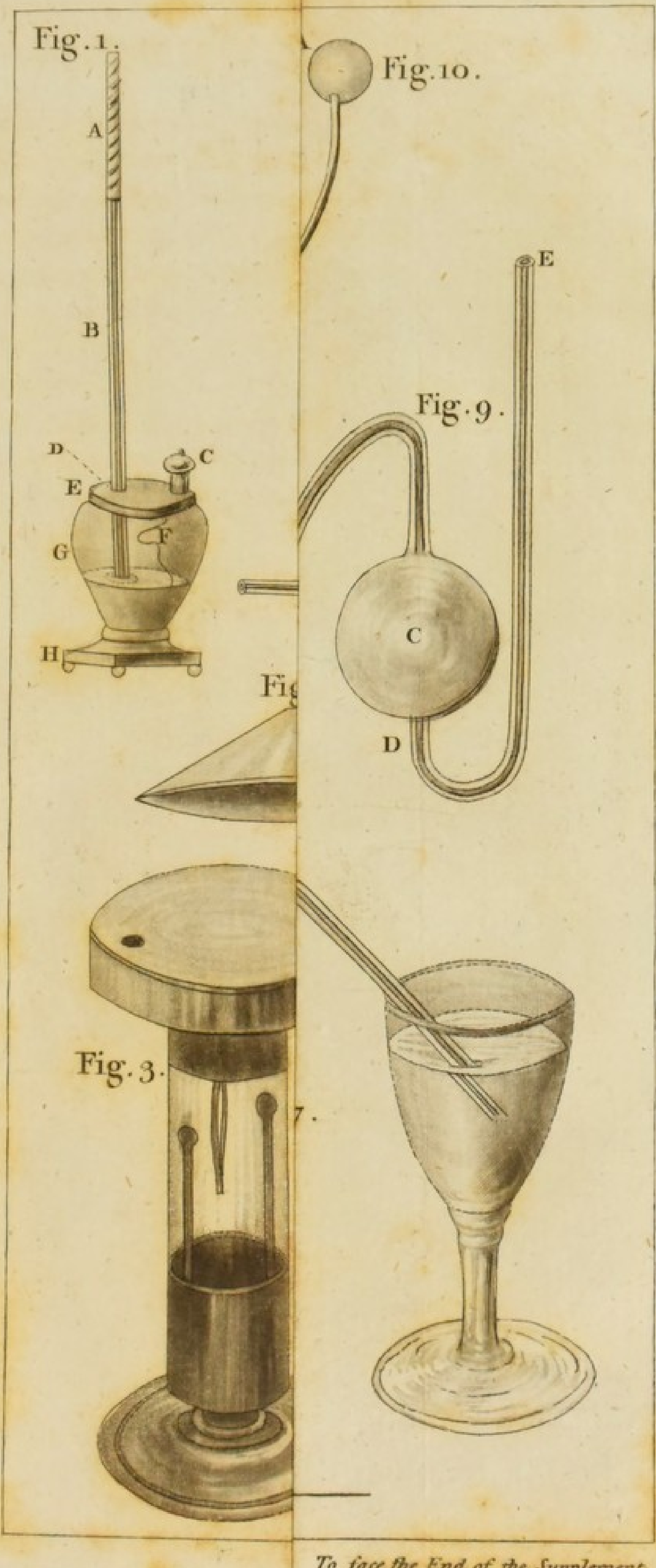

To face the End of the Supplement

AN

ESSAY

ON

ELECTRICITY.

CHAP. I.

OF ELECTRICITY IN GENERAL.

IT muſt appear ſurpriſing to every ſearcher after truth, that electricity, which is now allowed to be one of the principal agents employed in producing the phænomena of nature, ſhould have remained ſo long in obſcurity; for, comparatively ſpeaking, it's exiſtence was not known to the ancients. They were not, indeed, altogether ignorant of the peculiar properties of thoſe bodies that we now term electrics PER SE; neverthelefs their knowledge was circumſcribed, being confined to the obſervation only of thoſe phænomena which nature preſented to their ſenſes, in the ordinary courſe of her operations; hence near two thouſand years elapſed, before any addition was made to the little which was known to Theophraſtus, and this branch of natural hiſtory remained uncultivated, till the happy period arrived, when the philoſopher was emancipated from the chains of hypothetic reaſoning, and the uncertainties of vague conjecture.

The exiſtence of this ſubtle, and in moſt caſes inviſible, power, was then traced, and many of it's properties developed; it's agency was diſcovered to be univerſal, and it's extent unlimited.

Electricity has been dignified in a peculiar manner, by engaging the attention of the philoſophic hiſtorian; who, by delineating the gradual progreſs of it's diſcoveries, deſcribing the different theories which have been invented to account for it's effects, and pointing out the DESIDERATA which ſtill remain to be explored, has contributed, in a high degree, to enlarge the boundaries of electricity, and to increaſe the number of thoſe who cultivate it.

Since the publication of Dr. Prieſtley's hiſtory, the electrical apparatus has been conſiderably augmented, and many new experiments have

have been made. To defcribe the one, and to arrange the other, under fuch heads as will point out the connection between the experiments and the received theory of electricity, was one of the principal views I had in compofing this effay. I alfo wifhed to put into the hands of my cuftomers a tract, which might enable them to ufe, with eafe and fatisfaction, the electrical machines and apparatus which I recommend.

As electricity is in it's infancy, when confidered as a fcience, it's definitions and axioms cannot be ftated with geometric accuracy. I fhall endeavour to avoid, as much as poffible, the ufe of pofitive expreffion, in order to invite the reader to examine the experiments himfelf, to compare them one with another, and then draw his own conclufions; beginning with thofe experiments which were the foundation of the prefent ftate of electricity, and which gave rife to the principal technical terms made ufe of in this fcience.

EXPERIMENT I.—Rub a dry glafs tube with a piece of dry filk, prefent light bodies, as feathers, pith balls, &c. to it, they will be attracted, and then repelled. A piece of black or oiled filk, on which a little amalgam has been placed, makes the beft rubber for a fmooth glafs tube: ſoft new flannel ſucceeds well with ſealing wax.

EXPERIMENT II.—Rub a dry ſtick of ſealing wax, it will firſt attract and afterwards repel thoſe light bodies that are brought near to it.

The friction in the two preceding experiments has put in action an agent, or power, which attracts and repels light bodies; this power is called ELECTRICITY.

A certain quantity or natural ſhare of the electric fluid, is ſuppoſed to be diſſeminated in all bodies, in which ſtate it makes no impreſſion on our ſenſes; but when, by the powers of nature or art, this equilibrium is deſtroyed, and the agency of the fluid is rendered viſible to the ſenſes, then thoſe effects are produced which we term electrical, and the body is ſaid to be ELECTRIFIED.

Any ſubſtance, that is made by friction to exhibit electric appearances, is ſaid to be EXCITED.

Amber, ſilk, jet, dry wood, and a variety of other ſubſtances, being excited, attract and repel light bodies; theſe are called ELECTRICS. Such ſubſtances, as metals, water, &c. the friction of which will not produce this power of attraction and repulsion, are called NON-ELECTRICS.

When the excited glaſs tube, or ſtick of ſealing wax, is in good order, and the particles of electricity are ſufficiently united to act on the organs of viſion; pencils of light will dart from the tube in a beautiful manner, and a ſnapping noiſe will be heard on the approach of any conductor.

Electricity is often excited by other cauſes as well as friction. Thus it may be produced by heating or cooling of ſome ſubſtances, by blowing of air violently on a body, &c. nay, it is probable, that whatever removes the ſtratum of air from the ſurface of any body, or influences the coheſion of it's parts, will diſturb the electric fluid.

The diſcharge of large cannon, and the blowing up of powder magazines, has been known to electrify glaſs windows.

EXPERIMENT III.—Let a metallic cylinder be placed upon ſilk lines, or upon glaſs, bring an excited electric near to it, and every part of the metallic cylinder will attract and repel light bodies, as forcibly as the excited electric itſelf.

EXPERIMENT

EXPERIMENT IV.—Support a dry glaſs rod on ſilk lines, or by glaſs, bring an excited electric near it, and no attraction or repulſion will take place; becauſe the electricity cannot be tranſmitted through it.

From theſe experiments is deduced the diſtinction between thoſe bodies which produce the electric fluid and thoſe which do not.

Thoſe bodies which poſſeſs the power of tranſmitting electricity, are called CONDUCTORS and NON-ELECTRICS.

Thoſe ſubſtances, which are impervious to electricity, are called NON-CONDUCTORS, or ELECTRICS.

A body which communicates with nothing but electrics, is ſaid to be INSULATED.

If all ſubſtances poſſeſſed an equal power of retaining or parting with the electric fluid, the greater part of it's phænomena would have remained unknown to us; but, as it paſſes readily only over the ſurface of ſome ſubſtances, while others reſiſt it's paſſage, or are nearly impermeable to it, we are enabled to accumulate, condenſe, and retain it on the laſt, and thus ſubject it eaſily to the teſt of experiment.

From the third and fourth experiments we learn, that excited electrics will communicate the electric powers to conducting ſubſtances which

which are inſulated, that theſe will then attract and repel light bodies, &c. ſimilar to the electric itſelf; with this difference only, that a conductor, which has received electricity, parts with it at once, when it is touched by another conductor that communicates with the earth; whereas the excited electric, under the ſame circumſtances, only loſes it's electricity partially.

EXPERIMENT V.—Electrify, with excited GLASS or SEALING WAX, two inſulated cork balls, ſuſpended by lines about ſix inches long, and the balls will ſeparate from and repel each other.

EXPERIMENT VI.—Electrify ONE ball with GLASS, the OTHER with SEALING WAX, and they will be mutually attracted.

Theſe two oppoſite and remarkably diſtinct effects in the attractive and repulſive powers of electricity, whereby one attracts what the other repels, were diſcovered at an early period of the hiſtory of this ſcience.

The electric power produced by the excitation of glaſs, is called POSITIVE ELECTRICITY, and the power produced by the excitation of ſealing wax is called NEGATIVE ELECTRICITY. This difference was at firſt thought to depend on the electric, and it was then ſuppoſed that the two kinds of

electricities

electricities were effentially diftinct; but it is now known, that each of thefe powers may be produced from the excitation of either glafs or fealing wax.

Electricians have been engaged, by the difcovery of the two foregoing diftinctions, to examine the electric properties of moft bodies, to afcertain whether they poffeffed the pofitive or negative powers; by this means the catalogue of electrics has been confiderably increafed, and it was foon found that every fubftance, we were acquainted with, had more or lefs affinity with the electric fluid.*

CATALOGUE OF CONDUCTING SUBSTANCES.

1. *Stony Subftances.*

Stony fubftances in general conduct very well, though dry and warm.

Lime-ftone and lime juft burnt are equally imperfect conductors.

Marbles conduct confiderably better than free-ftone, and there is found very little differ-
ence

* See Dr. Prieftley's Hiftory. Cavallo on Electricity. Marât, Recherches fur l'electricité.

ence among any of the ſpecimens of marble that have been tried.

A large piece of white ſpar with a tinge of blue and ſemi-tranſparent, will hardly conduct in the leaſt degree: pretty ſtrong ſparks may be taken from the prime conductor, while it is in contact with it.

A piece of agate, ſemi-pellucid, receives the electric ſpark into it's ſubſtance; though it will paſs over about three quarters of an inch of it's ſurface to reach the finger that holds it, and it diſcharges the battery but ſlowly.

A piece of ſlate, ſuch as is commonly uſed to write on, is a much better conductor than a piece of free-ſtone, which conducts but poorly.

Touch-ſtone conducts pretty well.

A piece of gypſum and plaſter of Paris conducts very well, only the latter having a ſmoother ſurface takes a ſtronger ſpark.

A piece of aſbeſt from Scotland, juſt as it is taken from it's bed, will not conduct. While in contact with the conductor, ſparks may be taken at the diſtance of half an inch with a moderate electrification.

A piece of Spaniſh chalk conducts much like marble.

A piece of Egyptian granite conducts conſiderably better than free-ſtone.

2. *Saline Bodies.*

Oil of vitriol conducts very well.

The metallic falts in general conduct better than any neutrals.

Vitriol of copper and of iron conduct very well, though they will not tranfmit a fhock.

Vitriolated tartar gives a fmall fhock.

Salt-petre does not conduct fo well as fal-ammoniac. If the electric explofion paffes over it's furface, it difperfes into a great number of fragments, in all directions, with confiderable violence.

Volatile fal-ammoniac gives a fmall fhock.

Rock-falt conducts, but not quite fo well as allum; the electric fpark upon it is peculiarly red.

Sal-ammoniac exceeds rock-falt and allum in it's conducting powers, but will not take the leaft fenfible fpark; fo that it feems made up of an infinite number of the fineft points.

Salenitic falts conduct but poorly.

By allum the explofion is attended with a peculiar hiffing noife, like that of a fquib.

3. *Inflammable Bodies.*

A piece of pyrites, of a black colour, takes ſparks at a conſiderable diſtance from the prime conductor, like ſome of the inferior pieces of charcoal.

Another piece of pyrites, which has been part of a regular ſphere, conſiſting of a ſhining metallic matter, will not conduct near ſo well, though much better than any other ſtony ſubſtance. It is a medium betwixt a ſtone and an ore.

Black-lead in a pencil conducts a ſhock ſeemingly like metal or charcoal. A ſmall lump of it takes as full and ſtrong a ſpark from the prime conductor as a braſs knob.

4. *Metals and Ores.*

A piece of gold ore from Mexico is hardly to be diſtinguiſhed in this reſpect from the metal itſelf.

A piece of ſilver ore from Potoſi, though mixed with pyrites, conducts very well.

Two pieces of copper ore, one the moſt valuable that is known, and another of only half the value, are hardly to be diſtinguiſhed from one another in their conducting powers.

Lapis-hæmatites conducts pretty well.

Black-ſand from the coaſt of Africa, which is a good iron ore, and part of which is affected by the magnet as much as ſteel filings, is found to conduct electricity, but not a ſhock. Separating with the magnet all that will be eaſily attracted by it, it conducts a ſhock very well: the reſt would hardly conduct at all.

The ores in which the metal is mineralized with ſulphur or arſenic, as the ores of lead, tin, and cinnabar, the ore of quickſilver, are little inferior to gold and ſilver ore.

Ores that contain nothing but the earth of the metal, conduct electricity little better than other ſtones.

Lead, tin, iron, braſs, copper, ſilver, and gold.

5. *Fluids.*

The fluids of an animal body.

All fluids, excepting air and oils.

Fluids appear, in general, to be better conductors in proportion as they contain leſs inflammable matter.

Mr. Cavendiſh has ſhewn, that iron wire conducts about four hundred millions of times better than rain or diſtilled water; i. e. the electricity meets with no more reſiſtance, in paſſing through a piece of iron wire four hundred million inches long, than through a column of water of the ſame diameter only one inch long.

Sea water, or a ſolution of one part of ſalt in thirty of water, conducts an hundred times, and a ſaturated ſolution of ſea ſalt ſeven hundred and twenty times better than rain water.

The effluvia of flaming bodies.

Snow, ſmoke, the vapour of hot water, the vacuum produced by an air pump, charcoal, &c.

ELECTRIC BODIES.

Amber, jet, pitch, and ſulphur; likewiſe all the precious ſtones, as diamonds, rubies, garnets, topazes, hyacinths, chryſolites, emeralds, ſapphires, amethyſts, opals, and eſpecially tourmalins; all reſins and reſinous compounds, wax, ſilk, cotton; all dry animal ſubſtances, as feathers, wool, hair, paper, &c. White ſugar, air, oil, chocolate, calxes of metals, dry vegetables, &c.

I do not know whether it is altogether proper to add to this liſt of electrics, the Torpedo and Surinam Eel, living electrics, whoſe electricity is put in action by the will of the animal.

The real and intrinſic difference between electrics and non-electrics, remain among the electric deſiderata; for nothing more is aſcertained,

tained, than that the conducting power, in ſome meaſure, depends upon, or is governed by heat. Glaſs, reſin, and many other articles, are made conductors by heat; while on the contrary, cold, if not attended with moiſture, renders every electric ſubſtance more electric.

Mr. Achard, of Berlin, has publiſhed, in Rozier's Journal de Phyſique, a very ingenious paper on this ſubject; in which he proves, by experiment, 1ſt, That certain circumſtances will cauſe a body to conduct electricity, which before was a non-conductor. 2d, That theſe circumſtances are the degrees of heat to which this body is ſubjected. He endeavours to ſhew, that the principal changes which take place in any ſubſtance from an increaſe of heat, are an augmentation in the ſize of it's pores, and an increaſe of velocity in the igneous particles contained in, and acting on, that body. He then proves, that the laſt circumſtance does not occaſion the alteration in the electric properties; and infers, agreeable to the ſyſtem of Mr. Euler, that the principal difference between conductors and non-conductors of electricity conſiſts in the ſize of the pores of the conſtituent parts of the body.

A LIST

A LIST OF ELECTRIC SUBSTANCES AND OF THE DIFFERENT ELECTRICITIES PRODUCED BY THEM.

The back of a cat	Poſitive	Every Subſtance with which it has been hitherto tried.
Smooth glaſs	Poſitive	Every ſubſtance hitherto tried, except the back of a cat.
Rough glaſs	Poſitive	Dry oiled ſilk, ſulphur, metals.
	Negative	Woollen cloth, quills, wood, paper, ſealing-wax, white wax, the human hand.
Tourmalin	Poſitive	Amber, air.*
	Negative	Diamond, human hand.
Hare's ſkin	Poſitive	Metals, ſilk, loadſtone, leather, the hand, paper, baked wood.
	Negative	Other finer furs.
White ſilk	Poſitive	Black ſilk, metals, black cloth.
	Negative	Paper, hand, hair, weaſel's ſkin.

* i. e. By blowing with a pair of bellows upon it. By this means many electrics may be excited, and ſome better if the air blown is hot, although, in both caſes, very little electricity can be obtained.

Black ſilk	Poſitive	Sealing wax.
	Negative	Hare's, weaſel's, and ferret's ſkins, loadſtone, braſs, ſilver, iron, the hand.
Sealing wax	Poſitive	Metals.
	Negative	Hare's, weaſel's, and ferret's ſkins, hand, leather, woollen cloth, paper.
Baked wood	Poſitive	Silk.
	Negative	Flannel.

Many circumſtances, apparently trifling, will occaſion an alteration in theſe contrary electricities. It has been ſaid, that of two equal ſubſtances rubbed together, that which ſuffers the greateſt friction, or is moſt heated, acquires the negative electricity. Though this in many caſes holds true, with reſpect to ſilk ribbons, yet Mr. Bergman ſays, that if the ribbon A be black, it will never become poſitive, unleſs B be black likewiſe. With pieces of glaſs the effect is contrary; for, if they are both equal, the piece A, which is drawn acroſs the piece B, becomes negative; and B, which ſuffers the greateſt friction, becomes poſitive. Heating by fire produces the ſame effect as the greater friction. If one piece of glaſs be thicker than the other, the former becomes poſitive, the latter negative.

Coloured

Coloured glaſs, even when heated, becomes negative, if rubbed with common white glaſs. If a piece of blue glaſs is rubbed againſt a green one, the blue glaſs becomes ſtrongly poſitive, &c.———Bergman, Swediſh Tran. 1765.

The electricities produced by hair and glaſs rubbed together ſeem to ballance each other, and are therefore different according to the manner of rubbing and the quality of the hair.

Hair of a living animal, or hair newly cut, when rubbed with a glaſs tube lengthways, is poſitive; and here, the glaſs, which ſuffers the greateſt friction, is negative. But if the glaſs tube be drawn acroſs the animal's back, or acroſs a ſkain of hair newly cut, the glaſs becomes poſitive. Old dry hair, rubbed on glaſs or on living hair, always becomes negative; but if the hair is a little greaſed with tallow, the ſame effect is produced as with living hair. Wilke Swed. Tran. 1769.

Electrics differ from each other with reſpect to the facility with which they are excited, their force when excited, and the power with which they retain the effects of the excitation.

Silk ſeems preferable to any other electric ſubſtance, for exhibiting a permanent and ſtrong attractive and repulſive power.

Glaſs appears to have the advantage in exhibiting the electric light, attraction, and repulſion in quick ſucceſſion, in a very vigorous, though not a durable manner.

Negative electrics, as amber, gum-lac, ſulphur, reſin, and all reſinous ſubſtances, exhibit the electric appearances for the greateſt length of time. A ſingle excitation is ſufficient to make them do ſo for many weeks, in favourable circumſtances. They are alſo remarkable for the ſtrong electric powers which they communicate to conducting bodies that come in contact with them, and which they will continue to communicate for a conſiderable time.

It may be proper to obſerve here, that the two claſſes of electrics and non-electrics are not ſo ſtrongly marked by nature as to enable the electrician to arrange every ſubſtance with propriety: hence the ſame ſubſtance has been placed by different writers in a different claſs. Beſides this, the electric properties of the ſame ſubſtance vary on a change of circumſtances; thus a piece of green wood is a conductor; the ſame piece, after it has been baked, becomes a non-conductor; charred and formed into charcoal, it again conducts the electric fluid; but when reduced to aſhes, is impervious to it.

But further, the diſtinctions themſelves are very inaccurate, ſince every ſubſtance is in a certain degree a conductor of this fluid, though ſome reſiſt it's paſſage more than others.

CHAP. II.

OF THE ELECTRICAL MACHINE; WITH DIRECTIONS FOR EXCITING IT.

AS ſoon as the properties of electricity were in ſome meaſure developed, the philoſopher and the artiſt concurred in contriving and executing a variety of machines to excite and accumulate this extraordinary agent. The greater part of theſe have been laid aſide, in proportion as the ſcience advanced, and it's boundaries were extended. I ſhall, therefore, only deſcribe that electrical machine which is now in general uſe, whoſe conſtruction is ſimple, and well adapted to produce the electric fluid in great quantities, and tranſmit it in full and continued ſtreams to the prime conductor.

That the operator may ſucceed in producing this effect, I ſhall firſt enumerate thoſe parts of the machine which require moſt attention; then deſcribe the machine itſelf, and afterwards give inſtructions to enable him to excite it powerfully.

The following are the parts of an electrical machine, which fall more immediately under the care of the electrician.

1. The

1. The electric, which is to be excited, as the glass cylinder.

2. The mechanical contrivances by which the electric is put in motion.

3. The cushion and it's appendages.

4. The conductor or conductors.

Fig. 1 and 2, plate I. represent two electrical machines made on the most approved construction. They are both mounted and used in the same manner, and differ only in the mechanism by which the cylinder is put in motion.

The cylinder of the machine, fig. 2. is turned round by means of the two wheels a b, c d, which act on each other by a catgut band, part of which is seen at e and f.

The cylinder of the machine, which is represented in fig. 1, is put in motion by a simple winch, which is less complicated than the multiplying wheel, and therefore not so liable to be out of order. * Most practical electricians, however, prefer a machine which is moved by a multiplying wheel, as it fatigues the operator less than that which is moved by a simple winch; while at the same time a moderate increase of velocity

* I have lately improved the machines made with a multiplying wheel, rendered them more durable, and not more liable to be put out of order than those which turn only with a winch.

velocity in the cylinder augments the momentum of the electric fluid, and produces a greater quantity of it in the ſame time, and thus prevents it's being abſorbed by the cuſhion. And further, when the machine is fixed to a table, the poſition of the lower multiplying wheel is more advantageous to the operator, giving him a greater power over the cylinder and fatiguing him leſs; it may alſo be turned with the right hand, which cannot be done conveniently with the other. *

As the two machines, which are repreſented in fig. 1 and 2, plate I. are nearly ſimilar, the ſame letters of reference are uſed in deſcribing them.

Fig. 1 and 2. A B C repreſent the bottom board of the machine.

D and E, the two perpendicular ſupports, which ſuſtain or carry the glaſs cylinder F G H I.

The axis of the cap K paſſes through the ſupport D; on the extremity of this axis either a ſimple winch is fitted, as in fig. 1, or a pulley, as in fig. 2.

The axis of the other cap runs in a ſmall hole which is made in the top of the ſupport E.

O P is

* It may be proper to remark, that thoſe with a ſimple winch are cheaper than thoſe with a multiplying wheel.

O P is the glaſs pillar to which the cuſhion is fixed, T a braſs ſcrew at the bottom of this pillar, which is to regulate the preſſure of the cuſhion againſt the cylinder. This adjuſting ſcrew is peculiarly advantageous. By it the operator is enabled to leſſen or increaſe gradually the preſſure of the cuſhion, which it effects in a much neater manner than it is poſſible to do when the inſulating pillar is fixed on a ſliding-board, a method that diſgraces the maker.

g h i A piece of ſilk that comes from the under edge of the cuſhion, and lies on the cylinder, paſſing between it and the cuſhion, till it nearly meets the collecting points of the conductor.

On the top of the pillar O P is a conductor, which is connected with the cuſhion, which is called the negative conductor. In both figures this conductor is ſuppoſed to be fixed cloſe to the cuſhion, and to lie parallel to the glaſs cylinder. In fig. 1, it is brought forwards, or placed too near the handle, in order that more of it may be in ſight, as at R S; in fig. 2, the end R S only is ſeen.

Y Z, Fig. 1 and 2, repreſents the poſitive prime conductor, or that which takes the electric fluid immediately from the cylinder, L M the glaſs pillar by which it is ſupported and inſulated, infulated, and V X a wooden foot or bafe for the glafs pillar. In fig. 1, this conductor is placed in a direction parallel (which is the beft pofition) to the glafs cylinder; in fig. 2, it ftands at right angles to the cylinder; it may be placed in either pofition occafionally, as is moft convenient to the operator. In general, electrical machines are fold with a fingle conductor; though there are many experiments where two are convenient, and from fome improvements I have lately made in the apparatus, they are rendered exceeding proper for experimental inquiries.

DIRECTIONS FOR KEEPING THE MACHINE IN ORDER.

Before the electrical machine is put in motion, examine thofe parts which are liable to wear either from the friction of one furface againft another, or to be injured by the dirt, that may infinuate itfelf between the rubbing furfaces: fuch as the axes which work in the wooden fupports D E, and the axis of the large wheel c d, fig. 2.

If any grating or difagreeable noife is heard, the place from whence it proceeds muft be difcovered, wiped clean, and rubbed over with a fmall quantity of tallow; a little fweet oil or tallow

tallow ſhould alſo be occaſionally applied to the axis of the cylinder.

The ſcrews that belong to the frame ſhould be examined, and if they are looſe, they ſhould be tightened.

The different working parts of the machine having been looked into, and put in order, the glaſs cylinder, and the pillars which ſupport the cuſhion and conductor, ſhould be carefully wiped, to free them from the moiſture which glaſs attracts from the air, being particularly attentive to leave no moiſture on the ends of the cylinder, as any damp on theſe parts carries off the electric fluid, and leſſens the force of the machine.

Glaſs pillars have been ſometimes uſed to ſupport the cylinder, but they can be of no uſe, unleſs the foregoing circumſtance is conſtantly attended to; and if that is obſerved, they are ſuperfluous.

Take care that no duſt, looſe threads, or filaments adhere to the cylinder, it's frame, the conductors, or their inſulating pillars; becauſe theſe will gradually diſſipate the electric fluid, and prevent the machine from acting powerfully.

Rub the glaſs cylinder firſt with a clean, coarſe, dry, warm cloth, or a piece of waſh leather, and then with a piece of dry, warm, ſoft ſilk; do the ſame to all the glaſs inſulating pillars of the machine and apparatus; thefe pillars muft be rubbed more lightly than the cylinder, becaufe they are varnifhed.

A hot iron may in fome cafes be placed on the foot of the conductor, to evaporate the moifture which would otherwife injure the experiments.

OF THE CIRCUMSTANCES NECESSARY TO BE ATTENDED TO, IN ORDER TO EXCITE A LARGE QUANTITY OF THE ELECTRIC FLUID.

In order to find out an effectual mode of exciting powerfully an electrical machine, it is neceffary to frame fome idea of the mechanifm by which the cylinder extracts the electric fluid from the cufhion, and thofe bodies which are connected with it; I have, therefore, fubjoined thofe conjectures on which I have worked, and by which I have been able to excite, in the moft powerful manner, the machines which have paffed through my hands.

It appears to me, that the refiftance of the air is leffened, or a kind of vacuum is produced, where the cufhion is in clofe contact with the cylinder; that the electric matter, agreeable to the law obferved by all other elaftic fluids, is preffed towards that part where it finds leaft refiftance; the fame inftant, therefore, that the cylinder is

feparated

ſeparated from the cuſhion, the fire iſſues forth in abundance, becauſe the reſiſtance made to it by the action of the atmoſphere is leſſened at that part; a further circumſtance is alſo to be taken into this hypotheſis, namely, the effect which ariſes from the deſtruction of the attraction or coheſion between the cylinder and cuſhion. The more perfect the continuity is made, and the quicker the ſolution of it, the greater is the quantity which will proceed from the cuſhion. But, as the fluid in this ſituation will enter with avidity every conducting ſubſtance that is near it, if any amalgam lies above that part of the cuſhion which is in contact with the cylinder, it will abſorb and carry back part of the electric fire to the reſervoir from whence it was extracted.

If theſe conjectures be true, to excite an electrical machine effectually, we muſt,

1ſt, Find out thoſe parts of the cuſhion which are preſſed by the glaſs cylinder.

2d, Apply the amalgam only to thoſe parts.

3d, Make the line of contact between the cylinder and cuſhion as perfect as poſſible.

4th, Prevent the fire that is collected from eſcaping.

About the year 1772, I applied a looſe flap of leather to the front of the cuſhion; the amalgam was ſpread over the whole of the flap;

the cuſhion was then put in it's place, and the looſe flap of leather doubled down, or rather turned in, more or leſs, till by ſucceſſive experiments that ſituation was diſcovered which produced the greateſt effect; for, by this means, the quantity of amalgam acting againſt the cylinder was leſſened, and the true line of contact in ſome meaſure aſcertained. Hence I was naturally led to contract the breadth of the cuſhion, and afterwards to place it in ſuch a manner that it might be eaſily raiſed or lowered.

To find the line of contact formed between the cylinder and cuſhion, place a line of whiting, which has been previouſly diſſolved in ſpirits of wine, on the cylinder; on turning this round, the whiting is depoſited on the cuſhion, and marks thoſe parts of it which bear or rub againſt the cylinder. The amalgam is to be put on thoſe parts only, which are thus marked by the whiting: this line may alſo be aſcertained, by obſerving the parts of the cuſhion which gather the duſt from the cylinder, and laying the amalgam only on thoſe parts.

The line of contact being found, and the amalgam placed on it, the cylinder is to be rubbed with a piece of leather which is covered with amalgam, which will render the contact between the cylinder and cuſhion more perfect,

perfect, because it fills the smaller pores of the glass with amalgam, and deposits the superfluous particles on the cushion; it is also probable that the amalgam, thus deposited on the surface of the glass, forms a continued series of conducting particles, which carry the fire to the prime conductor, and will consequently, under certain circumstances, carry it back again to the cushion. When the cylinder is rubbed with the amalgamated leather, that part of the oil, or black silk, which lies above the cushion, is to be turned back, and if, by accident, any particles of amalgam stick to it, they must be wiped off carefully. If the machine has not been used for some time, it will be proper to place it, for a few minutes, before a fire, and to take off the cushion and dry the silk thereof.

If the electricity of the cylinder grows less powerful, it is easily renewed by turning back the silk which lies over it, and then rubbing the cylinder with the amalgamated leather, or by occasionally altering the pressure of the adjusting screw.

A very small quantity of tallow placed over the amalgam, is observed to give more force to the electric powers of the cylinder; the same end is answered by rubbing the cylinder with a coarse cloth that has been greased a little, and afterwards

afterwards wiping the cylinder with a clean cloth.

EXPERIMENT VII.—When the cylinder is put into good action, a number of circular lines of fire will iſſue from the cuſhion; preſent a row of metallic points towards theſe, and they will diſappear. This experiment ſhews, the conducting ſubſtance collects the electric fluid before it can take thoſe appearances, or be diſſipated into the air.

Hence we learn, that to prevent a loſs of the electric fluid which is excited, we muſt prevent the air from acting on the fluid, which is put in motion by the excitation; becauſe the air not only reſiſts the emiſſion of the fluid, but alſo diſſipates what is collected on account of the conducting ſubſtances, which are continually floating in it.

Theſe ends are effectually anſwered by letting a non-conducting ſubſtance, as a piece of black or oiled ſilk, proceed from the line of contact to the collecting points of the prime conductor, and placing theſe points within it's atmoſphere. The ſtreams of fire, which proceed from the cuſhion over the cylinder, ſhew whether the cuſhion bears uniformly againſt the cylinder; for they are moſt copious and denſe at thoſe parts where the

preſſure

preſſure is greateſt, but are uniformly denſe, when the preſſure is equable.

When the zinc amalgam is uſed, the ſilk will ſometimes adhere ſo ſtrongly to the cylinder as to render it very difficult to turn ; to obviate this, wipe the ſilk perfectly clean, and then rub it over with a very ſmall quantity of aurum muſivum, or a little whiting.

The operator ought not to think his machine in good order till it pours forth the fire in great abundance, and ſtrong denſe ſparks are obtained in quick ſucceſſion from the conductor. When the conductor is removed, the fire ſhould ſparkle round the cylinder, and throw out many beautiful bruſhes of light.

Two kinds of amalgam are much in requeſt at preſent. One is made of quickſilver five parts, zinc one part, which are melted together with a ſmall quantity of bees-wax: the other is the aurum muſivum of the ſhops. I find it difficult, after many trials, to ſay which of theſe act the beſt. To make either amalgam adhere cloſely to the ſilk, it is neceſſary to greaſe it, wipe off the ſuperfluous greaſe, and then ſpread the amalgam.

The following experiment illuſtrates and confirms the foregoing conjectures on the mechaniſm by which the fluid is extracted from the cuſhion, and thoſe bodies which are connected with it.

EXPE-

EXPERIMENT VIII.—Break a ſtick of ſealing wax in two pieces; thoſe extremities that were contiguous will be found electrified with contrary powers; one will be poſitively, the other negatively, electrified.

EXPERIMENT IX.—Put the machine in action, connect the cuſhion by a chain with the ground, and thoſe bodies which communicate with the poſitive conductor will be electrified poſitively. Connect the poſitive conductor with the earth by a chain, take off the chain from the cuſhion, and thoſe bodies which communicate with the cuſhion or negative conductor will be electrified negatively.

EXPERIMENT X.—Connect the poſitive conductor by a chain with the table; turn the cylinder, and the cuſhion will be found to be negatively electrified. Take the chain off from the poſitive conductor, and both will exhibit ſigns of electricity; but any electrified body, which is attracted by the one, will be repelled by the other. If they are brought ſufficiently near to each other, ſparks will paſs between them, and they will act on each other ſtronger than on any other bodies. If they are connected together, the electricity of the one will deſtroy that of the other; for though the

the fire ſeems to proceed from the cuſhion to the conductor, the two, when thus conjoined, will exhibit no ſigns of electricity, becauſe the fire is continually circulating from one to the other, and is therefore kept always in the ſame ſtate.

We ſee, by this experiment, that electric appearances are produced both in the electric which is excited, and the ſubſtance by which it is excited, provided that ſubſtance be inſulated; but their electric powers are directly reverſe of each other, and may be diſtinguiſhed by oppoſite effects.

EXPERIMENT XI.—If the cuſhion and the conductor are both inſulated, it is obſerved, that the leſs electric fluid is obtained, the more perfect the inſulation is made.

The moiſture which is at all times floating in the air, together with the ſmall points, from which it is impoſſible totally to free the cuſhion, do not permit it to be perfectly inſulated, ſo as to afford no ſupply of electric matter to the cuſhion.

If the air, and other parts of the apparatus, are very dry, little or no electricity will be produced in the above-mentioned circumſtances.

From this experiment it is inferred, that the electric powers do not exiſt in the electrics themſelves, but are produced from the earth by the excitation of electrics; or that the electric matter on the prime conductor is not produced by the friction of the cylinder againſt the cuſhion, but is collected by that operation from it, and from thoſe bodies which are connected with it.

As Dr. Franklin ſeems to have ſuggeſted this idea firſt that the electric fluid is collected from the earth, I have ſubjoined his own account of the experiment which led him to this concluſion.

EXPERIMENT XII.—Let one perſon ſtand on wax (or be inſulated) and rub a glaſs tube, and let another perſon on wax take the fire from the firſt, they will both of them (provided they do not ſtand ſo near as to touch each other) appear to be electrified to a perſon ſtanding on the floor; that is, he will perceive a ſpark on approaching either of them with his knuckle.

2. But if the perſons on wax touch one another during the excitation of the tube, neither of them will appear to be electrified.

3. If they touch one another after the exciting the tube, and draw the fire as aforeſaid, there will be a ſtronger ſpark between them, than was between either of them and the perſon on the floor.

 4. After

4. After ſuch a ſtrong ſpark neither of them diſcover ANY ELECTRICITY.

Theſe appearances he accounts for thus: he ſuppoſes the electric fire is a common element, of which each of the three perſons has his equal ſhare before any operation is begun with the tube.

A, who ſtands upon wax and rubs the tube, collects the electrical fire from himſelf into the glaſs, and his communication with the common ſtock being cut off by the wax, his body is not again immediately ſupplied.

B, who alſo ſtands upon wax, paſſing his knuckle along the tube, receives the fire which was collected from A, and being inſulated he retains this additional quantity.

To C both appear electrified; for he, having only the middle quantity of electrical fire, receives a ſpark on approaching B, who has an over quantity, but gives one to A, who has an under quantity.

If A and B approach to touch each other, the ſpark is ſtronger, becauſe the difference between them is greater. After this touch there is no ſpark between either of them and C, becauſe the electrical fluid in all is reduced to the original equality. If they touch while electrifying, the equality is never deſtroyed, the fire is only

 circulating;

circulating: hence we ſay, that B is electrified poſitively, A negatively.

As thoſe experiments have been deſcribed, which are the foundation of our preſent knowledge in electricity, I hope it will not be deemed improper to introduce in this place thoſe hypotheſes which have been built on them.

Dr. Franklin's hypotheſis depends on, and may be reduced to, the following principles.

1. That the atmoſphere and all terreſtrial ſubſtances are full of electric matter.

2. That the operations of electricity depend on one fluid SUI GENERIS, extremely ſubtle and elaſtic.

3. Glaſs and other electric ſubſtances, though they contain a great deal of electric matter, are IMPERMEABLE to it.

4. That the electric matter violently repels itſelf, and attracts all other matter.

5. That conducting ſubſtances are permeable to the electric matter through their whole ſubſtance, and do not conduct merely over their ſurface.

6. Poſitive electricity is when a body has more than it's natural ſhare of the electric fluid, and negative electricity when it has leſs than it's natural ſhare.

The

The following hypothefis is extracted from the analyfis of a courfe of lectures by Mr. Atwood, to which, and Mr. Eeles's philofophical effays, I muft refer the reader for a fuller account of it; in the courfe of this effay many obfervations will occur, which tend to confirm this, and refute the foregoing hypothefis.

HYPOTHESIS.

1. That two electric powers exift together in all bodies.

2. Since they counteract each other when united, they can be made evident to the fenfes only by their feparation.

3. The two powers are feparated in non-electrics by the excitation of electrics, or by the application of excited electrics.

4. The powers cannot be feparated in electric fubftances.

5. The two electricities attract each other ftrongly through the fubftance of electrics.

6. Electric fubftances are impervious to the two electricities.

7. Either power, when applied to an unelectrified body, repels the power of the fame fort, and attracts the contrary power.

A DESCRIPTION

A DESCRIPTION OF SOME PARTS OF THE ELECTRIC APPARATUS, WHICH COULD NOT BE REGULARLY INTRODUCED IN THE BODY OF THE WORK.

Fig. 1, plate II. repreſents a common diſcharging rod; it is generally made of braſs wire, with a ball at each of it's ends. To diſcharge a Leyden bottle with it, hold the ſemicircular part in the hand, place one ball of the diſcharging rod on the coating of the phial, then bring the other to touch the knob of the wire which communicates with the inſide, when an exploſion will enſue, and the phial will be diſcharged.

Fig. 2, plate II. is a jointed diſcharging rod with a glaſs handle, the legs of which may be moved, and ſet to any given diſtance from each other by means of the joint C; the extremities of the legs are pointed, the points enter into the balls a, b, which ſcrew on the legs, and from which they may be unſcrewed at pleaſure; ſo that either the balls or the points may be uſed as occaſion requires.

Fig. 3, plate II. repreſents the univerſal diſcharger; an inſtrument which is of very extenſive uſe in forming communications to direct or convey the electric ſhock through any part of a given ſubſtance. Many examples of the utility of this inſtrument will occur in the courſe of this eſſay.

eſſay. When the univerſal diſcharger is made on a large ſcale, it is a convenient apparatus to enable a perſon to electrify himſelf; ſee fig. 87.

A B. fig. 3, is the baſe of the univerſal diſcharger; on this are fixed two perpendicular glaſs pillars C, D; on the top of each of theſe is cemented a braſs cap, to which is fixed a double joint, or one which has both a vertical and horizontal motion; on the top of each joint is a ſpring tube which receives the wires E T, E F; theſe wires may be ſet at various diſtances from each other, and turned in any direction; the extremities of the wires are pointed, the points are covered occaſionally by the braſs balls, which are made to fit on the wires by ſpring ſockets: G H is a ſmall wooden table, on the ſurface of which a ſlip of ivory is inlaid; this table is furniſhed with a cylindrical ſtem, which fits into a cavity of the pillar I; it may be raiſed occaſionally to various heights, and fixed at any one of them by the ſcrew K.

Fig. 4, plate II. is a little wooden preſs, furniſhed with a ſtem, which fits the cavity in the pillar I, fig. 3, into which it is to be placed occaſionally, when the table G H is removed. The preſs conſiſts of two boards, which are brought cloſe to each other by means of the ſcrews a a.

Fig.

Fig. 5, plate II. is Mr. Kinnerſley's electrical air thermometer; a b is a glaſs tube, on each end of which a braſs cap is cemented; c d is a ſmall glaſs tube, open at both ends, which paſſes through the upper, and deſcends nearly to the under plate: a box ſcale, which is divided into inches and tenths of inches, is fitted to the upper part of this tube; g is a braſs wire with a ball on it, which is ſcrewed to the under plate, a ſimilar wire f h is made to paſs through a collar of leathers on the upper plate, and may be placed at any convenient diſtance from the lower wire.

Electricians have long wiſhed for an inſtrument which would aſcertain, in an exact and invariable manner, the degree of electricity excited when any experiment is made. For this purpoſe a great many contrivances have been propoſed and executed, which, upon trial, are all found to be very defective.

An electrometer ought to have the following properties,

1. It ſhould be ſimple in it's conſtruction, and not compoſed of many parts.

2. It ſhould not be effected by the variations of the atmoſphere.

3. It ſhould indicate ſmall as well as large degrees of electricity.

4. Not

4. Not to be adjufted to any fixed meafure.

5. The electric power fhould be expreffed by a fixed and invariable force, as that of gravity.

6. That the obferver be enabled to read off the divifions at a diftance, which will prevent his weakening the influence of the electric powers.

Plate II. fig. 6, reprefents the quadrant electrometer, the moft ufeful inftrument of the kind yet difcovered, as well for meafuring the degree of electricity of any body, as to afcertain the quantity of a charge before an explofion; and to difcover the exact time the electricity of a jar changes, when without making an explofion, it is difcharged by giving it a quantity of the contrary electricity. The pillar L M is generally made of wood, the graduated arch N O P of ivory, the rod R S is made of very light wood, with a pith ball at the extremity; it turns upon the center of the femicircle, fo as always to keep near it's furface; the extremity of the ftem L M may either be fitted to the conductor or the knob of a jar. When the apparatus is electrified, the rod is repelled by the ftem, and moves along the graduated arch of the femicircle, fo as to mark the degree to which the conductor is electrified, or the height to which the charge of the jar is advanced.

Beccaria recommends fixing the index between two ſemicircles, becauſe when it is placed over one only, the electricity of this repels and counteracts the motion of the index. Other improvements and variations have been made in this inſtrument, which will be deſcribed hereafter.

Plate II. fig. 9, is an electrometer which was contrived many years ſince by Mr. Townſend, to aſcertain the real force of the electric exploſion. a b is a ſmall ivory plate, c a looſe cone of ivory to be placed on the plate a b, e f g, a circle which turns freely on two centres, an arm, d, of wood proceeds from this circle and lies on the cone of ivory. The diſcharge is made to paſs under the cone which throws up the arm d, the elevation of which is marked by the index h; a piece of ſilk ſtring is fixed at one end to the bottom board at i, and paſſes over the wheel; a weight k is tied to the other end to regulate the friction of the circle e f g.

Fig. 8 is an inſulating ſtool; the feet are of glaſs. When it is uſed, the inſulation will be rendered more perfect by placing a ſheet of paper well dried under the feet of the ſtool.

CHAP.

CHAP. III.

THE PROPERTIES OF ELECTRIC ATTRACTION AND REPULSION, ILLUSTRATED BY EXPERIMENTS ON LIGHT BODIES.

NATURAL philoſophers were originally incited to conſider the nature of electricity from it's ſtrong attractive and repulſive powers. The phænomena exhibited by thoſe myſterious properties are ſo various and ſo pleaſing, that they were led, as by enchantment, to purſue the ſubject; and have been richly rewarded by the diſcoveries, which are both intereſting and important.

The powers of genius have been exerted with induſtrious ardour to inveſtigate the cauſes of thoſe properties; but they are ſtill involved in deep obſcurity, and we are ſtill totally ignorant of that mechaniſm by which light bodies, when electrified, approach to or recede from each other.

To enter into a diſcuſſion of the difficulties * which perplex this ſubject, would lead me too far

* "Qui pourroit concevoir qu'un corps agit *ou il n'eſt* "*pas*; ſans aucun intermede? Deux particules de *matiere* "ſont

far from the deſign of this eſſay; I ſhall, therefore, proceed to ſtate thoſe general properties, or modes of action, which are obſerved in electric attraction and repulſion, and then deſcribe the experiments from which thoſe properties have been deduced, or by which they are illuſtrated.

GENERAL PROPERTIES OF ELECTRICAL ATTRACTION AND REPULSION.

1. The electric fluid, when in action, diſpoſes or places light bodies in ſuch manner as will beſt facilitate it's tranſmiſſion through them, with the greateſt velocity; and this in proportion to the gravity of the body, it's conducting power, and the ſtate of the air.

2. Bodies that are electrified poſitively repel each other.

3. Bodies electrified negatively repel each other.

4. Bodies electrified by contrary powers attract each other ſtrongly.

5. Bodies that are electrified, attract thoſe ſubſtances which are not electrified.

6. Thoſe

"ſont à cent milles lieues, ou à cent milliemes parties d'un "ligne de diſtance l'un de l' autre, ſans aucune communi- "cation materielle entrelles, et à l'ocaſion de l'une l'autre "ſe mouvroit!!" De Luc. Lettres Phyſiques, &c.

6. Thofe fubftances that are brought within the influence of electrified bodies, become poffeffed of a contrary electricity; or electrified fubftances, without parting with their own electricity, act upon other bodies in their neighbourhood, producing in them an electricity which is contrary to their own; or bodies which are immerged in an electric atmofphere always become poffeffed of an electricity contrary to that of the body in whofe atmofphere they are immerged.

The experiments defcribed in this chapter are fimple, eafily performed, and certain in their refults; and, though they may at firft fight appear to be trifling, yet, on an attentive examination, they will be found of confiderable importance, as they afford a clue to inveftigate and explain a variety of electric phænomena, and exhibit, in a ftrong point of view, fome of the contrary effects of negative and pofitive electricity.

Thefe experiments may all be made with a fmall and portable apparatus; confifting generally of two brafs tubes, as A and B, fig. 22; each of thefe is fupported on a glafs pillar G, which fcrews into a wooden foot H; a pair of fmall pith balls fufpended on linen threads, as I, K, fit upon each tube by means of a fmall brafs ring; thefe tubes, with a piece of fealing-wax or a glafs

tube,

tube, are ſufficient to illuſtrate the greater part of the experiments in this chapter, as well as ſome of the principal phænomena in electricity.

The apparatus will be rendered more complete, when it conſiſts of four braſs tubes with their ſtands.

Mr. Wilſon, in a maſterly tract on this ſubject, entitled, "A ſhort View of Electricity," has, with a ſimilar apparatus, explained and illuſtrated all it's general principles.

EXPERIMENT XIII.—Touch a pair of inſulated pith balls with an excited glaſs tube, they will become electrified, and will ſeparate from each other; the balls are electrified poſitively, and are therefore attracted by excited wax, and repelled by excited glaſs.

As thoſe light ſubſtances, which poſſeſs the ſame electric power, repel each other; we can eaſily diſcover whether they are electrified poſitively or negatively, by preſenting an excited ſtick of ſealing-wax or glaſs to them. If they are attracted by the glaſs they are negatively, if repelled by it they are poſitively electrified; on the contrary, if repelled by the excited wax, they are negative, if attracted, poſitive.

In aſcertaining the nature of the electric powers, we muſt avoid bringing the bodies to be tried near each other ſuddenly; or one with a ſtrong electricity near another which is weakly ſo; as it may render the experiment doubtful by attracting and not repelling the light body.

EXPERIMENT XIV.—Hold an excited glaſs tube over one of the braſs tubes, but at ſome diſtance from it, part of the natural quantity of electricity contained in the braſs tube will be driven into the pith balls that are annexed to it, by the excited glaſs, the balls will diverge with poſitive electricity; remove the excited glaſs, the balls will then return to their natural ſtate, and cloſe.

If the excited glaſs continues in it's place, the balls will continue to be repelled; for the excited electric will always continue to ſeparate the powers of electricity, or in other words to force a quantity from the ſurface of the tube; and will alſo prevent it's return, ſo long as it continues of the ſame force, and acts at the ſame diſtance.

The nearer the excited electric is brought, the greater is the effect.

The ſphere of action of an excited electric has been diſtinguiſhed into two parts, one termed the SPHERE OF INFLUENCE, in which the balls will ſeparate, but cloſe when the electric is removed; the other is called the SPHERE OF COMMUNICA-

TION,

TION, in this the force acquired by the balls remains after the excited electric is removed.

EXPERIMENT XV.—Electrify the pith balls that are suspended from the brass tube A, fig. 27, then bring the end of this tube in contact with the end of the tube B, the balls of which are un-electrified; the stock of electricity given to the tube A will be equally divided between each pair of balls, those of the tube B will open, and those of A will close a little.

EXPERIMENT XVI.—Electrify the tubes A and B, fig. 27, equally and with the same power, put the ends of the tubes together, and the divergence of the balls will not be altered.

EXPERIMENT XVII.—Electrify the tubes equally, but with the different powers, one with glass, the other with wax, bring the ends of the tubes in contact, and the balls will close.

We learn from these experiments, that the positive and negative powers counteract each other; whence, if both are applied at the same time to any body, the electricity it acquires will be only the difference of the two, and consequently that of the strongest.

EXPERIMENT

EXPERIMENT XVIII.—Hold an excited glaſs tube to one of the braſs tubes, touching this tube at the ſame time with your finger, part of the natural quantity of the electrical fluid reſident in it will be forced by the excited glaſs tube into the finger; remove at the ſame inſtant the finger and glaſs, and the balls will remain negatively electrified.

EXPERIMENT XIX.—Place the braſs tubes, A and B. fig. 22, in a ſtrait line with their ends in contact, hold the excited glaſs over the tube A, part of the electric fluid naturally reſident in this will be driven into B; ſeparate the tubes, the balls of A will be negative, and thoſe of B will be in a poſitive ſtate; bring them together again, and the balls will cloſe.

The tube A was in the foregoing experiment electrified with the negative power, B with the poſitive; but when they were brought together the equilibrium was reſtored; evincing that no addition of electric matter was communicated to them; but that the natural powers of electricity reſident in the tubes were ſeparated by the atmoſphere of the excited electric; and proving the CO-EXISTENCE of the two powers in every ſubſtance. For the electric fluid, according to Mr. Eeles, conſiſts of two elaſtic mediums, which equally and ſtrongly attract each other, and are attracted by all other matter. Therefore when any body is immerged in an electric atmoſphere, this atmoſphere repels the power which is of the ſame kind in the body, and equally attracts that which is of a different kind in the ſame body; and while theſe bodies remain immerged in this atmoſphere, the powers remain ſeparated, different atmoſpheres exiſting and acting at each end. But when the electric is removed, the two powers inſtantly join, and becoming equal do not exert any ſenſible action.

EXPERIMENT XX.—Inſulate a long metallic rod, ſuſpend a pair of pith balls from each end of it, place one of the ends at about two inches from the prime conductor, the other end as far from it as poſſible, electrify the conductor, and the electric fluid in the rod will be driven to that end which is furtheſt from the conductor; ſo that one end will be electrified negatively, the other end poſitively, as will be ſeen by the balls.

EXPERIMENT XXI.—Apply a ſtick of excited wax to the tube D, fig. 23, as at A, while it remains there the balls I open with negative electricity; raiſe the wax, as at B, and the balls will

will cloſe; raiſe it ſtill higher to C, and they will open with poſitive electricity.

Experiment xxii.—Excited glaſs held over the middle of the tube A, fig. 24, forces ſome part of the natural quantity of electricity of A into the balls, and ſome part out at the two ends into the air. During this experiment, the balls of A are repelled by glaſs, and are therefore in a poſitive ſtate; but, after the excited glaſs is removed, they in a very little time change to a negative ſtate, becauſe part of the natural quantity had eſcaped from the pointed ends into the air, while the glaſs was held over the tube; but, when the glaſs is removed, the over-charge in the balls will of courſe return, and diffuſe itſelf equally in the tube, but as this is not ſufficient to ballance the loſs ſuſtained, the tube, thread, and balls muſt be in a negative ſtate.*

Experiment xxiii.—Place three tubes, A, B, C, fig. 25, in a line near to, or in contact with, each other; excited glaſs held over A forces out part of the natural quantity of fluid contained in A into B and C; ſeparate A from B and C, A will be electrified negatively, B and C will be in a poſitive ſtate. Put the three tubes

* Wilſon's Short View of Electricity, p. 7.

into their former ſituation, the equilibrium will be reſtored, and the balls will collapſe.*

EXPERIMENT XXIV.—Place four tubes, as A, B, C, D, fig. 26, in contact with each other; excited glaſs held over A forces part of the fluid contained in it into B, the quantity received in B will force out a certain portion from C into D; the moment before the excited glaſs is removed from A, ſeparate B and D from A and C, after which it will be found, that A and C are in a negative, and B and D in a poſitive ſtate.*

EXPERIMENT XXV.—Excited glaſs held at about one inch diſtance from the end B, of a ſolid cylinder of glaſs B, D, fig. 28, Plate III. which is ſix feet long, and about half an inch diameter, will force part of the fluid at the end B towards the remote end D; but, in doing this, the natural quantity belonging to the glaſs will undergo ſeveral alterations, which are diſcovered by the effect an excited glaſs tube has on a number of pith balls, which are ſuſpended at equal diſtances from each other between B and D; in a little ſpace of time the electricity of theſe is changed, thoſe that were poſitive will become negative,

* Ibid. p. 8.

negative, and thoſe that were negative will become poſitive.

If the excited glaſs is held in contact with the end B, the additional quantity received at B will, in going towards D, cauſe ſeveral alterations in the denſity of the fluid in B D, but theſe alterations will be converſe to the former, and after a little time will alſo be reverſed.

It may be inferred from theſe experiments, that whenever the electric fluid in any body becomes ſuddenly more denſe in any one part, the fluid in the neighbouring parts will be more rare, and vice verſa. Theſe alternate changes of rarity and denſity muſt, from the nature of an elaſtic fluid, continue to oſcillate many times backwards and forwards before the fluid can be at reſt; though, when theſe motions are weakened to a certain degree, they are imperceptible to the obſerver.*

Moſt of the preceding experiments may be made with cylinders of wood or glaſs inſtead of braſs. When glaſs is uſed it muſt be kept dry and not diſturbed by friction.

It is not improbable that the attractive and repulſive motions of electrified bodies are owing to the alternate condenſation and dilatation of the electric fluid on the ſurface of theſe bodies, as

* Ibid. p. 18.

as they are naturally carried where they meet with the leaſt reſiſtance.

That there is a vibratory motion, or ſtruggle, between the electric fluid, when in action, and the air, is evident from that ſenſation which is felt when a ſtrongly excited electric is brought near any part of the human body; and is ſuch as would be occaſioned by a ſpider's web drawn lightly along the ſkin. This circumſtance is rendered more clear by an experiment made by Dr. Prieſtley, in order to diſcover whether electricity was concerned in the freezing of water.

EXPERIMENT XXVI.—He placed two diſhes with water in the open air in the time of a ſevere froſt, one of them he kept ſtrongly electrified, and could obſerve no difference in the time when it began to freeze, or in the thickneſs of the ice when it had been frozen ſome time; but he obſerved, on each ſide of the electrified wire, the ſame dancing vapour which is ſeen near the ſurface of the earth in a hot day, or at any time near a body ſtrongly heated.

EXPERIMENTS

EXPERIMENTS ON THE ATTRACTION AND REPULSION OF EXCITED SILK RIBBON.

EXPERIMENT XXVII.—Put a black and white ribbon together, and draw them through the fingers; by this operation the white ribbon will be electrified positively, the black negatively, and will consequently attract each other.

EXPERIMENT XXVIII.—Lay either of the ribbons upon a quire of paper, and draw over it amber, sealing-wax, or any other negative electric, the ribbons will be excited positively.

If positive electrics are drawn over the ribbons, they will be excited negatively.

EXPERIMENT XXIX.—A piece of flannel and a black ribbon will excite as well together as a black and white ribbon.

EXPERIMENT XXX.—Dry two white silk ribbons at the fire, extend them on any smooth plane, draw the edge of a sharp ivory rule over them; while they continue on the plane they do not seem to have acquired any electricity, yet when taken up separately, they are observed to be negatively electrified, and repel each other.

When

When they are ſeparated from each other, electric ſparks are perceived between them, but when they are again put on the plane, no light is perceived without a ſecond friction.

EXPERIMENT XXXI.—Place the ribbons on a rough conducting ſubſtance, rub them as before, and they will, on their ſeparation, ſhew contrary electricities, which will alſo diſappear when they are joined together.

If the ribbons are made to repel each other and then joined together, and placed on the fore-mentioned rough ſubſtance, they will in a few minutes be mutually attracted; the uppermoſt being poſitively, the undermoſt negatively, electrified.

When two white ribbons receive their friction on a rough ſurface, they always acquire contrary electricities; the upper one is negatively, the lower one poſitively, electrified.

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

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

EXPERIMENT XXXIV.—Lay a number of ribbons of the ſame colour upon a ſmooth conducting ſubſtance, draw the ivory rule over them, take them up ſingly, and each will give a ſpark at the place where it is ſeparated from the other; the laſt will do the ſame with the conductor; they are all negatively electrified. Take them from the plate together, they will all cohere in one maſs, which is negatively electrified on both ſides.

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

The following very curious obſervations and experiments were made by Mr. Symmer. He had been accuſtomed to wear two pair of ſilk ſtockings, a black and a white, when theſe were pulled off both together no ſigns of electricity appeared; but, on pulling off the black ones from the white, he heard a ſnapping or cracking noiſe, and in the dark perceived ſparks between them. To produce this and the following appearances in great perfection, it was only neceſſary to draw his hand ſeveral times backward and forward over his leg with the ſtockings upon it.

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, 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 intire ſhape of the leg. When two black or two white ſtockings are held in one hand, they repel one another with conſiderable force. When a white and a black ſtocking are preſented to each other, they are mutually attracted, and ruſh together, if permitted, with great violence. As they approach the inflation gradually ſubſides, and their attraction of foreign objects diminiſhes, but their attraction of one another

another increaſes; when they actually meet, they become flat and joined cloſe together, like ſo many folds of ſilk; when ſeparated again, their electric virtue does not ſeem to be in the leaſt impaired for having once met. The ſame appearances will be exhibited by them for a conſiderable time.

When the ſtockings were ſuffered to meet, they ſtuck together with conſiderable force; at firſt Mr. Symmer found they required from one to twelve ounces to ſeparate them. Another time they raiſed 17 ounces. Getting the black ſtockings new dyed, and the white ones waſhed, and whitened in the fumes of new ſulphur, and then putting them one within the other, with the rough ſides together, they required three pounds three ounces to ſeparate them. When the white ſtocking was put within the black one, ſo that the outſide of the white was contiguous to the inſide of the black, they raiſed nine pounds, wanting a few ounces; when the two rough ſurfaces were together, they raiſed fifteen pounds, one penny weight and a half.*

* The Rev. Mr. Lyons hae made many curious experiments on the attraction of ribbons; their coheſion, &c. See Lyon's Experiments and Obſervations on Electricity.

CHAP. IV.

ENTERTAINING EXPERIMENTS BY THE ATTRACTION AND REPULSION OF LIGHT BODIES, WITH SOME REMARKS ON ELECTRICAL ATTRACTION.

FEW philoſophical ſciences afford ſo much entertainment as electricity: in it the uſeful and agreeable are intimately blended; and the philoſopher, while he is inveſtigating the abſtruſe parts, is entertained by the variety and beauty of the experiments, which confirm or diſprove the hypotheſis he wiſhes to eſtabliſh.

EXPERIMENT XXXVI.—Fix the end A of the wire A B, fig. 10, in the ſmall hole which is at the end of the prime conductor; turn the cylinder, and the feathers, which are connected with the wire by linen threads, will ſeparate from each other; the fibrous and downy parts will become turgid, and expand in a pleaſing manner, in a variety of directions.

Preſent a metallic point, the finger, or any other conducting ſubſtance to the feathers, the downy parts thereof will immediately collapſe, the divergence of the feathers will ceaſe, and they

they will approach each other, and cling round the non-electric body.

The feathers ſeparate from each other, and tend towards unelectrified bodies, from the effort made by the electricity which is communicated to them to diffuſe itſelf, and the reſiſtance it meets with from the air.

EXPERIMENT XXXVII.—Fix the end C of the wire C D, fig. 11, into the hole at the end of the conductor, put the machine in action, and the two ſmall balls, c d, will recede from each other. Bring a conducting ſubſtance within the ſphere of their action, and they will fly towards it; touch the conductor with a non-electric, and they will immediately come together.

The balls do not always diverge ſo much as might be expected from the action of their atmoſpheres, becauſe they are influenced by that of the conductor.

The balls, or feathers, will ſeparate, &c. in the ſame manner, if they are annexed to a negative conductor.

EXPERIMENT XXXVIII.—Preſent a fine thread towards an electrified conductor; when it is at a proper diſtance, it will fly towards, and ſtick to the

the conductor, and convey the electric fluid from it to the hand; remove the thread to a ſmall diſtance from the conductor, and it will fly backwards and forwards with great velocity, and in a very pleaſing manner: preſent the ſame thread towards one that hangs from the conductor, they will attract and join each other. Bring a non-electric body, as a braſs ball, near theſe threads, the ball will repel that held by the hand, and attract that which is affixed to the conductor: the upper thread renders the braſs ball negative, and therefore goes towards it; while the under thread, which is alſo negative, is repelled. Let the ball be brought near to the lower part of the under one, and it will be attracted by it. The junction of the threads ariſes from the effort the electric fluid makes to diffuſe itſelf through them.

Experiment xxxix.—To the edge of the braſs hoop b c d, fig. 12, are faſtened, at equal diſtances from each other, ſix or ſeven pieces of thread, about four inches long; a wire proceeds from the hoop, which fits into a cavity in the pillar D; z e is a braſs wire, to one end of which are faſtened ſeveral ſmall pieces of thread; fit the plain end of the wire into the hole at the end of the conductor, place the hoop b c d at right

right angles to the wire z e, and directly over the threads at the end z; turn the cylinder, and the threads tied to the hoop will be attracted by thofe which are faftened to the wire z e, and will point towards each other as fo many radii of a circle. The electric fluid paffes from the threads of the wire into thofe of the hoop, and thus occafions the feeming attraction between them.

Place the hoop b c d on an infulating ftand, and when it is faturated with the electric matter, the threads which are tied to it will be repelled by thofe of the wire; touch the hoop, and they will be again attracted. If the hand is brought near the threads, they will quit their central direction, and move towards it. The ends of the threads appear luminous in the dark.

EXPERIMENT XL.—Sufpend the fmall metal plate F, fig. 13, to the conductor by the hook H; place the ftand I directly under it, and the large plate G on the top of the ftand; the upper part of the ftand I is moveable, fo that the diftance of the two plates from each other may be occafionally varied. Lay fmall paper images, or any other light fubftances, on the under plate, then put the machine in action, and the light bodies will be attracted and repelled by each plate,

plate, and move from one plate to the other with confiderable velocity.

The light bodies placed on the under plate become poffeffed of an electricity which is contrary to that of the upper plate, and are therefore attracted by it, and acquire the fame electricity with it; they are then repelled, and part with this electricity to the ftand, and are again in a proper ftate to be attracted by the upper plate. That thefe bodies cannot be attracted by the upper plate, till they have acquired a power contrary to it, or till the equilibrium of the fluid in them is difturbed, will be evident from the following experiment.

EXPERIMENT XLI.—Remove the under plate and ftand, hold in it's ftead, by one corner, a pane of glafs, which has previoufly been made very clean and dry; now, as glafs does not tranfmit electricity, no contrariety in the electric ftates of the conductor and the light fubftances can be occafioned, and therefore no attraction or repulfion is obferved.

If a finger is prefented to the under fide of the glafs plate, the light bodies will be attracted and repelled: the caufe of this will be feen when the nature of the Leyden phial is explained.

Mr. Eeles,* ſpeaking of this alternate attraction and repulſion, ſays, they may be agreeably varied, by wetting firſt the head of the paper images, and when theſe are dry, wetting the feet.

"When you dry the head of one of thoſe "images, the power thrown out from the con- "ductor, cannot enter the image with the ſame "facility with which the contrary power from "the table enters at the feet, which are not ſo "dry; this will therefore aſcend to the upper "plate and remain there. Reverſe the experi- "ment; dry the feet and wet the head, and "the images will fix themſelves to the lower "plate. If the image retains ſo much more of "the attracted power as will ballance againſt "it's weight, than there is of the contrary power "which proceeds from the conductor, the image "will be ſuſpended between the two plates.

"This may be effected by making the head "of the image broad and round, which does not "admit the power coming out ſo readily as the "feet, being ſharp, admit the power going in; "a minute alteration will make the images "dance, or remain fixed to one of the plates.

* Philoſophical Eſſays. Preface, page 25.

EXPERIMENT XLII.—Place a ſquare piece of leaf braſs or ſilver on the under plate, hold this parallel to the upper one, at about five or ſix inches from it, turn the machine, and the leaf will then riſe up into a vertical ſituation, and remain between the two plates, without touching either of them. Preſent a metal point towards the leaf, and it will immediately fall down.

EXPERIMENT XLIII.—Place a braſs ball at K, fig. 14, at the end of the conductor, and when the leaf of braſs is ſuſpended between the plate and ball, move the plate round the ball, and the leaf will alſo move round, without touching either ball or plate.

A glaſs cylinder is occaſionally placed between the two metal plates F G, fig. 13, to prevent bran, ſand, or other light ſubſtances, being thrown off.

EXPERIMENT XLIV.—Place two wires directly under, and parallel to, each other, ſuſpend one from the conductor, let the other communicate with the table; a light image placed between theſe, will, when the conductor is electrified, appear like a kind of electrical rope dancer.—See fig. 15.

EXPERIMENT XLV.—Cut a piece of leaf braſs, with an obtuſe angle at one end, and a very acute one at the other, preſent the large end towards an electrified conductor, and when the leaf braſs is within it's atmoſphere, let it go; it will then fix itſelf to the conductor by the apex of it's obtuſe angle, and, from it's continual wavering motion, will appear to be animated.

The next experiment requires conſiderable attention to make it ſucceed; as a ſmall difference in the apparatus, or in the force of the machine, &c. will make it fail: when it anſwers, it generally affords pleaſure to, and excites admiration in, the ſpectators.

EXPERIMENT XLVI.—Fix the ring N O P, fig. 16, to the end of the conductor; place the plate G, fig. 13, on it's ſtand I under it, and at a little diſtance from it, put a very light hollow glaſs ball upon the plate, but within the ring; turn the cylinder, and the little ball will deſcribe an orbit about the ring, and turn at the ſame time about it's own axis: the poles of it's rotation are nearly at right angles to the plane of it's orbit.

EXPERIMENT XLVII.—Fig. 17 repreſents a ſmall ſet of bells, the two exterior ones are connected to the wire V Y, by a brafs chain, the middle bell and the clappers are fufpended on filk.

Hang the bells on the conductor by the hook R S, let the chain from the middle bell touch the table, turn the cylinder, and the clappers will fly continually from bell to bell, as long as the electricity continues.

The brafs chain, which connects the two exterior bells to the conductor, conveys the electric fluid to them, which attracts the clappers; thefe, when they have received the electric fluid, are repelled by the exterior bell, and attracted by the middle one, on which they depofit their electricity; they are then again attracted and repelled by the outer bells. Hold up, by a filk thread, the chain X, which proceeds from the middle bell, and the ringing will ceafe, becaufe it cannot convey the electric fluid communicated by the clappers to the ground.

Fig. 18 reprefents a more elegant form of mounting the bells. When this is ufed, the knob a fhould communicate with the conductor.

Fig. 19 reprefents another kind. In this the clapper is fufpended from the fly b c d, the axis of the fly refts in a fmall hole on the top of the glafs pillar e f, the upper part of the axis moves freely freeely in, and is ſupported by, a hole in the braſs piece g. Bells of different tones are placed round the board h I K. Remove the prime conductor, and place this apparatus in it's ſtead near the cylinder; when this is in action, it will cauſe the fly to turn round, the clapper will ſtrike each bell in rotation, and thus produce a pleaſing and harmonious ſound.

EXPERIMENT XLVIII.—Take ten or twelve pieces of thread, each about ten inches long, tie them together at the top and the bottom, as in fig. 20, then ſuſpend them from the conductor; the threads, when electrified, endeavour to recede from each other, and the knot at the bottom riſing upwards as the repulſion of the thread increaſes, will form them into a ſpheroidal figure.

EXPERIMENT XLIX.—Bring a downy feather or lock of cotton near the end of an excited tube, or the knob of a charged Leyden phial, the feather will at firſt fly towards the tube, but when it is ſaturated with the electric matter, it will recede from it, and may be driven about the room by the excited tube, till it touches ſome non-conductor, to which it can impart it's electricity. The ſame ſide of the feather is always turned

turned towards the tube; because the electricity acquired by the feather is forced, by the action of the tube, to that side which is farthest from it, which is therefore repelled.

It is easy to perceive, from this and the foregoing experiments, that it is not the mere matter which is attracted, but that the different phænomena are occasioned by the state of the electric fluid, in those substances which are influenced by the machine.

EXPERIMENT L.—Put a pointed wire into one of the holes which are at the end of the conductor, hold a glass tumbler over the point, then electrify the conductor, and turn the tumbler round, that the whole interior surface may receive the fluid from the point; place a few pith balls on the table, and cover them with this glass tumbler, the balls will immediately begin to leap up and down as if they were animated, and will continue to move for a long time. See fig. 21.

This experiment may be agreeably varied with two tumblers. Electrify the inside of one positively, of the other negatively; put the balls in one tumbler, and then bring the mouths of both in contact, the balls will pass from one to the other,

other, till the contrariety between them is deſtroyed.

An electric ſubſtance contained between parallel ſurfaces, however diſpoſed, is called an electric plate.

EXPERIMENT LI.—Electrified ſubſtances will attract thoſe which are not electrified, although a thin electric plate be interpoſed between them.

EXPERIMENT LII.—Bodies electrified with contrary powers, attract each other ſtrongly, although an electric plate is interpoſed between them: and indeed all thoſe phænomena, which depend on the influence of the electric atmoſpheres, may be produced, although an electric is interpoſed between the body and excited electric.

To account for any of the phænomena of electric attraction and repulſion, is very difficult, but more ſo to ſhew why bodies, which are electrified with the ſame power, repel each other, particularly thoſe which are negatively electrified. Philoſophers have invented various ſolutions of this difficulty; the following is eſteemed the beſt.

"* To underſtand why bodies, poſſeſſed of the ſame

* Cavallo's complete Treatiſe of Electricity, p. 110.

ſame electricity, repel each other, the reader muſt be reminded of the following principle, viz. that the electric fluid, proper to a body, can be neither augmented or diminiſhed on the ſurface of that body, except the ſaid ſurface is contiguous to an electric, which can acquire a contrary electricity at a little diſtance; from whence it follows, that no electricity can be diſplayed on the facing ſurfaces of two bodies, which are ſufficiently near each other, and both poſſeſſed of the ſame electricity, becauſe the air that lies between them has no liberty of acquiring a contrary electricity. This being premiſed, the explanation of electric repulſion becomes eaſy. Suppoſe, for inſtance, that two ſmall bodies are freely ſuſpended by inſulated threads, ſo that, when they are not electrified, they hang contiguous to each other: now ſuppoſe theſe bodies to be electrified poſitively or negatively, and they muſt repel each other; for either the increaſed or diminiſhed quantity of the electric fluid in theſe bodies, will endeavour to diffuſe itſelf equally over every part of the ſurfaces of theſe bodies, and this endeavour will cauſe the bodies to recede from each other, ſo that a quantity of air may be interpoſed between their ſurfaces ſufficient to acquire a contrary electricity, at a little diſtance from the ſaid ſurfaces: otherwiſe,

if

if the bodies possessed of the same electricity do not repel each other, so that a sufficient quantity of air may be interposed between their surfaces, the increased quantity of electric fluid, when the bodies are electrified positively, or the remnant of it, when they are electrified negatively, cannot be diffused equally over the surfaces of these bodies; for no electricity can appear upon the surfaces of bodies in contact, or that are very near each other: but the electric fluid, by attracting the particles of matter, endeavours to diffuse itself equally over the surfaces of these bodies, and the bodies are by this endeavour forced to repel each other."

"* The difficulty is not, however, solved by this theory, which only explains one fact by another, which requires as much explanation as the first: but overlooking this, it is still insufficient; for granting that bodies negatively electrified, ought to repel each other, till the electricity is equally diffused over their surfaces, yet when this is accomplished, the repulsion ought to cease. Further, there is no reason for supposing the electrification to take place while the bodies are in contact, or nearly so. One may be electrified negatively in one corner of a room, and another in the other. The electrifi-

L cation

* Encyclopædia Britannica, p. 2683.

cation may alſo be continued for any length of time we pleaſe. So that the electric matter muſt have diffuſed itſelf equally over the ſurfaces of both. Yet, if we attempt to bring theſe bodies together, they will repel each other, which ought not to be the caſe on the preceding ſuppoſition."

"* Poſitive electricity has been ſuppoſed by another to conſiſt of a vibratory motion in the air and electric fluid, in which the force of the vibration is directed outwards from the electric body: that in negative electricity there is alſo a vibratory motion, but the force is directed inwards. Now let us ſuppoſe a body poſitively electrified, ſuſpended by a ſmall thread, at a diſtance from any other, the vibratory motion being kept up by an equal preſſure on all ſides, the body is neither moved to one ſide nor another; but when a negatively electrified body is brought near, the force of the vibration being directed outwards in the one, and inwards in the other, the preſſure of the fluid in the intermediate ſpace between them is greatly leſſened, and conſequently the preſſure on the other ſide drives them both together, and they are ſaid to attract each other. If a body electrified poſitively is brought near the firſt, the force of the vibrations

* Ibid. p. 2699.

tions are directly oppofed to each other, and therefore the bodies recede from each other. The cafe is the fame with two bodies negatively electrified; for here the vibration being directed towards both bodies, as towards two centers, muft caufe them to recede from each other, becaufe if they remained in contact, the vibratory motions would interfere with each other.

"When a fmall body is brought within the fphere of another's electricity, the equable preffure of that vibratory or electrical fphere is fomewhat leffened upon the fide near which the body is brought, and it is therefore impelled towards the firft by the action of the furrounding fluid, in order to keep up the equilibrium. As foon as it arrives there, the vibrations of the fluid around the firft body being communicated to that within the pores of the fecond, it acquires a fphere of electricity as well as the firft, and is confequently repelled: the repulfion continues till the vibration ceafes, either by the action of the air, or by the body coming in contact with another larger than itfelf, in which cafe it's electricity is faid to be difcharged. If, after this difcharge, the fecond body is ftill within the fphere of the firft, it will be immediately attracted, and very foon after repelled, and fo on

 alternately,

alternately, till the electricity of the former totally ceases."

From several experiments of Beccaria's, it appears, that, if the air is thoroughly exhausted from a glass receiver, the attraction and repulsion of electrified light bodies within the receiver grows languid, and soon ceases altogether. This is confirmed by an experiment of Mr. Cavallo's. A pith ball electrometer was suspended within a receiver of an air pump, by it's brass cap; this was then electrified; the balls diverged a little when the air was only rarified 100 times; when it was rarified 300 times, the repulsion was scarce discernable: when the rarifaction was greater, they did not diverge at all; and that, whether a small or large quantity of electricity was communicated to the cap.*

* Phil. Trans. vol. 73, p. 452.

CHAP.

CHAP. V.

OF THE ELECTRIC SPARK.

EXPERIMENT LIII.

FIX the wire and ball B to the end of the conductor, as at A, fig. 29, turn the cylinder, and then bring the knuckle, or another metal ball, as C, towards B; if the machine is powerful, a long, crooked, brilliant, electric ſpark, with the appearance of fire, attended with a ſnapping noiſe, will paſs between the two balls, or between the knuckle and ball.

The experiments in the foregoing chapter ſhew, that thoſe ſubſtances, which are brought within the influence of electrified bodies, will become poſſeſſed of a contrary electricity, and are conſequently in a proper ſtate to receive a ſpark from any body that is charged with electric matter; and when brought near enough, they will receive the fluid in one exploſion. If the conductor is negative, it receives the fluid from the approaching body. The ſpark does not explode at the greateſt diſtance on a given body, until it has firſt been made to ſtrike at ſome

ſmaller

ſmaller diſtance, which, as it were, entices the diſcharge gradually forwards.

The longeſt and moſt denſe ſparks proceed from that end of the conductor which is fartheſt from the cylinder, though long curvilinear ſparks may alſo be taken near the inſulating pillar which ſupports the conductor.

The ſpark, or quantity of electricity diſcharged, is nearly in proportion to the ſize of the conductor; ſo that larger and longer ſparks are obtained from a conductor which has a conſiderable ſurface, than from a ſmall one. This has been extended ſo far, that the force of the ſpark from a conductor, has been equal to a ſhock from a good ſized phial.

The ſound is occaſioned by the momentary agitation into which the air is thrown by the electric fluid.

If the electric ſpark is received on any part of the body, it occaſions a ſenſation ſomething reſembling a ſmart blow, which is more or leſs painful, in proportion to the tenderneſs of the part, or the ſtrength and weakneſs of the ſpark.

When the quantity of electricity is ſmall, and incapable of ſtriking at any conſiderable diſtance, the ſpark appears ſtrait; but when it is ſtrong, and capable of ſtriking at a greater diſtance, it aſſumes a crooked or ziz-zag direction; and this,

this, probably, becaufe the more fluid electric matter has to pafs with great rapidity through the denfer and lefs fluid atmofphere, which reciprocally act upon each other.

It will be feen, by a great variety of experiments, that the electric fluid is diffipated, unlefs it is refifted by the preffure of the atmofphere, which keeps the fire together in a body, and by concentrating, it increafes it's fplendor. The fpark which explodes in the air is vivid, like lightning; but if the fame is tried in an exhaufted receiver, inftead of a fpark and explofion, we have only a filent, faint, diluted ftream.

Beccaria fays, that the air refifts the electric fpark in proportion to it's denfity, and the thicknefs of the ftratum it oppofes to the fpark, or the length of the paffage they open for themfelves through it's fubftance. He alfo fhews, by a variety of experiments, that the air is driven in every direction by the electric fluid, with a force, the action of which does not immediately fubfide. It will appear from this, as well as many other confiderations, that the exceeding great velocity and ftrength of the electric fluid, are not owing to a repulfive power among it's particles, but to the mutual action of the air and electric fluid upon themfelves and one another; and that it's momentum is produced by the incumbent

cumbent preſſure of the atmoſphere on the electric fluid, and the preſſure of one part of this matter upon another. This latter preſſure muſt be very great, if the particles of the electric fluid are in contact, or act immediately one on the other throughout the wide immenſity of ſpace.

The electric ſpark appears of a different colour, according to it's denſity: when it is rare, it appears of a blueiſh colour; when more denſe, it is purple; when highly condenſed, it is clear and white, like the light of the ſun.

The middle part of an electric ſpark often appears diluted, and of a red or violet colour; the ends are more vivid and white, probably becauſe the fluid meets with the greateſt reſiſtance at it's entrance and exit.

The ſpark is ſometimes divided into many parts, as in fig. 30. The rays of the pencil concentrate where they ſtrike the ball, and form upon it many denſe and ſhining ſparks.

EXPERIMENT LIV.—Place an ivory ball on the conductor, take a ſtrong ſpark, (or paſs the charge of a Leyden bottle through the center of it) the ball will appear perfectly luminous. If the charge is not taken through the center, it will paſs over and corrode the ſurface of the ball.

EXPERIMENT

EXPERIMENT LV.—Take a ſpark through a ball of box-wood, and it will appear of a beautiful crimſon, or rather a fine ſcarlet colour; or the ſhock may be paſſed through pieces of wood of different thickneſſes and denſity, which will afford a very ample field for obſervation and experiment.

The two forgoing experiments are ſo analagous to the famous experiment of Mr. Hawkſbee, and ſome others which have been made ſince his time, that I have ſubjoined them, and hope they will lead to a further inveſtigation of this curious ſubject.

EXPERIMENT LVI.—Mr. Hawkſbee lined more than half the inſide of a glaſs globe with ſealing-wax, he exhauſted the globe, and put it in motion, when, on applying his hand to excite it, he ſaw the ſhape and figure of it as diſtinctly on the concave ſuperficies of the wax within, as if only pure glaſs had intervened between his eye and his hand. The lining of wax, where it was thinneſt, would but juſt allow the light of a candle to be ſeen through it in the dark. In ſome parts the wax was at leaſt an eighth part of an inch thick; yet, even in thoſe places, the ſhape and figure of his hand were as diſtinguiſhable as any where elſe.

Beccaria discharged an electric shock through some brass dust, sprinkled between two plates of sealing-wax; the whole was rendered perfectly luminous and transparent.

EXPERIMENT LVII.—This extraordinary experiment was made by Dr. Priestley, and is thus described by him. I laid a chain, which was in contact with the outside of a jar, lightly on my finger, and sometimes kept it at a small distance by means of a thin piece of glass. If I made the discharge at the distance of about three inches, the electric fire was visible on the surface of the finger, giving it a sudden concussion, which seemed to make it vibrate to the very bone; and when it happened to pass on that side of the finger which was opposite to the eye, the whole seemed, in the dark, perfectly transparent.

EXPERIMENT LVIII.—Connect one end of a chain with the outside of a charged jar, let the other end lie on the table, place the end of another piece of chain at about one quarter of an inch distance from the former, then set a decanter of water on these separated ends, and, on making the discharge through the chain, the water will appear perfectly and beautifully luminous. This experiment was communicated

 to

to me by Mr. Haas, the inventor of an improved air-pump.

Do not theſe experiments indicate, that there is a ſubtle medium both in electric and non-electric bodies, that renders them tranſparent, when it is put in motion?

EXPERIMENT LIX.—The ſparks taken over a piece of ſilver leather, appear of a green colour.

EXPERIMENT LX.—E F, fig. 31, is a glaſs tube, round which, at ſmall, but equal diſtances from each other, pieces of tin-foil are paſted in a ſpiral form, (hence it is called the ſpiral tube) from end to end; this tube is incloſed in a larger one, fitted with braſs caps at each end, which are connected with the tin-foil of the inner tube. Hold one end in the hand, and apply the other near enough to the prime conductor to take ſparks from it, a beautiful and lucid ſpot will then be ſeen at each ſeparation of the tin-foil; theſe multiply, as it were, the ſpark taken from the conductor; for if there was no break in the tin-foil, the electric fire would paſs off unperceived.

EXPERIMENT LXI.—The luminous word. This experiment is exactly on the ſame principles as the foregoing. The word is formed by the ſmall ſeparations made in the tin-foil, which is paſted on a piece of glaſs, that is fixed in a frame of baked wood, as is repreſented in fig. 32. To make the experiment, hold the frame in the hand, and preſent the ball G to the conductor, the ſpark received on this will be communicated to the tin-foil, and follow it in all it's windings, till it arrives at the hook h, and is conveyed from thence to the ground by a chain: the lucid appearance at each break exhibits a word in characters of fire.

EXPERIMENT LXII.—To take the electric ſpark with a metal point, ſcrew a pointed braſs wire into one end of a ſpiral tube, and preſent it to the conductor while the machine is in action, when a ſtrong ſpark will paſs between the conductor and the point.

EXPERIMENT LXIII.—Take a clean dry glaſs tube, of about a quarter of an inch bore, inſert a pointed wire in this tube, keep the pointed end at ſome diſtance from the end of the tube, let the other end be connected with the ground, bring the former towards the prime conductor, and ſtrong zig-zag ſparks, attended with a peculiar noiſe, will paſs between the conductor and the point.

The

The ſeparation between the pieces of tin-foil, in experiment 62, forms a reſiſtance which hinders the immediate reception of the electric fluid, and thus, in ſome meaſure, prevents the common action of the point on the conductor; or, the power of a point to prevent an exploſion, depends on it's having a perfect uninterrupted metallic communication with the earth: though this is not always ſufficient, as may be ſeen by exper. 63, where the fluid is concentrated and collected by the non-conducting ſubſtance which ſurrounds the point: a caſe ſimilar, in many reſpects, to the conductors which are erected for the preſervation of buildings.

EXPERIMENT LXIV.—Let any perſon ſtand on the inſulating ſtool, and connect himſelf by wire or chain with the prime conductor, he will then exhibit the ſame appearances which are obtained from the conductor, and will attract light bodies, give the ſpark, &c. and thus afford a pleaſing mode of diverſifying every experiment. It is abſolutely neceſſary, to the complete ſucceſs of this experiment, that no part of the cloaths touch the floor, table, &c. and that the glaſs feet be carefully dried: a ſheet of dry brown paper placed under the ſtool, will be found of conſiderable ſervice, by rendering the inſulation more complete.

If

If the insulated person lays his hand on the cloaths of one that is not so, especially if they are woollen, they will both feel as it were many pins pricking them, as long as the cylinder is in motion.

EXPERIMENT LXV.—To fire spirits of wine with the electric spark, heat the ladle I, fig. 33, then pour a small quantity of spirits of wine into it, and fix it by it's handle to the end of the prime conductor; or fire the spirits, and blow them out a few minutes before the experiment is made; take a spark through the middle of the ladle with a brass ball, and the spirits will be fired by it.

Or let a person, standing on an insulating stool, and connected with the prime conductor, hold the ladle with the spirits in his hand, and let a person on the floor take a spark through them, and they will be fired. The experiment answers equally well, if the person on the floor holds the ladle, and the insulated person takes the spark.

EXPERIMENT LXVI.—The foregoing experiment may be agreeably diversified in the following manner. Let one electrified person, standing on an insulated stool, hold the spirits. Let another

another perſon, ſtanding alſo on an inſulated ſtool, hold in his hand an iron poker, one end of which is made red hot, he may then apply the hot end to the ſpirits, and even immerge it in them without firing them. But if he put one foot on the floor, he may ſet the ſpirits on fire with either end.

EXPERIMENT LXVII.—The ſpirits cannot be kindled by the inſulated perſon, becauſe, as the electric cannot eſcape through him to the earth, he is incapable of drawing a ſpark ſufficiently ſtrong to inflame them, and hot iron will ſeldom or never ſet ſpirits on fire.

If oil of turpentine is ſet on fire in a veſſel which is placed on the conductor, and the ſmoke is received on a plate, held by a perſon ſtanding on an inſulated ſtool, he will be electrified thereby, and enabled to fire ſpirits of wine, &c. If the inſulated perſon holds a braſs wire at the top of the flame of burning ſpirits of wine, which is connected with the conductor, he will alſo become electrified. Hence we find, that either ſmoke or flame conducts the electrical fluid.

Mr. Volta has ſucceeded in obtaining undoubted ſigns of electricity from the ſimple evaporation of water, and from various chemical efferveſcences.

EXPERIMENT

EXPERIMENT LXVIII.—Infulate a fmall crucible, containing three or four lighted coals, throw a fpoonful of water on the coals, and in a fhort fpace of time, an electrometer, which communicates with the coals by means of a wire, will diverge with negative electricity.

From hence it would feem, that the vapour of water, and, in general, thofe parts of a body that are feparated by volatilization, carry away an additional quantity of electric fluid, as well as of elementary heat; and that the body, from which thofe volatile parts have been feparated, remains both cooled and electrified negatively; and that thofe, which are refolved into a volatile elaftic fluid, have their capacity for holding common fire, and the electric fluid augmented.

OF INFLAMMABLE AIR, AND THE PISTOL FOR INFLAMMABLE AIR.

A fpecies of air, which is inflammable, is frequently generated in coal mines: the air alfo emitted by ftirring the mud of fome ftanding waters, has been found to be inflammable. Putrefcent animal matter alfo emits this fluid. It may be obtained by diftillation from wax, pitch, amber, coals, and other phlogiftic fubftances.

The

The following is the moſt convenient method of procuring it: put ſome ſmall nails or iron filings into the bottle r, fig. 38; cover theſe with water, then add to this a little oil of vitriol, about one quarter of the quantity there is of water, put the ground end of the bent tube into the mouth of the bottle, and paſs the other end through the water of the baſon T into the neck of the bottle K, which is filled with water, and inverted in the baſon; the bottle K muſt be ſupported during the operation: in a little time the mixture will efferveſce, and emit a fluid which will paſs through the bent tube, go into the bottle K, and at laſt fill it totally, expelling the water; the bottle is then to be removed, and corked as expeditiouſly as poſſible.

Fig. 39 repreſents a braſs piſtol for inflammable air; a b is the chamber of braſs, to the mouth a c of which a cork is fitted, a perforated piece of braſs g ſcrews on to the bottom of this chamber, (this piece is repreſented by itſelf in fig. 40) a glaſs tube f is cemented into the perforation of this piece, and a braſs wire is alſo cemented into the glaſs tube; one end of this wire is furniſhed with a ball, the other extremity is bent, ſo as to come within about a tenth of an inch of the braſs piece. Fig. 41 is a braſs cap, which ſcrews on the piſtol, to preſerve the glaſs tube from any accident. The air with which the piſtol is to be charged ſhould be kept in a corked bottle: take out the cork and apply in the ſame inſtant the mouth of the piſtol to the opening of the bottle, and the common and inflammable air will mix together, becauſe the former being heavier than the latter will naturally deſcend; keep the piſtol in this ſituation about 15 ſeconds, then remove it, and cork both the bottle and piſtol with the utmoſt expedition.

If the piſtol is held too long over the bottle, and is intirely filled with inflammable air, it will not explode.

DESCRIPTION OF ANOTHER APPARATUS FOR MAKING INFLAMMABLE AIR, AND FILLING THE AIR PISTOL, &c.

This apparatus conſiſts of the following articles.

1. A glaſs funnel.
2. A ſmall glaſs tumbler.
3. A bladder tied to a ſtop cock.
4. A braſs pipe paſſing through a cork; which cork is made tapering, to fit the neck of a common wine bottle: the upper part of the pipe has a male ſcrew, to fit the ſcrew on the lower end of the ſtop cock.
5. An air piſtol furniſhed with a valve at

the end *b* fig. 39; the wire paſſing through a glaſs tube, and to which the ſpark is to be given, is fitted into the ſide of the piſtol. At the end b of the piſtol is a male ſcrew which fits the lower end of the ſtop cock.

6. A box with iron filings.

7. A ſmall meaſure which will hold the proper quantity of iron filings.

8. A braſs tube and hollow flyer; the lower end of the braſs tube fits the ſtop cock.

Soak the bladder in water which is lukewarm, in order to ſoften it; and then render it pliable, by blowing air into it and ſqueezing it out again. After this ſcrew the conical pipe with the cork into the lower end of the ſtop cock, and it is ready for uſe. Then take a common quart wine bottle, and put into it a little hot water, to warm it. Pour as much oil of vitriol into the tumbler, as will about half fill it, and mix this in another tumbler with about three times the quantity of cold water. Throw the warm water out of the bottle, and put a meaſure of iron filings into it, then pour the diluted vitriol through the glaſs funnel upon the iron filings. As ſoon as the effervеſcence begins, put the cork with it's pipe into the neck of the bottle, and the inflammable air which is generated by the mixture, will enter into and gradually ſwell the bladder. When this is full, ſhut the ſtop cock, and remove the bladder from the bottle.

The bladder being thus filled, ſcrew the bottom of the piſtol upon the ſtop cock; compreſs the bladder, and introduce by this means about as much inflammable air, as you judge will fill one third of it's capacity, and put the cork immediately into the muzzle of the piſtol. To form a circle of fire with inflammable air, fill the bladder as before, unſcrew the conical tube from the ſtop cock, and ſcrew the braſs fly in it's place, open the cock, and compreſs the bladder; the air will paſs through the fly, and ſet it in motion; light the air at the end of the pipe, and a beautiful circle of fire will be formed by the motion of the bent tube, and the fired air which iſſues from it's points. The piſtol is fired as in experiment 69.

If too great a quantity of inflammable air is introduced into the piſtol, it will not explode; to remedy this, blow ſtrongly into the muzzle of the piſtol, this will force out a quantity of the inflammable air, and occaſion a quantity of common air to enter the piſtol, which will then readily explode.

The bottle ſhould be taken into the open air and be well waſhed, as ſoon as the bladder is filled.

EXPERIMENT LXIX.—Bring the ball of the piſtol, which is charged with inflammable air, near the prime conductor, or the knob of a charged bottle, the ſpark which paſſes between the end of the wire f and the piece g, fig. 40, will fire the inflammable air, and drive the cork to a conſiderable diſtance. This air, like all other, requires the preſence either of pure air, or the nitrous acid, to enable it to burn; but, if it is mixed with a certain quantity of common air, an exploſion will take place in paſſing the electric ſpark through it.

Mr. Cavallo recommends a piſtol made in the following manner, to thoſe who wiſh to make experiments on the exploſion of inflammable and dephlogiſticated air, or with known quantities of common and inflammable air. It conſiſts of a braſs tube, about one inch in diameter and ſix inches long, to one extremity of which a perforated piece of wood is ſecurely fitted; a braſs wire, about four inches long, is covered, except it's ends, firſt with ſealing-wax, then with ſilk, and afterwards with ſealing-wax again. This wire is to be cemented in the perforation of the wooden piece, ſo as to project about two inches within the tube, the reſt is on the outſide; that part of the wire, which is within, is bent ſo as to be be only about one tenth of an inch from the inſide of the braſs tube.*

To uſe this piſtol; fill it with, and then invert it into a baſon of water; make the required quantity of inflammable and common air in another veſſel, by putting in known and proportionable meaſures of each; introduce this mixture into the piſtol, and then ſtop it with a cork, take the piſtol out of the water, and paſs in the uſual manner the ſpark of a charged jar through it, and the inflammable air will be fired.

The inſtruments for firing the inflammable air with the electric ſpark, are often made in the ſhape of a cannon.

* Cavallo on Air, p. 818.

CHAP.

CHAP. VI.

OF ELECTRIFIED POINTS.

EXPERIMENT LXX.

PRESENT the pointed end of a wire towards a conductor which is poſitively electrified, a lucid globular point or ſtar will appear on the point, and the electric fluid will be evidently conveyed away and diſſipated from the conductor.

EXPERIMENT LXXI.—Preſent a pointed wire towards a conductor that is electrified negatively; a lucid cone or bruſh will be ſeen diverging from the point, and the quantity of fire will be increaſed.

EXPERIMENT LXXII.—The lucid ſtar is ſeen on the collecting points of a poſitive conductor, while a diverging cone will appear on a point placed at the end of the conductor.

To determine the direction of the electric fluid, has ever been an object of conſiderable importance to the electrician; as it would enable him to decide on the truth of thoſe theories,

ries, which have been invented to account for it's phænomena, and greatly aſſiſt him in the progreſs of future diſcovery: To this end much ſtreſs has been laid on the different appearance of the light, which is perceived on the pointed ends of electrified conducting ſubſtances; as theſe have been ſuppoſed to elucidate fully this interesting queſtion.

The electic fluid appears as a diverging ſtream darting forwards into the air, from a point electrified poſitively. The luminous appearance on a point negatively electrified, is that of a ſmall little globule or ſtar.

Now, as the air is known to reſiſt the motion of the electric fluid, the rays of it would by this reſiſtance be made to diverge; therefore, when this fluid is darting from a point into the air, it will aſſume the form of a lucid cone or bruſh, which is agreeable to experiments 71 and 72.

To this it has been objected, that theſe rays may poſſibly be converging from ſo many points in the air towards the point, and not diverging from it; but, as there does not appear any reaſon why a viſible ray ſhould break out from one place in the atmoſphere more than another, the former account ſeems more conformable to nature, and the known laws of other fluids. The

air

air refifts the motion of the electric fluid equally. Therefore, when this fluid is coming from the air towards a pointed conductor, it would percolate flowly and invifibly through the air, but equally on all fides, till it comes fo near as to be able to break through the intermediate fpace; but as this will be equal or nearly fo all around, the negative electricity muft appear like a fteady luminous globule on the point.* Notwithftanding the apparent probability of the above reafoning, it may ftill be objected, that no decifive conclufion can be drawn from thefe appearances, as they may be varied by augmenting or diminifhing the volume of the pointed body, and by a variety of other circumftances.

EXPERIMENT LXXIII.—A lucid cone appears on the collector of a negative conductor, and a lucid ftar on a point placed at the oppofite end of the conductor.

EXPERIMENT LXXIV.—Bring an excited glafs tube near a point that is fixed at the end of a pofitively electrified conductor, and the luminous brufh will be turned out of it's direction by the action of the excited tube; if the tube is held directly oppofite to the point, the brufh will vanifh.

* Encyclopedia Britannica, p. 2699.

EXPERIMENT LXXV.—Fix the point to the end of the negative conductor, the lucid ſtar will turn towards the excited tube.

Theſe two experiments coincide with and confirm experiments 70, 71, 72, 73, and lead to the ſame concluſion, viz. that the bruſh is a ſign of poſitive, and the ſtar an indication of negative electricity, which is ſtill further confirmed by the following experiment.

EXPERIMENT LXXVI.—Put a wire, which has a ball at one end, into the hole at the end of a poſitive conductor, place a lighted candle ſo that the middle of the flame may be even with the middle of the ball, and about an inch from it; turn the machine, and place the ſame wire at the end of the negative conductor, the appearance will be reverſed, and the knob will ſoon be heated by the flame of the candle which is carried towards it.

EXPERIMENT LXXVII.—Fix a pointed wire in the hole on the upper ſide of the conductor, then place the center of the braſs croſs K, fig 34, upon the point, the ends of which croſs are all bent one way; electrify the conductor, and the croſs will turn upon it's center with great rapidity.

If

If the room be darkened, a circle of light will be formed by the electric fluid on the points of the wires. The re-action of the air on the diverging cone of electric matter gives the retrogade motion to the points of the wire.

The fly turns round in the ſame direction, whether it is electrified negatively or poſitively; though it will not move in vacuo, unleſs the finger, or ſome other conductor, is applied to the glaſs receiver oppoſite to one of the points, it will then begin to move, and continue to do ſo briſkly till the glaſs is charged.

EXPERIMENT LXXVIII.—Electrify the two inſulated wires M N, o P, fig. 35, and the reſiſtance of the air againſt the electric ſtream, from the point of the fly L, (the axis of which rolls on the wires) will force the fly up the declivity of the inclined plane M N, o P.

EXPERIMENT LXXIX.—Fig. 36 repreſents a ſmall crane, which will move from the ſame cauſe as the foregoing, and raiſe a ſmall weight.

EXPERIMENT LXXX.—Several flyers may be made to turn at the ſame time, ſee fig. 37, and many other pleaſing experiments may be contrived on the ſame principle; or, the flyers may be placed one above another, diminiſhing gradually in ſize, and forming when electrified a luminous cone; the circles of light will be more brilliant, if the ends of the wires are covered with a thin coating of greaſe, ſealing-wax, or ſulphur.

Experiment lxxxi.—Immerge a metallic point in a metal veſſel nearly filled with oil of vitriol, and placed on an electrified conductor, ſcarce any ſpark will paſs to the point, although it is held very near the bottom of the veſſel. If this is filled with eſſential oil of turpentine, a ſmall light may be ſeen from time to time in the body of the fluid. If common oil is uſed, the point will take ſtrong ſparks, and the electric fluid, in endeavouring to reach it, will occaſion an ebullition in the oil.

So that the electric ſpark depends in a great meaſure on the conducting power of the medium through which it paſſes.

If ſmall boats or little ſwans, &c. are made of cork or light wood, they may be attracted, and made to ſwim in any direction, by applying a finger towards them; a fine needle ſtuck into the end of the boats, in the manner of a bowſprit, will cauſe them to be repelled from the hand held over it, and they may be ſteered

 by

by it, ſtern foremoſt, to what point of the compaſs you pleaſe. The boats might have the addition of ſails to them, and might then be made to move briſkly before an electrical gale, from the point of a wire held in the hand.

The operator in theſe tricks would certainly be looked upon as a magician, if the electrical machine is kept out of ſight. But a more ſtriking ſight, would be a number of theſe boats, with each of them a twirling fly, about an inch in length, fixt to the top of the maſt; the hand held over them would ſet them all in motion: in the dark, they would appear as ſo many rings of fire, moving in various courſes, and following the hand in any direction.

When a few young perſons have nothing elſe to do, they might very innocently amuſe themſelves, by making a repreſentation of a kind of ſea-engagement between theſe boats. Suppoſing each of them large enough to hold a ſmall coated phial without ſinking, theſe phials may be charged, ſome of them poſitively on the inſide, others negatively; they may then be placed at the bow of the boat, with the wire ball and uncoated part of the phial projecting over; a ſmall braſs chain ſhould be made to touch the outward coating of the phial, and the other end brought over the ſtern of the boat, and hang ſo as to touch the

water.

water. The boats being then put into a trough of water, and pretty highly charged, they will ſoon be in motion; thoſe that are electrified alike, will repel each other; and thoſe poſſeſſed of a contrary electricity, will be attracted, till the balls of the two phials approach pretty near together; they will then diſcharge their contents with a loud exploſion, and the boats will afterwards ſheer from each other.*

When the electric fluid percolates a wooden point, the ſtream or cone, which iſſues from it, ſeems diluted, and ſomething ſimilar to the purple electric light, which is obtained in vacuo. The action of the electric fluid on the air, by an electrified point, produces a ſenſible aura, or wind, of ſufficient force, as is ſeen above, to put light bodies in motion, or diſturb the flame of a candle, and occaſion an undulation in the fluids: the action of the fluid is ſo modified by points, as to produce an agreeable ſenſation, reſembling a gentle breathing: this ſenſation may be rendered more or leſs ſtimulating, by the reſiſtance the fluid meets with in it's action on our bodies, an effect which is productive of great advantages in medical electricity.

* Becket's Eſſay on Electricity, p. 36.

CHAP. VII.

OF THE LEYDEN PHIAL.

THE experiments upon the Leyden phial are ſome of the moſt intereſting in electricity; they excited the attention of the philoſopher to this ſubject more than any other experiment, and are ſtill viewed with wonder and ſurprize.

The phænomena attending this very extraordinary experiment ſeemed totally inexplicable, till they were elucidated by the ingenious theory of Dr. Franklin; which, in a plain and clear manner, accounts for moſt of the difficulties which attend this intricate branch of electricity; and accommodates itſelf ſo eaſily and ſatisfactorily to a variety of appearances, as to make us almoſt loſe ſight of the objections againſt it.

EXPERIMENT LXXXII.—Place the braſs ball of a coated jar in contact with the prime conductor while the outſide communicates with the table, turn the cylinder, and the bottle will in a little time be charged, or modify the electric fluid in a peculiar manner. To diſcharge the jar, or reſtore it to it's natural ſtate, bring one end of

a cona conducting ſubſtance in contact with the outſide coating, and let the other be brought near the knob of the jar which communicates with the inſide coating, a ſtrong exploſion will take place, the electric light will be viſible, and the report very loud.

EXPERIMENT LXXXIII.—Charge the Leyden bottle, then touch the outſide coating with one hand, and the knob with the other, the bottle will be diſcharged, and a ſudden peculiar ſenſation will be perceived, that is called the electric ſhock. The ſhock, when it is taken in this manner, generally affects the wriſts, elbows, and breaſt: when the ſhock is ſtrong, it reſembles an univerſal blow. This peculiar ſenſation is probably owing to the two-fold and inſtantaneous action of the electric fluid, which enters and goes out of the body, and the various parts through which it paſſes, at one and the ſame inſtant. It has been alſo obſerved, that nature has appointed a certain modification of the electric fluid in all terreſtrial bodies, which we violate in our experiments; when this violation is ſmall, the powers of nature operate in a gentle manner to rectify the diſorder we have introduced; but when the deviation is conſiderable, the natural powers reſtore the original conſtitution with extreme violence.

If ſeveral perſons join hands, and the firſt touches the outſide of a charged jar, and the laſt the knob, the bottle will be diſcharged, and they will all feel the ſhock at the ſame inſtant; but the greater the number of perſons that join hands to take a ſhock, the weaker it is.

The force of the ſhock is in proportion to the quantity of coated ſurfaces, the thinneſs of the glaſs, and the power of the machine; or, the effect of the Leyden phial is increaſed, in proportion as we deſtroy the equilibrium on the ſurfaces.

A given quantity of electricity, impelled through our body with a given force, produces a weaker ſenſation, than twice that quantity impelled with half that force, and conſequently the ſtrength of the ſhock depends rather more on the quantity of fluid, which paſſes through our body, than on the force with which it is impelled. Yet, the force of an exploſion ſeems to depend more on the degree to which the fluid is compreſſed, than on the quantity; hence a ſmall phial fully charged will act nearly as ſtrong as a larger jar which is half charged.

If a charged jar is coated very high, it will diſcharge itſelf before it has received near the charge it would take if the coating was lower. If it is coated very low, this part of the ſurface may be charged very high, but a conſiderable part of the glaſs is not charged at all.

When a jar is charged very high, it will often explode or diſcharge itſelf over the glaſs from one coated ſurface to the other; or, if the glaſs is thin, it will make a hole through it, and ſwell the coating on both ſides, the glaſs in the hole will be pulverized, and very often a variety of fiſſures will proceed from it in various directions.

A Leyden jar very often recovers it's electricity, in a ſmall degree, after a diſcharge has been made; this ſecond exploſion is called the reſiduum of a charge.

The form or ſize of the glaſs is no ways material to the receiving of a charge.

To avoid receiving the electric ſhock, be careful never to touch the top and bottom of the jar at the ſame time, and never to enter a circuit formed between the inſide and outſide of a jar; for the effect of the Leyden phial depends entirely on the reciprocal action of the two ſurfaces, and does not take place, when either is touched ſeparately. By attending to this obſervation, jars of any ſize may be handled with ſafety. Indeed, the human frame makes ſo little reſiſtance to the free paſſage of this ſubtle agent, that no other inconvenience will attend a ſhock from a

common-

common-ſized charged jar, than a tranſient diſagreeable ſenſation.

Touch the knob of a charged jar, no ſhock will enſue; but the finger, or part that touches the ball of the jar, will be affected with a ſharp ſenſation, as if it had been pricked with a needle. The diſcharge is ſilent and without an exploſion, when the communication between the two ſides of the jar is made by imperfect conductors.

A charged phial ſet upon electric ſubſtances, may be taken hold of without danger, either by the coating or the wire; a ſmall ſpark only will proceed from either.

DR. FRANKLIN'S THEORY OF THE LEYDEN BOTTLE.

Glaſs is ſuppoſed to contain at all times, on it's two ſurfaces, a large quantity of the electric fluid, which is ſo diſpoſed, that, if you increaſe the quantity on one ſide, the other muſt throw off an equal proportion; or, when one ſide is poſitive, the other muſt be negative. Now, as no more of the electric fluid can be forced on one ſide, than can go off on the other, there is no more in the bottle, after it is charged, than was there before; the quantity is neither increaſed or leſſened on the whole, though a change may be made in it's place and ſituation; i. e. we may throw an additional quantity on one of it's ſides, if, at the ſame time, an equal quantity can eſcape from the other, and not otherwiſe. That this change is effected by lining parts of it's two ſurfaces with a non-electric; through the mediation of which, we are enabled to convey the electric fire to every phyſical point of the ſurface we propoſe to charge, where it exerts it's activity in repelling the electric particles naturally belonging to the other ſide; all of which have an opportunity of eſcaping by the lining in contact with this ſurface, which, for that purpoſe, muſt communicate with the earth: when the whole quantity belonging to this ſurface has been diſcharged, in conſequence of an equal quantity thrown upon the other ſurface, the bottle is charged as much as it can poſſibly be. The two ſurfaces are at this time in a ſtate of violence; the inner, or poſitive ſide, ſtrongly diſpoſed to part with it's additional fire; and the outer, or negative ſide, equally deſirous to attract what it has loſt; but neither of them capable of having a change in it's ſtate effected, without the equal and cotemporary participation of the other. That notwithſtanding the vicinity of theſe two ſurfaces, and the ſtrong diſpoſition of the electric fluid contained in one of them, to communicate it's ſuperabundance to the other, and of that to receive it, yet there is an impenetrable barrier between them; for ſo impermeable is glaſs to the electric fluid, (though it permits one ſide of it to act upon the other,) that it's two ſurfaces remain in this ſtate of contrariety, till a communication is formed between them, *ab extra*, by a proper conductor, when the equilibrium is ſuddenly and violently reſtored, and the electric fluid recovers it's original ſtate of equality on the two ſides of the glaſs.

THE LEYDEN PHIAL CONSIDERED IN A DIFFERENT POINT OF VIEW.

We have already ſhewn, that whenever a quantity of the electric fluid is brought within a certain diſtance of the ſurface of any body, (whether metal, wood, or glaſs,) it will always produce on that body a contrary electricity; and this more readily, and permanently, when the body has a communication with the earth.

The equilibrium will not be reſtored ſo long as the power continues of the ſame force, and acting at the ſame diſtance; but the nearer this power is brought to the ſurface, the greater is the effect it will produce. It has alſo been ſhewn, that the electric fluid will communicate theſe powers through glaſs, nearly as well as through air.

Now as glaſs reſiſts the paſſage of the fluid more than wood or metal, the fluid will be longer in paſſing through a given length of glaſs, than through the ſame length of wood or metal.

But by means of the metallic coating on one ſide of the glaſs, the electric fluid is placed in the moſt advantageous ſituation for producing a ſtrong and uniform action on the contrary ſide, on which the reſiſtance is leſſened with as great advantages by the other metallic coating, which is connected with the earth ; and this contrariety will continue till the equilibrium is reſtored by connecting the oppoſite ſide with a conductor.

When an electric is excited, the two powers are ſaid to be ſeparated : they are alſo known to repel their own particles, and attract the contrary. When one ſide of a jar is made poſitive, may it not repel the poſitive electricity from the other ſide, ſeparating it from the negative, which is ſtrongly attracted through the glaſs ?

The outſide of the jar cannot then be ſaid to be deprived of it's electricity, but only has it's fluid changed ; and when the fluids are ſeparated, they are ever eager to conjoin again.*

COMBINED

* See Eeles's Philoſophical Eſſays ; Wilſon's Short View of Electricity ; and Milner's Obſervations on Electricity.

COMBINED APPARATUS.

The apparatus reprefented fig. 49, will be found exceedingly convenient for making a variety of experiments on the Leyden phial. I have endeavoured to combine the parts of it in fuch manner, as to render the apparatus extenfively ufeful, without being complicated. A is an infulated pillar of glafs, which is fcrewed to the wooden foot B: all the different parts of the apparatus may be fcrewed alternately on this pillar. C is an exhaufted tube of glafs, furnifhed at each end with brafs caps: at the end D is a valve, properly fecured under the brafs plate; a brafs wire, with a ball, projects from the upper cap; a pointed wire proceeds from the bottom plate; this tube is called the luminous conductor. The flafk, reprefented at E, is called the Leyden vacuum. It is furnifhed with a valve under the ball E; this ball unfcrews, in order to come more readily at the valve: a wire, with a blunt end, projects a little below the neck of the flafk; the bottom of the flafk is coated with tin-foil: a female fcrew is cemented to the bottom, in order to fcrew it on the pillar A.

F is a fyringe to exhauft the air occafionally, either from the luminous conductor, or the Leyden

Leyden vacuum. To do this, unfcrew the ball of the Leyden vacuum, or the plate of the luminous conductor, and then fcrew the fyringe in the place of either of thefe pieces, being careful that the bottom of the female fcrew G bears clofe againft the leather which covers the fhoulders a b, c d, then work the fyringe, and in a few minutes the glaffes will be fufficiently exhaufted. H and I are two Leyden bottles, each of which has a female fcrew fitted to the bottom, in order that they may be conveniently fcrewed on the pillar A. The bottle H is furnifhed with a belt, that it may be fcrewed fideways on the pillar A. K and L are two fmall wires, which are to fcrew occafionally into either the ball E, the knobs e or f, the cap c, or the focket g, on the top of the pillar: the balls may be unfcrewed from thefe wires, which will then exhibit a blunt point. M is a wooden table to be fcrewed on the glafs pillar occafionally.

EXPERIMENTS ON CHARGING AND DISCHARGING THE LEYDEN PHIAL, INTENDED TO ELUCIDATE AND CONFIRM DR. FRANKLIN'S THEORY.

EXPERIMENT LXXXIV.—Screw a Leyden phial, whoſe coating is free from points, upon an inſulated ſtand, and place it ſo that it's knob may be in contact with the conductor, taking care that no conducting ſubſtance is near the coating of the jar; turn the cylinder round a ſufficient number of times to charge the phial, then examine it with a diſcharging rod, and you will find it had received no charge; which ſhews clearly, that except the electric fluid can eſcape from one ſide of the jar, it can receive none on the other. If there are any points on the coating, or damp on the ſtand, the fluid will be carried off by them, and the jar will receive a ſmall charge. The air, which ſurrounds the coating, will alſo ſometimes carry off a ſmall quantity of electricity.

EXPERIMENT LXXXV.—Place the ſame inſulated phial ſo that it's knob may be about half an inch from the conductor, and while the cylinder is turning, hold a braſs knob near the coating of the jar; this knob will receive a ſpark from the coating for every one that paſſes between the conductor and the knob, and the jar will in a little time be charged, by adding electricity to one ſide, and taking it away from the other.

EXPERIMENT LXXXVI.—Screw the phial a, fig. 42, on the inſulated pillar d, and bring it's knob in contact with the conductor; hold another bottle c, of the ſame ſize with a, ſo that it's knob may be in contact with the outſide coating of the bottle a; turn the cylinder, and when the bottle a is charged, place c on the table, then unſcrew a from it's ſtand, and place it alſo on the table, but at ſome diſtance from the other; fit a braſs ball to the bottom ſtem of the quadrant electrometer, and hold the electrometer by a ſilk ſtring, ſo that the braſs ball may touch the knob of the bottle; obſerve at what height the index of the electrometer ſtands, and then remove it to the other bottle, which will raiſe the index to the ſame height; ſhewing clearly, that the bottle has thrown off from the outſide as much electricity as it received on the inſide.

EXPERIMENT LXXXVII.—Place the knob of an inſulated bottle in contact with a poſitive conductor, and connect the outer coating with the cuſhion, or a negative conductor, turn the cylinder, and the bottle will be charged with it's own electricity; the fluid from the exterior coating

coating being transferred to the interior one; the bottle is charged in this inſtance without any communication with the earth.

EXPERIMENT LXXXVIII.—Charge the two bottles, fig. 43, poſitively; connect their outſide coatings by a wire or chain, then bring their knobs together, there will be no ſpark between them, and the bottles will not be diſcharged, becauſe neither ſide has any thing to communicate to the other.

EXPERIMENT LXXXIX.—Charge the inſulated bottle, fig. 43, negatively, and the other poſitively; connect the coating by a chain, and bring the knobs towards each other, an exploſion will take place, and the bottles will be diſcharged. If a lighted candle is placed between the knobs, the exploſion will be made through the flame in a beautiful manner, and at ſome inches diſtance. See fig. 44.

EXPERIMENT XC.—Fix a quadrant electrometer to the ball of a Leyden bottle, and charge it negatively; when it has received a full charge, the index will ſtand at 90 degrees; then place the bottle with it's electrometer at the poſitive conductor, turn the cylinder, the electrometer will deſcend, and the bottle will be diſcharged by the contrary electricity.

Experiment xci.—Inſulate two Leyden bottles; let their coatings be in contact, and while you charge the inſide of one poſitively, let a perſon, ſtanding on the floor, touch the top of the other with his finger, and it will be charged negatively.

Experiment xcii.—L M, fig. 45, repreſents a Leyden jar, which is furniſhed with moveable coatings of tin; the inner one, N, may be removed by the ſilk ſtrings f, g, h; the jar may be taken from it's outer coating.

Charge the jar, and then remove the coatings, bring a pair of pith balls towards the jar, and they will be ſtrongly attracted by it; replace the coatings, and the jar will give a conſiderable ſhock; which ſhews, that the power or force of the charge is reſident in the glaſs, and not in the coatings.

Experiment xciii.—T V. fig. 46, repreſents a bottle, whoſe exterior coating is formed of ſmall pieces of tin-foil, placed at a little diſtance from each other. Charge this bottle in the uſual manner, and ſtrong ſparks of electricity will paſs

from

from one ſpot of tin-foil to the other, in a variety of directions; the ſeparation of the tin-foil making the paſſage of the fluid from the outſide to the table viſible. Diſcharge this bottle, by bringing a pointed wire gradually near the knob, and the uncoated part of the glaſs between the ſpots will be pleaſingly illuminated, and the noiſe will reſemble that of ſmall fired crackers. If the jar is diſcharged ſuddenly, the whole outſide ſurface appears illuminated. To produce theſe appearances, the glaſs muſt be very dry.

EXPERIMENT XCIV.—String a parcel of ſhot on a ſilk ſtring, leaving a ſmall ſpace between each of them; ſuſpend this from the conductor, ſo that it may reach the bottom of a coated phial, which is placed on an inſulated ſtand; connect another ſtring of ſhot to the bottom of the jar, and let it communicate with the table, turn the machine, and a vivid ſpark will be ſeen between each of the ſhot, both within and without the bottle, as if the fire paſſed through the glaſs.

EXPERIMENT XCV.—Hold a phial in the hand which has no coating on the outſide, and preſent it's knob towards an electrified conductor; the fire, while it is charging, will paſs from the outſide to the hand, in a pleaſing manner; on the diſcharge, difcharge, beautiful ramifications will proceed from that knob of the difcharger which is on the outfide all over the jar.

EXPERIMENT XCVI.—Let a chain be fufpended from the conductor and pafs into an uncoated bottle, fo that it does not touch the bottom; put the machine in action, and the chain will move round, in order, as it were, to lay the fire on the infide of the jar, and thus charge it by degrees.

EXPERIMENT XCVII.—Fig. 47 reprefents two Leyden phials, placed one over the other. Various experiments may be made with this double bottle, which are very pleafing, and elucidate clearly the received theory.

Bring the outfide coating of the bottle A in contact with the prime conductor, and turn the machine till the bottle is charged, then place one ball of the difcharging rod upon the coating of B, and with the other touch the knob of the jar A, which will caufe an explofion. Now place one ball of the difcharger on the knob of A, and bring the other ball to it's coating, and you have a fecond difcharge. Again, apply one ball of the difcharger on the coating of B, and carry the other to the coating of A, and it will produce a third explosion. A fourth is obtained by applying the discharger from the coating of A to it's knob.

The outer coating of the upper jar communicating with the inside of the under one, conveys the fluid from the conductor to the large jar, which is therefore charged positively; the upper jar does not charge, because the inside cannot part with any of it's electric fluid; but when a communication is formed from the outside of A to the inside of B, part of the fire on the inside of A will be conveyed to the negative coating of B, and the jar will be discharged. The second explosion is occasioned by the discharge of the jar A; but as the outside of this communicates, by conducting substances, with the positive inside of the jar B, if the ball of the discharging rod remains a small time after the discharge on the knob of A, part of the fire of the inside of A will escape, and be replaced by an equal quantity on the outside from the jar B, by which means A is charged a second time; the discharge of this produces the third, and of B the fourth explosion.

THE FOLLOWING PLEASING VARIATIONS OF THE FOREGOING EXPERIMENT WERE COMMUNICATED TO ME BY MR. J. FELL, OF ULVERSTON.

A the upper bottle, B the under bottle.

Knob of A applied to the conductor, and the charge given.

1ſt diſcharge. Balls of diſcharger from coating of A to knob of A.

2d ditto. From coating of B to knob of A.

3d diſcharge. From coating of B to coating of A.

4th ditto. From coating of A to knob of A.

Coating of A applied to the conductor, and the charge given.

1ſt diſcharge. Balls of diſcharger from coating of B to knob of A.

2d ditto. From coating of A to knob of A.

3d ditto. From coating of B to knob of A.

4th ditto. From coating of B to coating of A.

5th ditto. From coating of A to knob of A.

Coating of A applied to the conductor, and the charge given, touch the knob of A with one ball of the diſcharger, the other ball communicating with the earth, then proceed as follows.

1ſt diſ-

1ſt diſcharge.	Balls of diſcharger from coating of A to knob of A.
2d ditto.	From coating of B to knob of A.
3d ditto.	From coating of A to knob of A.
4th diſcharge.	From coating of B to knob of A.

Go on thus alternately, and fifteen, ſixteen, or more diſcharges may be produced.

THE CONTRARY STATE OF THE TWO OPPOSITE SIDES OF A CHARGED LEYDEN BOTTLE, SHEWN BY THEIR RESPECTIVE ATTRACTIVE AND REPULSIVE POWERS.

EXPERIMENT XCVIII.—Screw the bottle H, fig. 49, with the belt ſideways on the inſulating ſtand, as in fig. 48, and charge it poſitively, then touch the knob with a pair of pith balls, theſe will diverge with poſitive electricity; hold another pair to the coating, and they will ſeparate with negative electricity.

EXPERIMENT XCIX.—Electrify two pair of the pith balls which are fixed to the braſs tubes, as in fig. 22, plate II. by the knob of a poſitively charged bottle, and place them at a ſmall diſtance from each other, then puſh them together till the ends of the tubes are in contact, and the balls will remain in the ſame ſtate they were in before they were brought together, becauſe their electricity is of the ſame kind. The reſult is the ſame if both pair are electrified by the coating; but if one pair is electrified by the coating and the other by the knob, when they are brought in contact they immediately cloſe.

EXPERIMENT C.—A cork ball, or an artificial ſpider made of burnt cork with legs of linen thread, ſuſpended by ſilk, will play between the knobs of two bottles, one of which is charged poſitively, the other negatively, and will in a little time diſcharge them.

EXPERIMENT CI.—A ball ſuſpended on ſilk, and placed between two braſs balls, one proceeding from the outſide, the other from the inſide of a Leyden jar, when the bottle is charged, will fly from one knob to the other, and by thus conveying the fire from the inſide to the outſide of the bottle, will ſoon diſcharge it.

EXPERIMENT CII.—An inſulated cork ball, after having received a ſpark, will not play between, but be equally repelled by two bottles which are charged with the ſame power.

EXPERIMENT

EXPERIMENT CIII.—At fig. 58 a wire is fixed to the under part of the inſulated coated phial, b c another wire fitted to, and at right angles with the former, a braſs fly is placed on the point of this wire; charge the bottle, and all the time the bottle is charging the fly will turn round; when the bottle is charged the needle ſtops. Touch the top of the bottle with a finger, or any other conducting ſubſtance, and the fly will turn again till the bottle is diſcharged. The fly will electrify a pair of balls poſitively while the bottle is charging, and negatively when diſcharging.

EXPERIMENT CIV.—Place a clean, dry, and excited pane of glaſs, about one foot ſquare, on an inſulated box with pith balls, it will cauſe the balls to diverge with poſitive electricity, and they will continue to repel each other upwards of four hours in dry air. When the balls come together, remove the glaſs, and they will open with negative electricity; replace the glaſs, and they will cloſe; remove it, and they will open again; and thus alternately as long as any electricity remains in the glaſs.

If the pane of glaſs be placed in a frame of wood, and a light pith or cork ball be laid on it's ſurface, on preſenting towards it the end of a finger, or the point of a pin, the ball will recede from them with a very brifk motion, and may thus be driven about on the furface of the glafs, like a feather in the air by an excited tube. The ball being deprived of it's electricity by the pin, it inftantly flies to that part of the glafs which attracts it moft forcibly.

To excite the pane of glafs; lay it upon a quire of large paper, well dried, and then rub it with a piece of clean dry flannel.

THE CONTRARY STATES OF THE DIFFERENT SIDES OF A LEYDEN PHIAL, AND THE DIRECTION OF THE ELECTRIC FLUID IN THE CHARGE AND DISCHARGE THEREOF, INVESTIGATED BY THE APPEARANCE OF THE ELECTRIC LIGHT.

In Chap. VI. we obferved, that the different appearances of light on electrified points was deemed a criterion of the direction of the electric fluid; that the luminous ftar fhews a point in receiving the electric matter, whilft the luminous brufh, or cone, indicates that it is proceeding from a point.

We fhall now examine the ftate of the different fides of the Leyden bottle by thefe appearances.

EXPERIMENT

EXPERIMENT CV.—Screw the jar I on the insulating pillar, and the pointed wire into the hole g, place another pointed wire at the end of the conductor, bring the knob of the jar near this wire, and then turn the cylinder, a pencil of rays will diverge from the pointed wire in the conductor to the knob of the jar, at the same time another pencil of rays will diverge from the point at the bottom into the air. See fig. 50.

Repeat this experiment with the negative conductor, and a luminous star will appear on the end of each wire.

EXPERIMENT CVI.—Screw a pointed wire into the knob of the jar, (see. fig. 51) charge the bottle positively, the fire will be received from the conductor by the pointed wire, and appear there as a luminous star, while the wire on the outside of the jar will throw off a diverging cone.

Fig. 52 represents the foregoing appearances reversed, by charging the jar negatively at the positive conductor.

This experiment may be further varied, by applying the bottle to a negative conductor.

EXPERIMENT CVII.—After the jar is charged, as in the foregoing experiments, turn that wire from the cylinder which before was nearest to it, then put the machine in action, and the afflux and efflux will be more apparent than before; one point throwing off, and the other receiving the fluid with extreme avidity, which will in a little time discharge the jar.

EXPERIMENT CVIII.—Charge the jar as before, then touch the wire which is connected with the negative side, and the opposite wire will throw off a diverging cone; but if the positive side is touched, a luminous cone only will be seen on the other wire.

EXPERIMENT CIX.—Fig. 53 is an electric jar, B B the tin-foil coating, C a stand which supports the jar, D a socket of metal which carries the glass rod E; a curved metallic wire, pointed at each end, is fixed to the end of the rod G, which rod is moveable at pleasure in a spring tube N, that tube being fixed by a socket upon the top of the glass rod E, the charging wire communicates with the different divisions of the inside coating of the jar by horizontal wires.

Place the jar as usual, and put the machine in action, a small luminous spark will appear upon

upon the upper point of the wire F, (a plain indication that the point is then receiving electricity from the upper ring of the coating on the outſide of the jar) a fine ſtream or pencil of rays will at the ſame time fly off, beautifully diverging from the lower point of the wire F upon the bottom ring of the coating on the jar; when theſe appearances ceaſe, which they will as ſoon as the jar is charged, let a pointed wire be preſented towards the prime conductor, this will ſoon diſcharge the jar ſilently, during which, the lower point will be illuminated with a ſmall ſpark, while the upper point of the wire will throw off a pencil of rays, diverging towards the upper ring of the coating.

EXPERIMENT CX.—Take a Leyden phial, the neck of which ſhould not be very broad, ſet the coating on the conductor, and charge it negatively; when charged, if not too dry, the upper edge of the coating will throw off one or more bruſhes of light into the air, which will viſibly incline towards the charging wire of the bottle, and ſometimes actually reach it. Preſent the knob to the prime conductor, and charge the jar poſitively, a ſmall ſpark of light will firſt appear on the edge of the cork in the neck of the bottle, through which the wire paſſes after a few turns of the cylinder; this ſpark becomes a bruſh, darting out from the cork, and gradually lengthening till it forms an arch, the end of it extending downwards till it reaches and touches the end of the coating. If the bottle be dry, it will in both caſes be diſcharged ſpontaneouſly. See fig. 54 and 55.

EXPERIMENT CXI.—An inſulated poſitively charged bottle will give a ſpark from it's knob to an excited ſtick of wax, while no ſpark will paſs between it and an excited glaſs tube.

EXPERIMENT CXII.—An analyſis of the Leyden phial, by means of the Leyden vacuum E, fig. 49.——Screw this on the inſulated ſtand, with the pointed wire from the bottom. Fig. 56 repreſents the appearance of the fluid on the points when the bottle is charged negatively, at a conductor loaded with poſitive electricity.

Fig. 57, the appearances it diſplays when it is charging poſitively at the ſame conductor.

Fig. 59 is the ſame bottle charging poſitively at a negative conductor. Fig. 60, it is charging negatively at the ſame conductor.

EXPERIMENT CXIII.—Fig. 61 repreſents the luminous conductor on the inſulating ſtand. Set the

the collecting point near the cylinder, and place the knob of an uncharged phial in contact with the ball, or hang a chain from it to the table, and, on working the machine, the ball will be enveloped in a denſe electric atmoſphere. If the point be brought in contact with an inſulated rubber, and a communication is made from the ball to the table, the atmoſphere will be on the point in the tube. If a bottle, poſitively charged, be preſented, the appearances in the tube will be as delineated in fig. 62. But if a bottle negatively charged be thus applied, the appearance will be as in fig. 61.

This tube, when mounted on it's inſulating ſtand, may be uſed inſtead of the prime conductor, and all the common experiments may be performed with it; the tube will be luminous during the whole of the operation.

OF THE DIRECTION OF THE ELECTRIC MATTER IN THE DISCHARGE OF THE LEYDEN PHIAL.

EXPERIMENT CXIV.—Place a charged jar on a ſmall glaſs ſtand under the receiver of an air-pump; as the receiver is exhauſting the electric fire will iſſue from the wire of the phial, in a very luminous pencil of rays, and continue flaſhing to the coating till the air is exhauſted, when the jar will be found to be diſcharged.

If the phial is charged negatively, the current of fire will appear to have a different direction from that which it had before.

From this experiment we may infer the effects of the atmoſpheric preſſure upon the charge of the Leyden phial, and learn that it is the natural boundary to every charge of electricity we can give; and, conſequently, that a phial would contain double the charge, in air doubly condenſed, as it does in the common atmoſphere, ſince it would increaſe the intenſity of the electric atmoſphere.

EXPERIMENT CXV.—Place a ſmall lighted taper between the two balls of the univerſal diſcharger, then paſs a very ſmall charge of a poſitive phial through them, and the flame of the taper will be attracted in the direction of the fluid towards the coating. See. fig. 63.

EXPERIMENT CXVI.—The ſame ſmall charge from a negative bottle will reverſe the appearance.

In both theſe experiments it is neceſſary to uſe the leaſt charge that can be given, juſt ſufficient to leap the interruption in the circuit.

4 EXPERIMENT

EXPERIMENT CXVII.—Place a card on the table of the univerſal diſcharger, and bring one of the points under the card, then connect this point with the coating of a jar poſitively charged, place the other point on the top of the card, and at about an inch and a half from the forme rnow complete the circuit, by bringing a diſcharging rod from the laſt wire to the top of a bottle, and the electricity will paſs through the upper wire, along the ſurface of the card, till it comes to the point which is underneath, where it will make a hole in the card, and paſs through the wire to the coating of the bottle. See fig. 64.

EXPERIMENT CXVIII.—Four cork balls, A, B, C, D, being placed at equal diſtances from each other, from the balls of the diſcharging rod, and from the coating of a poſitively charged bottle; on making the diſcharge, the ball A next the rod was repelled to B, which was again repelled to C, C remained immoveable, but D flew to the coating of the bottle.

EXPERIMENT CXIX.—Take a card, and paint both ſides with cinnabar about the breadth of the finger, fix this card vertically by a little wax on the table of the univerſal diſcharger, let the pointed ends of one of the wires touch one ſide of the card, and the end of the other wire the opposite side; the distance of the points from each other must be proportioned to the strength of the charge; discharge a jar through the wires, and the black mark, left by the explosion on the coloured band, shews that the electric fluid passed from the wire, communicating with the inside of the bottle, to that which communicates with the outside, against which it makes a hole.

Experiments which seem to militate against the received Theory of Electricity.

Experiment cxx.—Let the surfaces of an electric plate be very slightly charged and insulated, let an interrupted circuit be formed, the two powers will be visible, illuminating the points of the interrupted circuits, and each power will appear to extend farther from the surface contiguous to it, the stronger the charge is communicated to the plate; but if the illuminations on each side meet, there will immediately follow an explosion of the whole charge. The length of the interrupted circuit used for this experiment was twelve feet.*

Experiment cxxi.—If a cylindrical plate of air,

* Atwood's analysis of a course of lectures, p. 121.

air, contained in the receiver of an air-pump, be charged, it is obſerved, the more air that is exhauſted from between the ſurfaces, the more eaſily the powers will unite.

EXPERIMENT CXXII.—If an exhauſted receiver be made part of the electric circuit, and the charge ſhould not be ſufficient to cauſe an exploſion, an electric light will appear to proceed in oppoſite direction from the parts communicating with the negative and poſitive ſurfaces.

EXPERIMENT CXXIII.—Let a coated phial be ſet on an inſulating ſtand, and let it's knob be touched by the knob of another phial negatively electrified, a ſmall ſpark will be ſeen between them, and both ſides of the inſulated phial will be inſtantly negatively electrified.*

Faſten a pith ball electrometer by a little wax to the outſide coating of a jar, charge the jar ſlightly with poſitive electricity, and ſet it on an inſulated ſtand, the ball will either not diverge, or only a very little; bring the knob of a bottle which is ſtrongly charged with poſitive electricity near the knob of the former, and the balls will diverge with poſitive electricity.

EXPERIMENT

* Encyclopædia Britannica, Vol. IV, p. 2698.

EXPERIMENT CXXV.—Let the ſame phial, with the pith balls affixed to it's outſide coating, be ſlightly charged negatively, and then inſulated, bring the knob of a phial, which is ſtrongly electrified negatively, to that of the inſulated one, and the pith balls will diverge with negative electricity.

EXPERIMENT CXXVI.—Charge a jar poſitively, and then inſulate it, charge another ſtrongly with negative electricity, bring the knob of the negative bottle near that of the poſitive one, and a thread will play between them; but when the knobs touch each other, the threads, after being attracted, will be repelled by both. The negative electricity is ſome how ſuperinduced on the poſitive, and, for a few minutes after they are ſeparated, both will appear negatively electrified; but if the finger is brought near the knob of that bottle on which the negative electricity was ſuperinduced, it will inſtantly be diſſipated, a ſmall ſpark will ſtrike the finger, and the bottle will be poſitively charged as before.

One of the poſitions which ſupport the Franklinian hypotheſis, has been already conſidered; we are now at a proper ſtage for pointing out ſome of thoſe deficiencies which have been obſerved in other parts of it. To ſupport this hypotheſis, pothefis, it is neceffary to maintain THAT GLASS AND OTHER ELECTRIC SUBSTANCES, THOUGH THEY CONTAIN A GREAT DEAL OF ELECTRIC MATTER, ARE NEVERTHELESS IMPERMEABLE TO IT.

This pofition appears contradictory at the firft view, for it is not eafy to conceive, that any fubftance can be full of a fluid and yet impermeable by it. Efpecially when a confiderable quantity of this fluid is taken from one fide, and added to the other; and what is more furprifing, the thinner the glafs, and the lefs quantity it is capable of containing, the more we are able to put into it, and the ftronger will be the charge.*

The following among other experiments has been adduced as a ftrong argument in favour of the impermeability of glafs. Let a coated phial be fet upon an infulated ftand, and the knob of another coated phial be brought near it; for every fpark difcharged from the prime conductor to the knob of the firft jar, a fpark will pafs from the coating of the firft to the knob of the fecond: now a common obferver generally imagines that the fire runs through the glafs; Dr. Franklin concludes it does not, becaufe there is found a great accumulation of electricity on the infide of the jar, which manifefts itfelf when the infide and outfide are made to communicate with each other.

* Encyclopædia Britannica, p. 2687.

other. But we cannot from this and fimilar experiments conclude that glafs is impermeable, except we fuppofe the electric matter to be accumulated on one fide of the glafs, and deficient on the other; but this has never yet been proved, it has indeed been faid, that if glafs was permeable to this fluid, it could never be charged, but this refts wholly on the fuppofition, that there is an accumulation of the fluid in bodies pofitively electrified, and a deficiency in thofe which are negatively fo.*

Mr. Wilfon, to prove the permeability of glafs, took a very large pane of glafs a little warmed, and holding it upright by one edge, while the oppofite edge refted upon wax, he rubbed the middle part of the furface with his finger, and found both fides electrified PLUS; he accounted for this from the electric fluid paffing through the glafs from his finger. But Dr. Prieftley fays this appearance ought to take place on Dr. Franklin's principles; for the fire given to the glafs by the finger on one fide, repels an equal quantity from the other, which ftands as an atmofphere, fo that both fides appear pofitively electrified. Mr. Wilfon tried alfo another experiment, which feems more decifive than the former. Having by him a pane of glafs, one fide

* Ibid. p. 2687.

ſide of which was rough, and the other ſmooth; he rubbed it on one ſide, upon doing this both ſides were electrified MINUS. Dr. Prieſtley attempts to reconcile this to Dr. Franklin's hypotheſis, as the electric fluid, contained in the glaſs, ſays he, was kept equal on both ſides by the common repulſion. If the quantity on one ſide is diminiſhed, the fluid on the other ſide being leſs repelled retires INWARD, and leaves that ſurface MINUS. But ſurely thoſe words militate ſtrongly againſt the ſyſtem he means to eſtabliſh. The quantity of fluid in one ſide being diminiſhed, that on the other, he ſays, RETIRES INWARD. But into what does it retire? If into the ſubſtance of the glaſs, then is the glaſs permeable by it, which is the very thing Dr. P. argues againſt.*

Dr. Franklin's theory reſts upon the following poſition, "That poſitive electricity is an accumulation, or too great a quantity of electric matter contained in a body; and negative electricity is when there is too little." Of this however there is not one proof, and all the attempts that have hitherto been made to prove it, are only arguing in a circle, or proving the thing by itſelf. Thus, for inſtance, a body electrified poſitively, attracts one that is electrified

T negatively,

* Ibid. p. 2688.

negatively, becauſe the firſt has too much and the other too little electric matter. But how do we know that one has too much and the other too little electricity? Becauſe they attract each other.

Again, it has been proved, that when a jar is electrified poſitively, there is as conſtant a ſtream of fire from the outſide coating, as there is from the conductor to the inſide coating. Therefore, it is ſaid, the outſide has too little, and the inſide too much electricity. But how is this known to be the caſe? Becauſe in the above experiment one ſide has too much and the other too little electricity. Thus, in every inſtance, the arguments for Dr. Franklin's hypotheſis return into themſelves, and no concluſion can be drawn from them.*

If the reader wiſhes to inveſtigate this ſubject further, he may conſult Eeles's Philoſophical Eſſays, Wilſon's ſhort View of Electricity, Màràt's Rècherches Phyſique ſur l'Electricité, Milner's Obſervations, Lyon's Obſervations and Experiments on Electricity, and the Encyclopædia Britannica.

* Ibid. p. 2691.

CHAP.

CHAP. VIII.

OF THE ELECTRICAL BATTERY, AND THE LATERAL EXPLOSION OF CHARGED JARS.

TO increaſe the force of the electric exploſion, ſeveral Leyden phials are connected together in a box; this collection is termed an electrical battery. Fig. 65 repreſents one of the moſt approved form.

The bottom of the box is covered with tin-foil, to connect the exterior coatings; the inſide coatings of the jars are connected by the wires b, c, d, e, f, g, which meet in the large ball A; C is a hook at the bottom of the box, by which any ſubſtance may be connected with the outſide coating of the jars; a ball B proceeds from the inſide, by which the circuit may be conveniently completed. The following precautions are neceſſary to be attended to by thoſe who make uſe of an electrical battery.

To keep the top and uncoated part of the jars dry and free from duſt, and after the exploſion to connect a wire from the hook to the ball, which ſhould be left there till the battery is to be charged again, which will totally obviate the inconveniencies that have occaſionally happened from the reſiduum of a charge.

If one jar in a battery is broke, it is impoſſible to charge the reſt till the broken jar is removed.*

To prevent the jars of a large battery breaking at the time of the exploſion, it has been recommended not to diſcharge a battery through a good conductor, except the circuit is at leaſt five feet long; but what is gained on one hand by this method, is loſt on the other, for, by lengthening the circuit, the force of the ſhock is weakened proportionably.

I have been informed, that it is very difficult to break by an exploſion the jars which are made of green glaſs, fabricated at Newcaſtle, but have had no opportunity to make any experiments on this glaſs myſelf.

The force of a battery may be conſiderably increaſed by concentrating the ſpark from the exploſion, which is effected by cauſing it to paſs through ſmall circuits of non-conducting ſubſtances. By this means the reſiſting medium, through which the ſpark is to paſs, may be ſo prepared

* A cracked jar may be made to receive a charge, by taking away the external and internal coatings which were over the crack, ſo as to leave a ſpace of about one fourth of an inch between the crack and remaining tin-foil.

prepared as to augment it's power. If the ſpark is made to paſs through a hole in a plate of glaſs, one twelfth or one ſixth part of an inch in diameter, it will be leſs diſſipated, more compact and powerful. If the part round the hole is wetted with a little water, the ſpark, by converting this into vapour, may be conveyed to a greater diſtance, with an increaſe of rapidity, attended with a louder noiſe than common.

Mr. Morgan, by attending to theſe and ſome other circumſtances, has melted wires, &c. with ſmall bottles. I hope he will be induced to communicate this, as well as the reſt of his important diſcoveries, to the public.

EXPERIMENT CXXVII.—Paſs the charge of a ſtrong battery through two or three inches of ſmall wire, it will ſometimes appear red hot, firſt at the poſitive ſide, and the redneſs will proceed regularly towards the other end.

EXPERIMENT CXXVIII.—Diſcharge a battery through a quire of paper, a perforation will be made through it; each of the leaves is protruded by the ſtroke from the middle towards the outward leaves, as if the fire darted both ways from the center. If the paper is very dry, the fire meets with more difficulty in it's paſſage, and the hole is ſmall. If that part of the paper, through which the exploſion is made, is wet, the hole is larger, the light more vivid, and the exploſion louder.

EXPERIMENT CXXIX.—The diſcharge of a battery through a ſmall ſteel needle will, if the charge is ſufficient, communicate magnetiſm to the needle.

EXPERIMENT CXXX.—The diſcharge of a battery through a ſmall and ſlender magnetic needle, will generally deſtroy the polarity of the needle, and ſometimes invert the poles thereof. To ſucceed in this experiment, it is often neceſſary to paſs ſeveral ſtrong charges through the needle, before it is removed from the circuit.

It appears, from Beccaria's experiments, that the magnetic polarity, which is communicated to the needle by electricity, depends on the poſition of the needle when the charge is ſent through it, and is not regulated by the direction of the electric matter in entering the needle.

EXPERIMENT CXXXI.—Let a quire of paper be ſuſpended by a line in the manner of a pendulum from any convenient altitude, ſo that it's

plane

plane may be vertical. Let the largeſt charge from a battery be cauſed to paſs through it, while quieſcent in an horizontal direction perpendicular to the plane, the rods of communication not touching the paper; the phænomena are; firſt, the aperture mentioned in Exp. 128, the leaves being protruded both ways from the middle: ſecond, not the ſmalleſt motion is communicated to the paper from the force of the diſcharge.

A quire of the thickeſt and ſtrongeſt paper was made uſe of for this experiment, the height from which it was ſuſpended ſixteen feet. It is an extraordinary appearance on the hypotheſis of a ſingle electric fluid, that a force ſufficient to penetrate a ſolid ſubſtance of great tenacity and coheſive force, ſhould not communicate the ſmalleſt motion to the paper, when a breath of air would cauſe ſome ſenſible vibration in it. But this difficulty is not unanſwerable: for a velocity may be aſſigned, with which a body impinges againſt and paſſes through a pendulum of any given weight and reſiſting force, ſo that a ſmaller angular volocity ſhall be communicated to it, than any that ſhall be propoſed, and we know no limit to the velocity of the electric power or powers. But the other phænomenon, i. e. the oppoſite direction in which the

leaves

leaves are protruded, tends very much to ſtrengthen the opinion of two oppoſite currents: perhaps either of thoſe phænomena, conſidered ſimply, may admit of an eaſy ſolution from the hypotheſis of a ſingle power; when they are taken both together, it ſeems more difficult to reconcile this hypotheſis with matter of fact.*

EXPERIMENT CXXXII.—Diſcharge a battery through a ſlender piece of wire, ex. gr. one 50th of an inch in diameter, the wire will be broken to pieces, or melted, ſo as to fall on the table in glowing balls.

When a wire is melted in this manner, the ſparks fly frequently to a conſiderable diſtance, being ſcattered by the exploſion in all directions.

If the force of the battery is very great, the wire will be entirely diſperſed by the force of the exploſion. Small particles of ſuch ſubſtances as cannot be eaſily drawn into wire, as platina, grain gold, ores, &c. may be placed in a groove of wax, and then put into the circuit; if a diſcharge of ſufficient ſtrength is paſſed through them, they will be melted.

The force, by which wires are melted by a battery, varies with the length of the circuit, as the fluid meets with more reſiſtance in propor-

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* Atwood's Analyſis.

tion as the paſſage through which it is to paſs is longer. Dr. Prieſtley could melt nine inches of ſmall iron wire at the diſtance of fifteen feet, but at twenty feet diſtance he could only make ſix inches of it red hot, ſo that metals reſiſt with conſiderable force the paſſage of the electric fluid, and therefore in eſtimating the conducting powers of different ſubſtances, their length muſt be particularly attended to.

EXPERIMENT CXXXIII.—Incloſe a very ſlender wire in a glaſs tube, diſcharge a battery through this wire, and it will be thrown into globules of different ſizes, which may be collected from the inner ſurface of the tube: they are often found to be hollow, and little more than the ſcoria of the metal.

Many experiments have been made, in order to try the different conducting powers of metals, by paſſing the diſcharge of a battery through them; but it has not yet been determined, whether the greater facility with which ſome metals are exploded depends on the eaſe with which the fluid paſſes through them, or whether it proceeds from the degree of reſiſtance they make to it's paſſage, or from a want of ductility in the metal, which is therefore leſs capable of expanſion.

EXPERIMENT CXXXIV.—Difcharge a battery through a chain which is laid on paper, and black marks will be left on the paper in thofe places where the rings of the chain touch each other; the rings will be more or lefs melted at thofe places.

EXPERIMENT CXXXV.—Take two pieces of window glafs, of about 3 by 2 inches, place a flip of brafs or gold leaf between them, leaving the metallic leaf out beyond the glafs at each end; then place the two pieces of glafs in the prefs of the univerfal difcharger, bring the points of the wires E T, E F, fig. 33, to touch the ends of the leaves, and pafs a difcharge through them, which will force part of the metal into the glafs and ftain it with a colour which differs from the metal that is made ufe of. The metallic leaf fhould be made narroweft in the middle, becaufe the force of the electric fire is in proportion to it's denfity, which is increafed when the fame quantity of fire is compelled to pafs through fewer conducting particles.

The explofion in melting the ftripes of leaf-gold, &c. renders them non-conducting, and lefs capable after each difcharge to tranfmit another. Some particles of the metal are driven into the glafs, which is really melted; thofe parts of the metal,

metal, which lie contiguous to the glafs, are the moft perfectly fufed. The pieces of glafs which cover the flip of metal are generally broken to pieces by the difcharger.

EXPERIMENT CXXXVI.—Place a thick piece of glafs on the ivory plate of the univerfal difcharger, fig. 3, Pl. II. and a thick piece of ivory on the glafs, on which a weight from one to feven pounds is to be placed; bring the points of the wires EF ET againft the edge of the glafs, and pafs the difcharge through the wires, by connecting one of the wires, as EF, with the hook C of the battery, fig. 65, Pl. IV. and forming a communication, when the battery is charged, from the other wire ET to the ball, and the glafs will be broken, and fome part of it fhivered to an impalpable powder. When the piece of glafs is ftrong enough to refift the fhock, the glafs is often marked by the explofion with the moft lively and beautiful colours. I have been informed by Mr. Morgan, that if the glafs is cemented down, the effect is the fame as when it is preffed by the weights; and this mode is in various experiments more convenient.

Place a piece of very dry white wood between the balls of the univerfal difcharger, the fibres of the wood to be in the fame direction with the wires, paſs the ſhock through them, and the woods will be tore to pieces, or run the points into the wood, and then paſs the ſhock through them.

EXPERIMENT CXXXVII.—If the diſcharge is paſſed under the piece of ivory with the weights upon it, without any glaſs between the piece of ivory and the table GH of the univerſal diſcharger, the weights will be lifted up by the lateral force of the diſcharge; the number of weights muſt be proportioned to the force of the exploſion.

EXPERIMENT CXXXVIII.—Fig. 66, a repreſents an inſulated rod, nearly touching a charged jar, b is another inſulated rod, placed in a line with and near to the former; make the diſcharge by the rod e, from which a chain hangs that does not touch the bottom of the jar, and the rod b will receive an electric ſpark, which quits it again almoſt in the ſame inſtant, becauſe the fineſt threads hung upon it will not be electrified by the ſpark.

This electrical appearance, without the circuit of a diſcharging jar, is called the Lateral Exploſion.

If pieces of cork, or any light bodies, be placed

placed near the explosion of a jar or battery, they will be moved out of their place in all directions from the center of the explosion; and the greater the force of the explosion, so much greater will the distance be to which they are removed. It is not surprising, therefore, that heavy bodies should be removed to considerable distances by a strong flash of lightning. Dr. Priestley apprehends, that this species of lateral force is produced by the explosion of the air from the place through which the electric discharge passes.

This lateral force is not only exerted in the neighbourhood of an explosion, when it is made between pieces of metal in the open air, but also when it is transmitted through pieces of wire that are not thick enough to conduct it perfectly. The smaller the wire is, and the greater the fusion, the greater is the dispersion of light bodies near it.

EXPERIMENT CXXXIX.—If circuits, different in length and of different substances, form a communication between two charged surfaces of an electric plate, it is observed, the discharge will be made through the best conductors, whatever be the length of the others.

2. If circuits of the same substance be different

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in length, the discharge will be made through the shortest of them.

3. If the circuits be the same in every respect, the discharge will be made through many of them at the same time.*

If one circuit consists of undried wood, and is of considerable length in comparison of another which consists of metal, the discharge will be made wholly through the latter, unless the charge should be very great, in which case some small part will pass through the wood.

If a short metallic rod and any part of the human body form two circuits between the same charged surfaces, the discharge will, in general, be made wholly through the metallic rod; but if the charge is very great, or if the rod is very slender, or if it should be very long, in either of these cases the discharge may be perceived to pass through that part of the body which forms one of the circuits.

This will be the case when the charge is small, but it may be so increased as to pass through both the longer and shorter circuits.

I have been informed by a gentleman, that it was his custom to make a variety of circuits for the discharge of a large jar or battery; and, that having a sufficient number of these, he could

* Atwood's Analysis, p. 119, 120.

could introduce himſelf into one of them, and take his part of the ſhock without inconvenience, it even was not diſagreeable; and he could by this means leſſen the ſenſation almoſt to nothing.

EXPERIMENT CXL.—Mr. Henly made a double circuit, the firſt by an iron bar, one inch and a half in diameter, and half an inch thick; the ſecond, by four feet and a half of ſmall chain. On diſcharging a jar, containing five hundred ſquare inches of coated ſurface, the electricity paſſed in both circuits, ſparks being viſible on the ſmall chain in many places. On making the diſcharge of three jars, containing together ſixteen ſquare feet of coated ſurface, through three different chains at the ſame time, fig. 67, bright ſparks were viſible in them all. The chains were of iron and braſs, of very different lengths; the ſhorteſt ten or twelve inches, the longeſt many feet in length. When thoſe jars were diſcharged through the iron bar before-mentioned, together with a ſmall chain, three-quarters of a yard in length, the whole chain was illumined, and covered throughout with beautiful rays, like briſtles, or golden hair. Having placed a large jar in contact with the prime conductor, and affixed to the coating of it an iron chain, which was alſo connected with a plate of metal, on which was made the diſcharge by the diſcharging rod: this done he hooked another chain, much longer, and of braſs, to the oppoſite ſide of the jar, and brought the end of it within eight inches and an half of the metal plate. In contact with this end a ſmall oak ſtick was laid, eight inches long, which was covered with ſaw-duſt of fire-wood. On making the diſcharge upon the plate, both the chains were luminous through their whole lengths, as was alſo the ſaw-duſt, which was covered by a ſtreak of light, making a very pleaſing appearance.

At the glaſs-houſe there is generally a great number of ſolid ſticks of glaſs, about one quarter of an inch diameter; if theſe be examined narrowly, ſeveral of them will be found tubular a conſiderable length; the diameter of the cavity ſeldom exceeds the 200th part of an inch. Select and break off the tubular part, which may be filled with quickſilver by ſucking, care being taken that no moiſture previouſly inſinuates itſelf; the tube will then be prepared for the experiment.

EXPERIMENT CXLI.—Paſs the ſhock through this ſmall thread of quickſilver, which will be inſtantly

inſtantly diſploded, and will break or ſplit the tube in a curious manner.*

EXPERIMENT CXLII.—Take a glaſs tube, the bore of which is about one quarter of an inch, fill it with water, and ſtop the ends with cork, inſert two wires through the corks into the tube, ſo that their ends may nearly touch, make the ends of theſe part of a circuit from a battery; on the diſcharge, the water will be diſperſed in every direction, and the tube blown to pieces by the diſcharge.

The electric fluid, like common fire, converts the water into an highly elaſtic vapour. Dr. Franklin, on repeating this experiment with ink, could not find the leaſt ſtain upon the white paper, on which the tube had been placed. Beccaria paſſed the ſhock through a drop of water, which was ſupported, in the center of a ſolid glaſs ball, between the ends of two iron wires, and the ball was ſhivered in pieces by the exploſion. On this principle he contrived what he calls an electrical mortar, which will throw a ſmall leaden ball to the diſtance of twenty feet. It is clear, from ſeveral of the foregoing experiments, that the electric fluid endeavours to ex-

* Nicholſon's Introduction to Philoſophy, p. 413.

plode, in every direction, the parts of the resisting substances through which it passes.

EXPERIMENT CXLIII.—Place a building, which is formed of several loose pieces of wood, on a wet board in the middle of a large bason of water, let the electric flash from a battery be made to pass over the board, or over the water, or over both; the water will be strongly agitated, and the building thrown down. The report is louder than when the explosion passes only through the air. The electric fluid endeavours to pass near the surface of the water where it meets with more resistance, than if it is forced to pass through it. This partly arises from the power the electric fluid has of raising an expansive vapour from the surface of the water, which drives off the resisting air.

A discharge passed over the surface of a piece of ice will leave on it small unequal cavities, exhibiting the same appearance as if a hot chain had been placed on it.

A discharge sent through a green leaf tears the surface in various directions, leaving an image in miniature of some of the effects of lightning. A discharge will pass to a certain distance over spirit of wine, without inflaming it; but, if the distance is increased, it will set it on fire. From hence it appears, that the facility with which the electric fire is tranſmitted over the ſurface of moiſt ſubſtances, depends on the eaſe with which they are turned into vapours.

The diſcharge, in melting the particles of metals, drives into it's paſſage the conducting vapours which ariſe from them; and in proportion as the parts of any body are more readily driven into vapour or duſt, the ſpark will run to a greater diſtance.

EXPERIMENT CXLIV.—If a wire is ſtretched by weights, and a ſhock is ſent through it that will render it red hot, it is found to be conſiderably lengthened after the diſcharge. When the wire is looſe, it is ſaid to be ſhortened by the exploſion.

EXPERIMENT CXLV.—If a long narrow trough of water is made part of the circuit in the diſcharge of a battery, and a perſon's hand be immerged in the water at the time of the exploſion, he will feel an odd vibration in the water, very different from an electrical ſhock. The quick ſtroke from the repercuſſion of the air and the vapour, is communicated to the hand by the water, and the hand receives a ſhock ſimilar to that received by a ſhip at ſea during an earthquake.

EXPERIMENT CXLVI.—Place a plain piece of metal between the points of the univerſal diſcharger, paſs ſeveral exploſions of a battery through the wires, and the diſcharges will gradually form on the metal different circles, beautifully tinged with the priſmatic colours. The circles appear ſooner, and are cloſer to each other, the nearer the point is to the ſurface of the metal. The number of rings, or circles, depend on the ſharpneſs of the point; the experiment therefore ſucceeds better if a ſharp needle is faſtened to one of the points of the diſcharger.

Several very curious experiments were made by Dr. Watſon and others, to aſcertain the diſtance to which the electric ſhock might be conveyed, and the velocity with which it moves. In his firſt experiment, the ſhock was given and ſpirits fired by the electric matter, which had been conveyed through the river Thames. In the next experiment, the electric fluid was made to paſs through a circuit of two miles, croſſing the New-river twice, going over ſeveral gravel-pits, and a large field. It was afterwards conveyed through a circuit of four miles. It paſſed over these ſpaces inſtantaneouſly as to ſenſe. This ſenſible inſtantaneity in the motion of the electric fluid was aſcertained by an obſerver, who, though in the room with the charged phial, was, at the ſame time, in the middle of a circuit of two miles, and felt himſelf ſhocked at the ſame inſtant he ſaw the phial diſcharged.

Notwithſtanding this ſurpriſing velocity, it is certain, that both ſides of a charged phial may be touched ſo quickly, even by the beſt conductors, that all the electric matter has not time to make the circuit, and the phial will remain but half diſcharged; and there are ſeveral inſtances where the motion appears ſlow, and not eaſily reconcilable with this immeaſurable velocity; and it is alſo certain, that this fluid is reſiſted in it's paſſage through, or over, every ſubſtance.

The wonderful part of the foregoing experiments will vaniſh, if we admit the reaſoning of Mr. Volta on this ſubject; and the reader will find his reaſoning conſiderably ſtrengthened by experiments 120, 121, 122 of this Eſſay, which were originally made by Mr. Atwood; though it muſt be owned, theſe experiments ſeem to lead much further, and give an idea of the direction of the electric fluid in the diſcharge of the Leyden phial, which differs altogether from the received theory.

The

The following account is extracted from a very long paper of Mr. Volta, in the Journal de Physique for 1779:

Let us suppose that *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *k*, *l*, *m*, *n*, *o*, hold hands; let *a* grasp the outside of a charged Leyden phial, and *o* touch the knob; at the instant *o* receives the fire discharged from the inside by the knob, *a* will furnish from his natural stock to the outside, without waiting till the fire arrives to him from *o*, by *n*, to *m*, &c. in the mean while the loss of *a* is compensated from *b*, and *b* is furnished with fresh matter from *c*, and so on. It is still true, that there is but one stream, if we consider only the direction of the fluid, which is excited simultaneously at the two extremities, and moves at the same instant of time; though, to speak more accurately, it is not one stream, but two united in one. If the extreme rapidity with which the fire passes, did not prevent our perceiving the successive commotions received by the persons who form the chain, we should find they did not follow the order *o*, *n*, *m*, *l*, but were felt simultaneously, first at the two extremities *o* and *a*, then at *n* and *b*, *m* and *c*, &c. advancing towards the middle of the chain. Agreeable to this, if the bottle is small, the longer the circuit is made, those who are furthest from the extremities find the shock weaker.

To

To render this account more clear, ſeparate the circuit, and form on a dry floor two rows, *a*, *b*, *c*, *d*,—*e*, *f*, *g*, *h*, interrupted in the middle; let *e* graſp the bottle by the outſide, and *a* excite the diſcharge by touching the knob of the bottle; now, if the electric fire was obliged to take the ſhorteſt courſe to come to the exterior and negative ſurface, it ought to deſcend to the feet of *e*, paſs over the boards to the feet of *e*, and then through him to the outſide, without acting on *f*, *g*, *h*, which would be out of it's circuit. But, contrary to this, the fluid goes out of the direct courſe, to follow that of the conducting perſons, which afford it a proper receptacle, and comes to the outſide by another ſource. The fire which goes from the inſide from *e* to *f*, *g*, *h*, gives them a ſenſible ſenſation in their hands and their heels, ſhewing itſelf by a ſpark, if the hands and the feet are ſeparated a little from each other, and finiſhes by diſſipating itſelf in the common reſervoir. In the ſame manner *d*, who firſt gives the fire to the outſide, receives it ſucceſſively from *c*, *b*, *a*, who all draw it in from the floor. The ſtream therefore, which proceeds from the knob of the bottle, paſſing through the conducting ſubſtance, loſes itſelf in the general ſource; while, from the ſame ſource, a ſufficient

quantity

quantity is taken to ſupply the deficiency of the exterior ſurface.

If *f*, *g*, *h*, do not form a chain, but are irregularly placed round *e*, the poſitive part of the fluid may be ſeen to ſpread itſelf on different ſides, and divide itſelf in different branches to reach the floor. The fluid will in the ſame manner riſe from the floor to reach *d*, if *a*, *b*, and *c*, are irregularly placed round him; ſo that each ſurface excites it's own ſtream; one that enters the bottle, the other proceeding from it. Thus alſo, in the foregoing experiments of Dr. Watſon, where it has been ſuppoſed that the electric fluid has made ſuch amazing circuits through rivers, over fields, &c. the fluid from the inſide was diſperſed in the river, at the inſtant that the outſide collected, from the ſame ſource, ſupplies for it's own deficiency.

It appears alſo, from other experiments, that one ſide of a charged electric may contain more of one power than is ſufficient to ballance the contrary power on the other ſide. For, if a charged jar is inſulated, and the diſcharge is made by a diſcharger with a glaſs handle, after the exploſion, the diſcharger, and both ſides of the jar, will poſſeſs a contrary power to that obtained on the ſide of the jar, which was touched the laſt before the diſcharge.

CHAP.

CHAP. IX.

ON THE INFLUENCE OF POINTED CONDUCTORS FOR BUILDINGS.

THE importance of electricity, as well as it's universal agency, becomes more conspicuous, in proportion as our acquaintance with it increases. We find no substance in nature which is not acted on by it, either as a conductor or non-conductor; and discover, that the surprising phænomena of thunder and lightning owe their origin to, and are of the same nature with it. Very little progress had been made in electricity, when the analogy between the electric spark and lightning was discovered: but the sublime idea of realizing these conjectures, and proving that the fire which flashes in the sky, is the same agent which explodes and gives a shock in our experiments, was given to Dr. Franklin; who also first suggested the utility of pointed conductors of metal, to preserve buildings from the dreadful effects of lightning; an idea which was received with general applause and approbation. Since this period, many electricians have been induced to change their opinion relative to the utility of these conductors; and among those who underſtand the ſubject well, it has been diſputed, whether the preference ſhould be given to a conductor with a pointed end, or to one which has an obtuſe termination.

The experiments which have been made on this ſubject are very numerous; but the greater part appear to me very inconcluſive, and preſent only a very partial view of the ſubject. Among theſe we may reckon thoſe in which different ſubſtances have been introduced, to repreſent the action of conductors on clouds; ſince the various ſubſtances made uſe of in theſe experiments, were cohering maſſes, in which they differ eſſentially from the clouds which float in the air. It appears alſo, from many inſtances, that lightning does not paſs in one undivided tract, but that neighbouring bodies carry off their ſhare, according to their quantity and conducting power.

A pointed conductor, which communicates with the earth, has not any particular power of attracting electricity, and acts only as any other conducting ſubſtance, which does not reſiſt the paſſage of the electric fluid.

It is true, that electricity paſſes with more eaſe from an electrified body to a conductor which is pointed, than to one which is flat or globular; becauſe, in this caſe, the elaſticity of the

the electric fluid, and it's power to break through the air, are weakened by the flat surface, which acquires a contrary electricity, and compensates the diminished intensity more than a point can; the point being easily rendered negative, while the effort of the fluid to escape from the electrified body, is greater than when it is opposed by a flat surface. So that it is not the particular property of a point, or flat, but the different state of the electrified body, which causes it to part with it's electricity easier, and from a greater distance, when a pointed conducting substance is presented to it, than it does to a flat or globular conductor.*

The capacity of conductors to hold electricity, is in proportion to the surfaces which are free, or uninfluenced by a similar atmosphere; a circumstance which will, more or less, affect those conductors which are applied to buildings, according to the state of the clouds and their atmosphere, the time their influence has been exerted, the nature of the conducting strata of the earth, and it's electric situation.

Besides, the electric powers must be separated before any body can be electrified; and the point must be in a state to give one kind of electricity, before it can receive the other. They cannot act

* See Volta's Paper, Phil. Tran. vol. 72.

beyond the electric atmosphere of the body to which they are presented, and their action is differently modified by the state of the air.

Fig. 68 represents the gable end of a house, fixed vertically on the horizontal board F G; a square hole is made in the gable end at h i, into which a piece of wood is fitted; a wire is inserted in the diagonal of this little piece; two wires are also fitted to the gable end; the lower end of one wire terminating at the upper corner of the square hole; the top of the other wire is fixed to it's lower corner; the brass ball on the wire may be taken off, in order that the pointed end may be occasionally exposed to receive the explosion.

EXPERIMENT CXLVII.—Place a jar with it's knob in contact with the conductor, connect the bottom of the jar with the hook H, then charge the jar, and bring the ball under the conductor, and the jar will be discharged by an explosion from the conductor to the ball of the house. The wires and chain being all in connection, the fire will be conveyed to the outside of the jar, without affecting the house: but if the square piece of wood is placed so that the wires are not connected, but the communication cut off, the electric fluid, in passing to the outside of the bottle,

bottle, will throw out the little piece of wood to a confiderable diftance, by the lateral force of the explofion. See fig. 68.

Unfcrew the ball, and let the point which is underneath be prefented to the conductor, and then you will not be able to charge the jar; for the fharp point gradually draws the fire from the conductor, and conveys it to the coating on the outfide of the jar.

The prime conductor is fuppofed to reprefent a thunder cloud difcharging it's contents on a weather-cock, or any other metal, at the top of a building. From this experiment many have inferred, that if there is a connection of metal to conduct the electric fluid down to the earth, the building will receive no damage; but where the connection is imperfect, it will ftrike from one part to another, and thus endanger the whole building.

EXPERIMENT CXLVIII.—Mr. Henly affixed to the top of a glafs ftand a wire, three-eighths of an inch in diameter, terminated at one end by a ball, three-fourths of an inch in diameter, and at the other end by a very fharp point; (fee fig. 69.) round the middle of this wire hung a chain, twelve inches long; he connected the chain with the coating of a charged bottle, and brought the knob

knob of it very gently towards the ball on the insulated wire, in order to observe precisely, at what distance it would be discharged upon it, which constantly happened at the distance of half an inch, with a loud and full explosion. Then charging the bottle, he brought it in the same gradual manner towards the point of the insulated wire, to try also at what distance it would be struck; but this, in many trials, never happened at all; the point being approached in this gradual manner, always drew off the charge imperceptibly, leaving scarce a spark in the bottle.

EXPERIMENT CXLIX.—The same gentleman connected a jar, containing 509 square inches of coated surface, with the prime conductor; see fig. 68. If the jar was so charged as to raise the electrometer to 60°, by bringing the ball on the wire of the thunder house, to half an inch distance from that connected with the prime conductor, the jar would be discharged, and the piece in the thunder house thrown out to a considerable distance. Using a pointed wire as a conductor to the thunder house, instead of the knob, the charge being the same, the jar was discharged silently, though suddenly, and the piece was not thrown out.

EXPERIMENT

EXPERIMENT CL.—He afterwards made a double circuit to the thunder houfe; the firft by a knob, the fecond by a fharp pointed wire, at an inch and a quarter diftance from each other, but exactly the fame height. The charge being the fame, the knob was firft brought under the prime conductor, which was half an inch above it, and followed by the point at an inch and a quarter diftance, yet no explofion fell upon the ball, as the point drew off the charge filently, and the piece in the thunder houfe remained unmoved.

EXPERIMENT CLI.—He infulated a large jar, and connected, by chains, with the external coating, on one fide, a knob, on the other a fharp pointed wire, both being infulated, and ftanding five inches from each other, (fee fig. 70,) and placed an infulated copper ball, eight inches in diameter, fo as to ftand exactly at half an inch diftance both from the knob and the point; the jar was then charged, and the difcharge made by the difcharging rod on the copper ball, from whence it leaped to the knob A, which was three quarters of an inch in diameter, the jar was difcharged by a loud and full explofion, and the chain was very luminous.

EXPERIMENT CLII.—Mr. Henly fufpended by a filk ftring, from one end of a wooden bar, which turned freely in an horizontal direction upon the point of a needle, a large bullock's bladder, gilded with leaf copper; the bladder was balanced by a weight at the other end of the arm; (fee fig. 71;) he gave a ftrong fpark from the knob of a charged phial to the bladder; he then prefented towards it a brafs ball, two inches in diameter, and obferved that the bladder would come towards it at the diftance of three inches; and when it got within an inch, would throw off it's electricity in a full fpark. He then gave it another fpark, and prefented a pointed wire towards the bladder, which never approached to the point, nor ever gave any fpark, the electricity being carried off.

EXPERIMENT CLIII.—Take two or three fine locks of cotton, faften one of them to the conductor by a fine thread, another lock to that, and a third to the fecond, put the machine in action, and the locks of cotton will expand their filaments, and will extend themfelves towards the table. Prefent a fharp point under the loweft, and it will fhrink up towards the fecond, and this towards the firft, and all together towards the

the prime conductor, where they will continue as long as the point remains under them.

EXPERIMENT CLIV.—Faften a number of fine threads, or hair, to the end of the prime conductor; when the cylinder is turned, thefe will diverge like rays proceeding from a center: continue turning the cylinder, and prefent a point towards one fide of the conductor, and the threads on one fide will hang down, and lofe their divergence, but thofe on the other fide will ftill continue to diverge; which fhews, that the power of points to draw off electricity, does not extend round the electrified body, when means are ufed to keep up the fupply of electricity.

Fig. 72 reprefents an oval board, three feet long and two feet broad, coated on both fides with tin-foil, and fufpended by filk lines from a double hook; this turns on an axis, which is faftened to one arm of a nice ballance, and counterpoifed at the other arm by a weight; part of the table underneath the board is to be covered with tin-foil, and communicate to the floor by a chain.

EXPERIMENT CLV.—Connect the pendulous board with the prime conductor by a fmall wire, a few turns of the machine will electrify the apparatus. When this experiment was made, the board was attracted by the table at fifteen inches diſtance, and diſcharged itſelf with a ſtrong ſpark. The ſame happened to a metal ball which was placed on the table, the board approaching till it was about one inch from the ball, and then diſcharging itſelf by a ſpark. If a point is fixed on the board inſtead of a knob, the pendulous board, though it begins to approach, ſtops at about four or five inches from the table, and it will not approach nearer, or give a ſpark: a ſmall light is ſeen upon the point in the dark. A Leyden phial was then connected with the prime conductor; it now required more turns of the machine to charge the apparatus; the effect was the ſame as before. The counterpoiſe was now held, that the board might not diſcend till it had received a full charge: when ſet at liberty, it was not only attracted by, but alſo gave a loud exploſion on the point, inſomuch, that the tin-foil round it was ſtained by the overflowing of the fire.

The following experiment is extracted from "An Account of Experiments made at the Pantheon, on the Nature and Uſe of Conductors," by Mr. Wilſon. It was made in order to point out what he deemed erroneous in an experiment

of

of Mr. Henly, which is the 151ſt of this Eſſay.

The circuit of communication was divided into two parts.

A bent rod of braſs, with a ball of the ſame metal, three quarters of an inch in diameter, ſcrewed on to the upper extremity of it, and a copper ball, five inches in diameter, ſcrewed on to the lower end, forms one of the parts. This part was ſupported by a ſtand of wood that had a cap of braſs at the top, into which the braſs rod was occaſionally ſcrewed.

The other part of the circuit conſiſted of a braſs rod alſo; one end of which branched out in the form of a fork, with two prongs that pointed towards the center of the copper ball; and thoſe prongs were ſo conſtructed, that either of them could be made longer or ſhorter, juſt as the experiment required. On the end of one of the prongs was fixed a ball of braſs, three quarters of an inch in diameter, and on the other a ſharp ſteel point or needle. The ſhoulder of this fork ſcrewed into a ſmall plate of iron, that was fixed on the inſide of a wooden veſſel, which contained the greateſt part of a cylindrical glaſs jar, twelve inches three quarters high, and about four inches in diameter. This glaſs was rather thick than otherwiſe, and the coating of it (which was tin-foil) meaſured nearly 144 ſquare inches on each ſurface. Beſides this coating, part of the inſide of the wooden veſſel was coated alſo with tin-foil, for the purpoſe of making a ſecure communication between the iron plate and the outward coating of the jar. Within the jar itſelf was fitted a cylinder of wood, that was covered with tin-foil alſo, to make a communication between the inſide coating of the glaſs and a braſs rod, that was fixed upright in the center of the wooden cylinder. This upright rod having a ball of braſs at the end, three quarters of an inch in diameter, was bent towards the firſt part of the circuit; ſo that the two balls A and B, in fig. 73, being upon a level, looked towards each other, but were placed from time to time at different diſtances, as occaſion required; and thus anſwered the purpoſe of an electrometer.

Mr. Wilſon began the experiments where the electrometer was ſtruck at the greateſt diſtance, and then adjuſted the diſtances of the ball accordingly; ſo that if the point was ſtruck when they were adjuſted, the moving of the ball the thirty-ſecond part of an inch would occaſion the ball to be ſtruck in preference to the point, and *vice verſa*. Afterwards he leſſened the ſtriking diſtance of the electrometer, in every experiment, till he attained the leaſt diſtance.

Upon

Upon reverſing part of the apparatus, and fixing the ball to the bottle, and the fork to the ſtand, all thoſe experiments were repeated again; the copper ball being put neareſt to the glaſs, in the place of the forked part, and the forked part in the place of the copper ball. This ſet of experiments being completed, he made others, where the ball only was oppoſed; and after them, where the point only was oppoſed to the copper ball.

Having gone through all theſe experiments, as they are ſet down in the firſt table, he then repeated the experiment with the chain, after Mr. Henly's manner. The reſult of which, and with the apparatus reverſed, will appear in the ſecond table.

TABLE I.

EXPERIMENTS MADE AT DR. HIGGONS'S, JUNE 19, 1778, WITH THE LEYDEN PHIAL AND FORKED APPARATUS.

N. B. The meaſures expreſſed in the following tables were taken from a ſcale containing 32 parts in one inch.

The number oppoſite the word electrometer, denotes the diſtance between the balls which conſtitute the electrometer; and the numbers oppoſite to the words *ball* and *point*, ſhew the greateſt diſtance at which they were reſpectively ſtruck.

		Ball and Point oppoſite the Leyden Phial.	*Ball only.*	*Pt. only.*	*Apparatus reverſed.*	*B. only.*	*Pt. only.*
I.	Electrometer	32	32	32	32	32	32
	Ball — —	34	48	—	34	36	—
	Point — —	45	—	88	43	—	42
II.	E. — —	28	28	28	28	28	28
	B. — —	30	43	—	36	33	—
	P. — —	38	—	78	42	—	39
III.	E. — —	25	26	26	25	26	26
	B. — —	28	36	—	31	32	—
	P. — —	37	—	67	32	—	33
IV.	E. — —	20	20	20	20	20	20
	B. — —	28	29	—	29	25	—
	P. — —	51	—	64	28	—	24
V.	E. — —	16	16	16	16	16	16
	B. — —	22	20	—	22	23	—
	P. — —	44	—	47	24	—	26
VI.	E. — —	13	13	13	13	13	13
	B. — —	21	14	—	16	18	—
	P. — —	38	—	36	22	—	22
VII.	E. — —	10	10	10	10	10	10
	B. — —	12	10	—	13	12	—
	P. — —	18	—	25	20	—	20

TABLE II.

Experiments with the Chain, after Mr. Henly's Manner.

Point and Ball opposite the Leyden Phial.		*Apparatus reversed.*		
Electrometer —	21 —	— 23	repeated at different times.	23
Ball — —	26 —	— 28		26
Point — —	24 —	— 26		30

TABLE III.

The Experiments of the 2d and 3d Table, repeated at Mr. Partington's, June 23, 1778, a Brass Chain being made Use of instead of the Forked Apparatus.

	Ball and Point opposite the Leyden Phial.		*B. only.*	*P. only.*	*Apparatus reversed.*		*B. only.*	*P. only.*
I.	Electrometer	32	32	32	32 ——		32	32
	Ball — —	40	39	—	30 ——		29	—
	Point — —	76	—	71	38 ——		—	39
II.	E. — —	28	28	28	28 ——		28	28
	B. — —	33	36	—	29 ——		28	—
	P. — —	72	—	66	37 ——		—	38
III.	E. — —	25	26	26	25	repeated. 25	26	26
	B. — —	33	33	—	28	28	27	—
	P. — —	46	—	64	35	37	—	37
IV.	E. — —	20	20	20	20 ——		20	20
	B. — —	21	23	—	24 ——		24	—
	P. — —	50	—	60	26 ——		—	27
V.	E. — —	16	16	16	16	alternately.	16	16
	B. — —	21	15	—	19		19	—
	P. — —	55	—	53	21		—	24
VI.	E. — —	13	13	13	13 ——		13	13
	B. — —	16	11	—	14 ——		15	—
	P. — —	44	—	42	19 ——		—	22
VII.	E. — —	10	10	10	10	alternately.	10	10
	B. — —	11	9	—	11		12	—
	P. — —	38	—	37	19		—	19

Electrometer —	21	Apparatus reversed.	23
Ball — —	24		25
Point — —	64		30

EXPERIMENT

EXPERIMENT CLVI.— If an interruption is made in each of two ſimilar circuits, which form communications between the charged ſurfaces of an electric plate, and if the ſpace of air in one of the interruptions is terminated by points, and in the other by balls, the diſcharge will be made through the circuit of which the points make a part, although the length of the interrupted ſpace of air is conſiderably greater than that in the other circuit.

Before any diſcharge takes place, the two powers are ſuſpended on the oppoſite ſurfaces of the charged electric.

An electric plate may be diſcharged two ways, either ſilently in ſome ſenſible portion of time, or by exploſion in an inſtant: in either caſe experiments abundantly ſhew, that, *cæteris paribus*, the diſcharge will be made through a pointed body in preference to a round termination.

When a pointed body is preſented to any charged ſurface, a cylindrical plate of air, of evaneſcent diameter, is charged with the contrary electricities ſtrongly attracting each other through it; and the quantity of air being ſo ſmall, there will be little reſiſtance to their union; the diſcharge will be made by exploſion in preference to the gradual diſcharge, according as the oppoſite ſurfaces (the pointed body and the ſurface oppoſed to it) are larger, as they are nearer each other, and as the charge is greater; for it will be obſerved, that a point, or very ſmall ſpherical termination, which is in a phyſical ſenſe a point, will diſcharge any quantity of electricity ſilently and gradually without exploſion, while it is at a ſufficient diſtance from the oppoſite charged ſurface: by bringing it nearer, the method of diſcharge will be altered; which will now be a ſucceſſion of ſmall exploſions very quickly following each other. The reaſon of this ſeems to be, that when the charged ſurfaces are very near, there is not ſufficient time for the contrary powers to unite gradually, nor ſufficient room in which they may be diffuſed among the ſurrounding air.

This is confirmed by again removing the two oppoſed ſurfaces to ſuch a diſtance, that the diſcharge may be made gradually; in this caſe, if the parts of the apparatus are ſo diſpoſed, by any kind of contrivance, that the diſcharge muſt neceſſarily be made ſuddenly, the method of diſcharge will be again altered, becoming now a ſucceſſion of exploſions, inſtead of a gradual current between the oppoſed ſurfaces: this ſuddenneſs of the diſcharge may be effected by a proper uſe of interruptions in the circuit; it may alſo be cauſed by motion; if either ſurface be moved briſkly toward the other, the exploſion of the charge will be promoted.

Elevated conductors applied to buildings, as a ſecurity from the effects of lightning, will contribute to diſcharge the electricity from a cloud that paſſes over them: and a greater quantity of the diſcharge will paſs through a pointed conductor, than through one which is terminated by a ball; but whether the diſcharge will be made by a gradual current, or by exploſion, will depend on the ſuddenneſs of the diſcharge, on the proximity of the cloud, it's motion, and the quantity of the electricity contained in it. If a ſmall cloud hangs ſuſpended under a large cloud loaded with electric matter, pointed conductors on a building underneath will receive the diſcharge by exploſion, in preference to thoſe terminated by balls, the ſmall cloud forming an interruption, which allows only an inſtant of time for the diſcharge. If a ſingle electric cloud is driven with conſiderable velocity near to a pointed conductor, the charge may be cauſed to explode upon it by the motion of the charged body. In other caſes, pointed conductors contribute to diſcharge a thunder cloud gradually without exploſion.

Mr. Wilſon's experiments, publiſhed in the Philoſophical Tranſactions 1778, have contri-

buted

buted greatly to explain the effects of points in difcharging the electric matter.

If a conical pointed body were inferted into a fimilar hollow cone, formed into an electrified folid, the furfaces of the two cones being equi-diftant, no greater difcharge of the electrics would follow, than if the two conical furfaces had been plain, and oppofed to each other at the fame diftance.

EXPERIMENT CLVII.—If two electric plates be charged, and a communication formed between the pofitive fide of one, and the negative fide of the other, no difcharge will follow; unlefs a communication be formed between the other two furfaces at the fame time.

The natural electricity in the atmofphere is frequently difcharged in this manner: Two clouds being electrified with oppofite powers, the furfaces of the earth immediately under them are likewife electrified with powers contrary to thofe in the clouds above them; and the moifture of earth forming a communication between the two contiguous charged furfaces, whenever the two clouds meet, there will follow a difcharge, both of the clouds and furfaces on the earth op-pofed to them. If the earth fhould be dry, and confequently afford a refiftance to the union of the two electricities accumulated on or under it's surface, there will follow an explosion in the earth as well as in the atmosphere, which will produce concussions and other phænomena which have frequently been observed to happen in dry seasons, particularly in those climates which are the most liable to storms of thunder and lightning.

OBSERVATIONS ON THE ACTION OF CONDUCTORS.

" Ever since the discovery of the identity of electricity and lightning, it has been allowed by all parties, that conductors of some kind are in a manner necessary for the safety of buildings in those countries where thunder storms are very frequent. The principle on which they act is this; that the electric fluid, when impelled by any power, always goes to that place where it meets with the least resistance. Now, as metals are found to give the least resistance to it's passage, it will always choose to run along a metalline rod, in preference to a passage of any other kind. But it is necessary to observe here, that electricity never strikes a body merely for the sake of the body itself, but as by means of that body it can arrive at the place of it's destination. When a quantity of electricity is collected

collected from the earth, by means of an electric machine, a body communicating with the earth will receive a ſtrong ſpark from the prime conductor; it receives this ſpark, not becauſe it is capable of containing all the electricity of the cylinder and conductor, but becauſe the natural ſituation of the fluid being diſturbed by the motion of the machine, a ſtream of it is ſent off from the earth. The natural powers, therefore, make an effort to ſupply what is thus drained off from the earth; and as the individual quantity which comes out is moſt proper for ſupplying the deficiency, as not being employed for any natural purpoſe, there is always an effort made for returning it to the earth. No ſooner, then, is a conducting body, communicating with the earth, preſented to the prime conductor, than the whole effort of the electricity is directed againſt that body; not merely becauſe it is a conductor, but becauſe it leads to the place where the fluid is directed by the natural powers by which it is governed, and at which it would find other means to arrive, though that body were not to be preſented. That this is the caſe, we may eaſily ſee, by preſenting the ſame conducting ſubſtance in an inſulated ſtate to the prime conductor of the machine, when we ſhall find only a ſmall ſpark will be produced. In like manner,

manner, when lightning ſtrikes a tree, a houſe, or a thunder-rod, it is not becauſe theſe objects are high, or in the neigbourhood of the cloud, but becauſe they communicate with ſome place below the ſurface of the ground, againſt which the impetus of the lightning is directed, and at that place the lightning would certainly arrive, though none of the above-mentioned objects had been interpoſed.

" When the atmoſphere begins to be electrified, either negatively or poſitively, the earth, by means of the inequality and moiſture of it's ſurfa..., but eſpecially by the vegetables which grow upon it, abſorbs that electricity, and quickly becomes electrified in the ſame manner with the atmoſphere; this abſorption, however, ceaſes in a very ſhort time, becauſe it cannot be continued without ſetting in motion the whole of the electric matter contained in the earth itſelf. Alternate zones of poſitive and negative electricity will then begin to take place below the ſurface of the earth, for reaſons given in the courſe of this Eſſay. Between the atmoſphere and one of theſe zones the ſtroke of lightning will always be. Thus, ſuppoſing the atmoſphere is poſitively electrified, the ſurface of the earth will, by means of trees, &c. quickly become poſitively electrified alſo, we will ſuppoſe to the depth of ten

feet;

feet: the electricity cannot penetrate further, on account of the resistance of the electric matter in the bowels of the earth. At the depth of ten feet from the surface, a zone of negatively electrified earth begins, and to this zone the electricity of the atmosphere is attracted; but to this it cannot get, without breaking through the positively electrified zone, which lies uppermost, and shattering to pieces every bad conductor which lies in it's way. We are therefore sure, that in whatever place the outer zone of positively electrified earth is thinnest, there the lightning will strike, whether a conductor happens to be present or not. If there is a conductor, either with a knob or sharp pointed, the lightning will infallibly strike it: but it would also have struck a house situated on that spot without any conductor; and if the house had not been there, it would have struck the surface of the ground itself. Again, if we suppose the house with it's conductor to stand on a part of the earth where the positively electrified zone is very thick, the conductor will neither silently draw off the electricity, nor will the lightning strike it; though, perhaps, it may strike a much lower object, or even the surface of the ground itself at no great distance; the reason for which undoubtedly is, that

that there the poſitively electrified zone is thinner than where the conductor was.

"To ſuppoſe that a pointed conductor will exhauſt a thunder cloud of it's electricity, muſt at firſt ſight appear trifling, to inſiſt on it, ridiculous. Innumerable objects are all conſpiring to draw off the electricity as well as the conductor, if it could be drawn off; but of affecting this, there is an impoſſibility, becauſe they have the ſame kind of electricity with the clouds themſelves.

"Beſides, Beccaria has obſerved, that during the progreſs and increaſe of the ſtorm, though the lightning frequently ſtruck to the earth, yet the ſame cloud was the next moment ready to make a greater diſcharge, and his apparatus continued to be as much affected as ever.

"The conductor has not even the power of *attracting* the lightning a few feet out of the direction it would chooſe itſelf: of this we have a moſt deciſive inſtance in what happened to the magazine at Purfleet, in Eſſex. That houſe was furniſhed with a conductor, raiſed above the higheſt part of the building; nevertheleſs, a flaſh of lightning ſtruck an iron cramp in the corner of the wall of the building, conſiderably lower than the top of the conductor, and only forty-ſix feet in a ſloping line diſtant from the point.

"The conductor, with all it's power of *drawing off* the electric matter, was neither able to prevent the flash, nor to turn it forty-six feet out of it's way. The matter of fact is, the lightning was determined to enter the earth at the place where the Board-house stands, or near it; the conductor, fixed on the house, offered the easiest communication, but forty-six feet of air intervening between the point of the conductor and the place of the explosion, the resistance was less through the blunt cramp of iron, and a few bricks moistened with the rain to the side of the metalline conductor, than through the forty-six feet of air to it's point, for the former was the way in which the lightning actually passed.

"The zig-zag kind of lightning is the most dangerous, because it must overcome a very violent resistance of the atmosphere, and wherever that resistance is in the smallest degree lessened, there it will undoubtedly strike, and even at a considerable distance. It is otherwise with that kind that appears in flashes of no determinate form; the electric matter of which is evidently dissipated in the air by some conducting substances which are present there, and they are therefore rendered less powerful.

"The most destructive kind of lightning is that which assumes the form of balls. These are produced by an exceeding great power of electricity, gradually accumulated till the refiftance of the atmofphere is no longer able to confine it. In general, the lightning breaks out from the electrified cloud by means of the approach of fome conducting fubftance; but the fire-balls feem to be formed not becaufe there is any fubftance at hand to attract the electric matter from the cloud, but becaufe the electricity is accumulated in fuch a quantity that the cloud can no longer contain it. Hence, fuch balls fly off flowly, and have no particular deftination; their appearance indicates a prodigious commotion and accumulation of electricity in the atmofphere, without a proportionable difpofition in the earth to receive it. This difpofition is however altered by a thoufand circumftances, and the place which firft becomes moft capable of admitting electricity will firft receive a fire-ball. Hence this kind of lightning has been known to move flowly backwards and forwards in the air for a confiderable time, and then fuddenly fall in one or more houfes, according to their being more or lefs affected with an electricity oppofite to that of the ball at the time. It will alfo run along the ground, break into feveral parts, and produce feveral explofions at the fame time.

" It is very difficult to imitate this kind of lightning

lightning in our electrical experiments. The only cases in which it hath been done in any degree, are those in which Dr. Priestley made the explosion of a battery pass for a considerable way over the surface of raw flesh, water, &c. In these cases, if, while the electric flash passed over the surfaces of the flesh, it had been possible to interrupt the metallic circuit by taking away the chain, the electric matter discharged would have been precisely in the situation of one of the above-mentioned fire-balls; i. e. it would have been at a loss for a conductor. The negative side of the battery was the place of it's destination, but to that it could not easily have got, because of the great quantity of atmosphere which lay in it's way, and the incapacity of the neighbouring bodies to receive it. But, while the electric matter was thus stationary for want of a conductor, if any one standing near, or touching the negative side of the battery, presented a finger to this seemingly inoffensive luminous body, he would be instantly struck very violently, because a free communication being now made by means of his body, the powers by which the electric fluid is impelled from one place to another would urge it upon him. But if we suppose a person, who has no communication with the battery, to present his finger to the same body, he may perhaps receive a ſlight ſpark from it, but not a ſhock of any conſequence.

" We may now account for the ſeemingly capricious nature of all kinds of lightning, but eſpecially of that kind which appears in the form of balls. Sometimes it will ſtrike trees, high houſes, &c. without touching cottages, men, or animals, who are in the neighbourhood; in other inſtances, low houſes and cattle have been ſtruck, while high trees and ſteeples in the neighbourhood have eſcaped.* The reaſon of this is, that in thunder ſtorms there is a zone of earth conſiderably under the ſurface, which the lightning deſires to ſtrike, (if we may uſe the expreſſion) becauſe it has an electricity oppoſite to the lightning itſelf. Thoſe objects, therefore, which form the moſt perfect conductors between the electrified clouds and that zone of earth, will be ſtruck by lightning, whether they are high or low. Let us ſuppoſe a poſitively electrified cloud is formed over a certain part of the earth's ſurface; the electric matter flows out from it firſt into the atmoſphere all round, and

* Of this two remarkable inſtances have been adduced, in a paper read by Mr. Achard at the Berlin Academy of Sciences. And Beccaria cautions perſons from depending on a higher, or, in all caſes, a better conductor than their own body.

and while it is doing ſo, the atmoſphere is electrified negatively. In proportion, however, as the current pervades greater and greater portions of the atmoſpherical ſpace, the reſiſtance to it's motion increaſes, till at laſt the air becomes poſitively electrified as well as the cloud, and they both act as one body. The ſurface of the earth then begins to be electrified, and it ſilently receives the electric matter by means of the trees, graſs, &c. which grow upon it's ſurface, till at laſt it becomes alſo poſitively electrified, and begins to ſend off a current of electricity from the ſurface downwards.

"The cauſes which firſt produced the electricity ſtill continuing to act, the power of the electric current becomes inconceivably great. The danger of the thunder-ſtorm now begins; for, as the force of the lightning is directed to ſome place below the ſurface of the earth, it will certainly dart towards that place, and ſhatter every thing to pieces which reſiſts it's paſſage.

"The benefit of conducting rods will now alſo be evident. For we are ſure, the electric matter will, in all caſes, prefer that way where it meets with the leaſt reſiſtance, and this is over the ſurface of metals. In ſuch a caſe, therefore, if there happen to be a houſe furniſhed with a conductor

conductor directly below the cloud, and at the same time a zone of negatively electrified earth not very far below the foundation of the house, the conductor will almost certainly be struck, but the building will be safe. If the house wants a conductor, the lightning will nevertheless strike in the same place, in order to get at the electrified zone above-mentioned; but the building will be now damaged, because the materials of it cannot readily conduct the electric fluid."*

* See Encyclopædia Britannica, Art. Lightning, Vol. VI. p. 4224.

That the electric matter, which forms and animates the thunder-clouds, issues from places far below the surface of the earth, and buries itself there, is probable from the deep holes that have been made in many places by lightning, by the violent inundations that have accompanied thunder-storms, not occasioned by rain, but by water bursting from the bowels of the earth, from which it must have been dislodged by some internal concussion, &c.——See Dr. Priestley's History of Electricity, p. 328.

CHAP.

CHAP. X.

TO CHARGE A PLATE OF AIR.

AS air is an electric, it will receive a charge like all other electric ſubſtances. To this property may be aſcribed many of the phænomena which are obſerved in the courſe of the common electrical experiments; for the air which ſurrounds an electrified non-electric is always in ſome degree charged with the fluid, and thus acts upon the atmoſphere of the electrified conductor, not only by it's preſſure, but alſo by it's acquired electric powers; and that it pervades the air to a conſiderable diſtance, is evident from the different methods by which the air of a room may be electrified.

Cover two large boards with tin-foil; ſuſpend one by ſilk ſtrings from the ceiling, and then connect it with the conductor; place the other board parallel to the former, on an inſulating ſtand that may be eaſily raiſed or lowered, to regulate the diſtance of the plates from each other. Or place the boards in a vertical ſituation, on inſulating ſtands of the ſame height. In moſt caſes this form will be found the moſt convenient.

venient. Theſe boards may be conſidered as the coatings to the plate of air which is between them.

EXPERIMENT CLVIII.—Connect the upper board with the poſitive conductor, and the other with the ground; turn the cylinder, and the upper one will be electrified poſitively, and the under one negatively; the ſpace of air between the two plates acts as a plate of glaſs, it ſeparates and keeps aſunder the two electric powers. Touch the negative plate with one hand, and the upper one with the other, and a ſhock will be received ſimilar to that from the Leyden phial.

The electric ſhock will always be felt whenever a quantity of the fluid paſſes through any body in an inſtantaneous manner, and the force of the ſhock will be proportional to the quantity of electricity accumulated, and the eaſe with which it can eſcape; for the whole energy of the electricity depends on it's tenſion, or the force with which it endeavours to fly off from the electrified body.

The two plates, when in contrary ſtates, ſtrongly attract each other, and will come together, if they are not kept aſunder by force. A ſpark will ſometimes paſs between the plates, and

and deſtroy the electricity of each. If an eminence is placed on the under plate, the ſpark, in the ſpontaneous diſcharge, will ſtrike it. The experiments with theſe boards will be more pleaſing, if one ſurface of the upper board is covered with gilt leather. The two plates, when charged, are ſuppoſed to repreſent the ſtate of the earth and the clouds in a thunder ſtorm. The clouds being in one ſtate, and the earth in an oppoſite one, while the plate of air acts as the electric, and the ſpontaneous diſcharges exhibit the phænomena of lightning.

An obſervation has been made on this experiment, which ſeems to affect one of the principal ſupports of the received theory. I have ſubjoined it, in order to invite thoſe who are converſant with electricity to a cloſer inveſtigation of the ſubject.

In this experiment it ſeems impoſſible to deny, that air is penetrated by the electric fluid. The diſtance between the plates is ſo ſmall, that it muſt appear abſurd to ſay, that this ſpace is penetrated only by a repulſive power, when in other caſes we ſee the fluid pervading much greater ſpaces of air. But if one electric ſubſtance is penetrable by the electric fluid, we muſt be led ſtrongly to ſuſpect at leaſt that all the reſt are ſo too. If glaſs was altogether impenetrable to the fluid, it is natural to think that it would run over it's ſurface very eaſily. But inſtead of this, ſo great is it's propenſity to enter, that a ſhock ſent through between two glaſs plates, if they are preſſed pretty cloſe together, always breaks them to pieces, and even reduces part of them to a powder like ſand. This laſt effect cannot be attributed to any other than the electric fluid entering the pores of the glaſs, and meeting with reſiſtance, the impetus of it's progreſſive motion violently forces the vitreous particles aſunder in all directions.

EXPERIMENT CLIX.—Turn that ſide of the upper board, on which the gilt leather is paſted towards the lower one; place one or two ſmall metal hemiſpheres on the lower board; connect the upper board with the poſitive conductor, and the lower one with that which is negative, put the machine in action, and the upper board will diſcharge the whole of it's contents on one of the hemiſpheres in a ſtrong flaſh, attended with a ſmart exploſion; vivid coruſcations of electric light will be ſeen darting in various directions on the ſurface of the gilt leather. This experiment, ſays Mr. Becket, is more than a reſemblance of lightning, it is nature inveſted with her own attire.

Connect

Connect a coated phial with the positive conductor, so that it may be discharged with the boards, and the flashes of light will extend further, and the explosion will be louder.

EXPERIMENT CLX.—Place the wire, fig. 10, with the feathers tied to it in the middle of one of these large boards, their divergence will not be near so much in this situation, as when they are at the edge of the board. If a piece of down or a feather is placed near the edge of the board, it will fly off to the nearest non-electrified body; but, if it is placed in the middle, it will be a considerable time before it will move, and it will scarcely shew any signs of attraction.

EXPERIMENT CLXI.—Place bran, or small pieces of paper, near the center of the lower board; when the machine is put in action, these will be alternately attracted and repelled with great rapidity, and agitated in an amazing manner. A pleasing variation is made in this experiment by taking off the chain from the lower board, and now and then touching it with the hand; touch both boards at the same time, and the motion ceases. But the most surprizing appearance in this experiment is, that sometimes, when the electricity is strong, a quantity of paper or bran will accumulate in one place, and form a kind of column between the boards, it will ſuddenly acquire a ſwift horizontal motion, moving like a whirling pillar to the edge of the boards, and from thence fly off, and be ſcattered about the room to a conſiderable diſtance.

EXPERIMENT CLXII.—Take two phials, the one charged poſitively, the other negatively, place them on the inſulated board, but as far from each other as the board will permit; inſert a range of candles in a piece of wood, about two inches diſtance from each other, ſo that the flame of each may be exactly parallel; when theſe candles are quickly introduced between the knobs of the phials, the ſpark will be ſeen to dart through all of them, and will have the appearance of a line of fire, variegated in a thouſand different curves.

CHAP. XI.

OF THE ELECTROPHORUS.

FIG. 73 repreſents an electrophorus. This inſtrument was invented by Mr. Volta, of Coma in Italy.* It conſiſts of two plates of a circular form, the under plate is of braſs covered over with a ſtratum of an electrical ſubſtance, generally of ſome negative electric, as wax, ſulphur, &c. the upper plate is of braſs, with a glaſs handle ſcrewed on the center of it's upper ſurface.

Reſinous electrics generally ſucceed better for an electrophorus, than thoſe made only of glaſs, not only as they are leſs affected by the humidity of the air, but as they ſeem to have the power of retaining longer the electricity which is communicated to them.

To uſe this apparatus, firſt excite the under plate c, by rubbing it's coated ſide with a piece of clean dry flannel, or hare-ſkin; when this plate is well excited, it is to be laid on the table with

* Mr. Wilck, in Auguſt, 1762, contrived a reſinous apparatus, to which he gave the name of a perpetual electrophorus. See Scripta Academiæ Suec. 1762.

with the electric uppermoſt. Secondly, place the metal plate upon the electric, as in fig. 74 and 75. Thirdly, touch the metal plate with the finger, or any other conductor. Fourthly, ſeparate the metal plate from the electric by the glaſs handle. This plate, when raiſed to ſome diſtance from the under one, will be found ſtrongly electrified with the power which is contrary to that of the electric plate, and will give a ſpark to any conductor that is brought near it. By repeating this operation, i. e. by ſetting the metal plate on the electric, and then touching it with the finger, a great number of ſparks may be ſucceſſively obtained without a freſh excitation of the electric.

The following experiments, which were made with a view to analyſe this curious little inſtrument, are extracted from a paper of Mr. Achard's, in the Memoirs de l'Academie Royale de Berlin for 1776.

EXPERIMENT CLXIII.—Mr. Achard placed horizontally a circular plate of glaſs, which was about two tenths of an inch in thickneſs, and one foot in diameter, on a tin plate, which only touched the glaſs in a few places; having excited the upper ſurface of the glaſs, it produced all the effects of the electrophorus; from whence he he infers, that it is not neceſſary that the inferior metallic plate ſhould touch exactly in all it's ſurface the electric coating.

EXPERIMENT CLXIV.—He inſulated, in an horizontal poſition, a plate of glaſs of one foot diameter, he excited this, and then applied the upper plate in the uſual manner, and obtained a ſucceſſive number of weak ſparks; but in order to procure them, he was obliged to let the finger remain ſome time on the upper plate. If, inſtead of inſulating the plate of glaſs by glaſs, he inſulated it by wax or pitch, he conſtantly found that the ſparks were ſtronger. From this experiment he concludes, that the inferior plate is not neceſſary to the production of the effects obſerved in this inſtrument, and that when deprived of it, it retains all it's properties.

EXPERIMENT CLXV.—Having excited the upper ſurface of an electrophorus of wax, he placed the upper plate on it, and after ſome time lifted it off by it's inſulating handle, without previouſly touching it with the finger; it gave no ſpark, and was not poſſeſſed of the leaſt power of attraction and repulſion; which proves, that the electrophorus cannot render the upper plate electric, unleſs it is touched by a body which is capable of giving or taking electricity from it.

EXPERIMENT CLXVI.—Place the upper plate on an excited electrophorus, bringing a finger near the upper plate, and a ſpark will paſs between them. Now as the electric fluid never appears as a ſpark, except when it paſſes with rapidity from one body to another, and as the upper plate exhibits no electric appearance, if it has not been previouſly touched by a conductor, we may conclude, that the electrophorus only renders the upper plate electric when it has received or loſt a quantity of electricity.

EXPERIMENT CLXVII.—Place one of the ſmall braſs conductors with it's pith balls on the upper plate, and then put them both on the electrophorus, the balls will immediately ſeparate a little; touch the upper plate with the finger, and the divergence ceaſes; but on lifting this plate from the electrophorus by it's glaſs handle, the balls diverge with great force, forming a very large angle; on taking a ſpark from the plate they immediately cloſe. The ſeparation of the balls ſhews clearly, that the upper plate either abſorbs a quantity of electricity, or imparts a portion of it's natural ſhare to the under one; it it alſo ſhews, that the former, as ſoon as it is laid on the electrophorus, acquires a ſmall degree of electricity, which it loſes on being touched with the finger; but it again becomes electrical when it is ſeparated from the electrophorus.

EXPERIMENT CLXVIII.—Inſulate an electrophorus, and ſuſpend a pith ball by a linen thread, in ſuch a manner that it may be about one quarter of an inch from a piece of metal which is connected with the bottom plate; the ball does not move when the upper plate is laid on the electrophorus, but when this is touched by the finger the ball is attracted. As ſoon as the upper plate is taken off, the inferior metallic coating attracts the ball, but quits it if the coating is touched by the finger. It is alſo attracted if the upper plate is put on before the ſpark has been taken from it, though it laſts longer and is ſtronger if the ſpark is taken before it is placed on the electrophorus.

EXPERIMENT CLXIX.—Electrify the under ſide of the electrophorus, by connecting the under plate with the conductor of a machine; the upper plate will give ſtrong ſparks to the hand, or any other non-electric. Touch the upper plate with one hand, and the under one with the other, a ſhock will be received. The ſame effect is produced, if the upper plate is electrified by the machine. See fig. 74.

EXPERIMENT CLXX.—Inſulate an electrophorus which is not excited, and place the upper plate upon it, then electrify the under plate by a chain from the prime conductor; take a ſpark from the chain, and the electrophorus acquires all the properties which are given to it by exciting the upper ſurface.

EXPERIMENT CLXXI.—Connect the upper plate by a chain with the prime conductor, and electrify it; then take a ſpark from the chain, and the electrophorus will acquire, as before, the ſame powers which it gains when the upper ſurface is rubbed.

EXPERIMENT CLXXII.—The ſame effect is produced by placing a Leyden phial on the upper plate of an unexcited electrophorus, then charging and diſcharging it on the plate.

From the three laſt experiments we learn, that the electrophorus may be put in action by communication, as well as by friction.

EXPERIMENT CLXXIII.—Mr. Achard placed the upper plate on an excited electrophorus, and

a cube

a cube of metal, furniſhed with a glaſs handle, on this plate; on taking the cube by it's handle from the upper plate, without previouſly touching it, it attracted a light ball. On repeating this experiment, and touching the upper plate before the cube was taken off, it did not appear in the leaſt electrical.

EXPERIMENT CLXXIV.—By examining the electrophorus with ſmall pith balls, we find,

1. That as ſoon as the upper plate is placed on an electrophorus of wax, it acquires a weak poſitive electricity; and the contrary, if placed on an electrophorus of glaſs.

2. That when the upper plate is touched by the finger, it loſes all it's electricity.

3. When the upper plate is touched by the finger, and removed from the electrophorus, it acquires a ſtrong negative electricity, if the electrophorus is of glaſs; and a poſitive electricity, if it is of wax.

The electrophorus may be conſidered as formed of ſeveral horizontal ſtrata; ſo that when the upper one is excited, either by friction or communication, it is inſulated by the inferior ſtrata. Now all inſulated electrics preſerve their electricity a conſiderable time, and it is from that caufe that the electricity of the electrophorus continues fo long.

Infulated and excited glafs induces the negative electricity on bodies brought within the fphere of it's action, while negative electrics, in fimilar circumftances, produce the pofitive electricity. Therefore the furface of the electrophorus ought to communicate immediately a pofitive electricity, if it is of wax; the negative, if it is made of glafs; which is perfectly conformable to experiments. But when the upper plate is touched by the finger, the upper furface of the electrophorus ceafes to be infulated, and gives the negative electricity to the upper plate, if it is of glafs, and the contrary, if of wax, agreeable to the different experiments which are defcribed in Chap. IV.

Electric bodies do not put the fluid in that degree of motion, which is neceffary to produce the fpark, or exhibit the phænomena of attraction and repulfion, while they are in contact with conducting fubftances, which is the reafon why the upper plate exhibits no figns of electricity while it remains in contact with the under one, though they become fenfible the inftant it is removed from it.

As the theory of this inftrument has been deemed

deemed very intricate, I have ſubjoined another explanation of it, which is given by the editors of the Monthly Review.

"Therefore, (in the caſe of a glaſs electrophorus) as it is a caſe which admits of a ſomewhat eaſier illuſtration, the excited plate acts upon the electric matter naturally contained in the upper braſs plate, ſo as to repel a part of it's natural quantity from it in form of a ſpark, at that part where the finger is applied to it. If the braſs plate in this ſtate is lifted up by it's handle, it will receive a ſpark from the finger. On being replaced, and the ſame operation taking place, the ſame reſult will be obtained; which may be continued for a great length of time, without diminiſhing the virtue of the excited electric, which in fact does not part with any of it's own electricity, but only repels a part of what is in the upper plate, which is repeatedly reſtored to it from the earth by the perſon who makes the experiment."

EXPERIMENT CLXXV.—Place a piece of metal on an excited electrophorus, it may be of any ſhape; a pair of triangular compaſſes are very convenient for this purpoſe. Electrify the piece of metal with the power which is contrary to that of the electrophorus, and then remove it by means

of

of ſome electric, and afterwards ſift upon the electrophorus ſome finely powdered reſin, which will form on it's ſurface curious radiated figures. When the plate is negative, and the piece of metal poſitive, the powder forms itſelf principally about thoſe parts where the metal was placed; but if the plate is poſitive, and the ſpark is negative, the part where the metal touched will be free from powder, and the other parts more covered.

EXPERIMENT CLXXVI.—To recover the force of an electrophorus by itſelf. Place the metallic cover on the reſinous cake, touch it as uſual; then take it up, and diſcharge it on the knob of a Leyden phial; repeat this operation ſeveral times, and then place the bottle on the cake, and move it over it's ſurface, holding the bottle by the knob; this will augment the force of the electrophorus, and by reiterating the operation it will become very powerful.

EXPERIMENT CLXXVII.—Inſulate a metal quart mug, and ſuſpend a pair of ſmall pith balls by ſilk, ſo that the whole of the electrometer may be within the mug, electrify the mug, and the electrometer will not be in the leaſt affected. The ſimilar atmoſpheres counteract each other; and

as

as no contrary power can take place in the electrometer, it will remain unelectrified. Touch the mug with ſome conducting ſubſtance, and it will immediately attract the balls.

EXPERIMENT CLXXVIII.—Suſpend a ſmall cylinder of gilt paper by tin-foil, and then touch the electrified and inſulated mug with it, a ſpark will paſs between them, and the electricity will be diffuſed in each in proportion to their capacity. Now plunge the inſulated cylinder to the bottom of the mug, and it will reſtore to it the electricity it had received, but does not give the leaſt ſign of electricity when taken out.

EXPERIMENT CLXXIX.—Connect a pair of pith balls with an inſulated metal veſſel, in which a metal chain is placed, raiſe the chain by means of a ſilk thread, and the divergence of the balls will diminiſh in proportion as the chain is raiſed and diſplayed; ſhewing, that the electricity is rarified, and it's denſity is diminiſhed, in proportion as it ſpreads itſelf from the ſurface of the veſſel on the extended chain; which is confirmed by the balls diverging again when the chain is let down into the veſſel. This experiment affords an eaſy ſolution for many of the phænomena of atmoſpheric electricity, as why the vapour of electrified water gives ſuch ſmall ſigns of electricity, and why the electricity of a cloud is increafed by being compreffed or condenfed.

EXPERIMENT CLXXX.—Excite a flip of white flannel, or a filk ribbon, and take as many fparks from it as it will give; then double or roll it up, and the contracted flannel will be ftrongly electrical, give fparks, and throw out brufhes of light.

OF THE ADVANTAGES WHICH MAY BE DERIVED FROM AN IMPERFECT INSULATION, AND OF RENDERING VERY SENSIBLE VERY SMALL DEGREES OF NATURAL AND ARTIFICIAL ELECTRICITY, BY MR. VOLTA.

A conductor, properly conftructed for making obfervations on atmofpherical electricity, will feldom affect the moft fenfible electrometer when the fky is free from electrical clouds; but by means of the apparatus now to be defcribed, it will appear, that thefe conductors are always electrical, and confequently the air which furrounds them muft be at all times electrified. This method not only determines the exiftence, but alfo the quality of the electricity, whether pofitive or negative, and that, even when the conductor will not attract the fineft thread; but if if a very ſmall attraction is viſible in the conductor, then the apparatus will give long ſparks.

The electrophorus uſed for this purpoſe may with propriety be termed a micro-electrometer, or condenſer of electricity.

Whenever the atmoſpherical conductor gives ſufficient ſigns of electricity, then the condenſing apparatus becomes uſeleſs. For when the electricity is ſtrong, it often happens that part of the electricity of the metal plate is impreſſed upon the other, in which caſe the apparatus acts as an electrophorus, and becomes unfit for our purpoſe.

The apparatus adapted for this purpoſe conſiſts of the upper plate of an electrophorus, and a ſemi-electric, or an imperfect conducting plane, which will only hinder in a certain degree the paſſage of the fluid. Many conductors of this kind may be formed; ſuch as a clean dry marble ſlab, a plate of wood, covered with a coat of varniſh, &c. the ſurface of thoſe bodies not contracting electricity, or if any ſhould adhere to them, it ſoon vaniſhes, on account of their ſemi-conducting nature; for which reaſon they cannot anſwer the end of an electrophorus, but are fit to be uſed as condenſers of electricity.

Care ſhould be taken however in chooſing this plane, that it be not of too free a conducting nature, nor likely to become ſo by uſe, it being abſolutely neceſſary that the electricity ſhould find a conſiderable reſiſtance in pervading it's ſurface. In preparing ſuch a plane, by drying, or otherwiſe, it is much better to come too near than too far from a non-conductor. A marble ſlab or board, properly dried, anſwers well, and is preferable to any other plane; otherwiſe the plate of the electrophorus is preferable to all bodies unprepared.

The worſt ſort of marble, if coated with copal, amber, or lac-varniſh, and then kept in an oven for a ſhort time, will anſwer very well, even without previouſly warming for the experiment.

This, in fact, it may be ſaid, is returning to the electrophorus: as marble, wood, &c. varniſhed, if they are hot, may be excited by a very ſlight friction, and ſometimes by only laying the metal plate on them; to prevent which, they ſhould be uſed without warming.

The advantages plates of this kind have over the common electrophorus are, 1. That the varniſh is always thinner than the common reſinous ſtratum of an electrophorus; and 2. That the varniſh acquires a ſmoother and plainer ſurface: hence the metal plate can with more advantage be adapted to it.

Any ſort of plane, covered with dry and clean oil-cloth, or oiled-ſilk, or ſattin, and any other

ſilk

ſilk ſtuff that is not very thick, may be uſed with equal advantage, if it is ſlightly warmed. Silk ſtuffs anſwer better for this purpoſe than thoſe made of cotton or wool, and both better than linen. Paper, leather, wood, ivory, bone, and every other ſort of imperfect conductors, may be made to anſwer to a certain degree, if they are previouſly dried, and kept hot during the experiment.

This apparatus is rendered more ſimple by applying the ſilk, &c. to the upper plate of metal, which is fixed to the glaſs handle, inſtead of the marble or other plate, which now becomes uſeleſs; for in it's ſtead, a plane of any kind may be uſed, as a common wooden or marble table, even not very dry; a piece of metal, a book, or any other conductor with a flat ſurface.

Nothing more is requiſite in theſe experiments, than that the electricity, which tends to paſs from one ſurface to the other, ſhould meet with ſome reſiſtance or oppoſition in one of the ſurfaces, as will be evident in the ſecond part.

It is immaterial whether the non-conducting or ſemi-conducting ſtratum be laid upon one or the other of thoſe planes; all that is neceſſary is, that they ſhould coincide together, which renders it proper to uſe two planes that have been ground together, and one of them varniſhed. A ſingle metal plate, covered with ſilk, with three ſilk ſtrings faſtened to it by way of handle, may be conveniently uſed for ordinary experiments.

To uſe the apparatus, the upper metal plate muſt be placed upon the unelectrified plate and in perfect contact with it.

The plates being thus placed, let a wire, communicating with the conductor, be brought to touch the metal plate of the electrophorus, and that only.

The apparatus being left in that ſituation a certain time, will acquire a ſufficient quantity of electricity, but very ſlowly.

Remove the communicating wire from the metal plate, and, by means of it's inſulated handle, ſeparate it from the under one; it will now attract a thread, electrify an electrometer, and, if it is ſtrong, will give ſparks, &c. though the atmoſpherical conductor ſhewed no, or only ſmall, ſigns of it.

It is not eaſy to determine the exact time neceſſary for this apparatus to remain in contact with the conductor, as it will depend on many circumſtances; for, if there are no ſigns of electricity in the conductor, it will require eight or ten minutes, but if it attracts a fine thread, as many ſeconds will be found ſufficient.

It is difficult alſo to determine the preciſe degree to which the electricity may be condenſed, or how much the electrical phænomena may be increaſed by this apparatus, as it depends on various circumſtances. The augmentation is, however, greater in proportion as the body which ſupplies the metal plate has a greater capacity, and is larger in proportion as the electricity is weaker. Thus, though the atmoſpherical conductor has ſcarcely power ſufficient to attract a fine thread, it is nevertheleſs capable of giving ſuch a quantity of electricity to the metal plate of the electrophorus, as not only to actuate an electrometer, but even dart ſtrong ſparks. But if the electricity of the atmoſpherical conductor is ſtrong enough to afford ſparks, or to raiſe the index of the electrometer to 5 or 6 degrees, then the receiving plate of the electrophorus, according to this method, will raiſe it's index to the higheſt degree and give a ſtronger ſpark; yet it may be plainly perceived, that the condenſation is proportionably leſs in this than in the other caſe; for this reaſon the electricity cannot be accumulated beyond the greateſt degree; that is to ſay, when it is increaſed ſo much as to be diſſipated every way: Therefore, as the electric power, which ſupplies the condenſer, is neareſt to the higheſt degree, the condenſation is proportionably leſs; but in this caſe the condenſer is uſeleſs; it's

principal

principal ufe being to collect and render fenfible that fmall quantity of electricity, which would otherwife remain imperceptible and unobferved.

Hitherto we have adapted our condenfer to the detecting weak atmofpherical electricity, as brought down by the conductor; but this, though the principal, is not the only ufe to which it may be applied. It will likewife difcover artificial electricity, when it is fo weak as not to be difcoverable by any other means.

A Leyden phial charged, and then difcharged by touching it's coated fides with the difcharging rod or the hand, appears to be quite deprived of it's electricity; yet if you touch the knob of it with the metal plate of the condenfer, (fituated upon an imperfect conducting plane) and immediately take up the plate, it will be found to give very confpicuous figns of electricity. But if juft fufficient charge is left in the phial to attract a fine thread, and the metal plate is then brought to touch the knob for a moment, it will, when lifted up, give a ftrong fpark, and if touched again, a fecond fcarce fmaller than the former; and thus fpark after fpark may be obtained for a long time.

This method of producing fparks, by means of a phial which is not charged fo high as to give fparks of itfelf, is very convenient for vari-

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ous pleasing experiments; as to fire or light the inflammable air-pistol, or lamp; especially when a person is provided with one of those phials contrived by Mr. Cavallo, which, when charged, may be carried in the pocket a long time. These phials, as they retain a sensible charge for several days, will retain an insensible one for weeks and months; or, such a one as cannot easily be discovered without the condenser, in which case it becomes more than sensible, and sufficient for the experiments of the inflammable air-pistol, &c.

Secondly. If you have an electrical machine so far out of order that it's conductor will not give a spark, nor attract a thread, then let this conductor touch the metal plate of the condenser, and continue in that situation a few minutes, (the machine being still in motion) lift up the metal plate, and you will obtain from it a strong spark.

Thirdly. If the electrical machine acts well, but the conductor is so badly insulated that it will not give a spark, either from it's being connected with the walls of the room, or by having a chain from it to the table, let the conductor in this state touch the metal plate of the condenser, while the machine is in action, the plate will afterwards give sufficient strong signs of electricity; which proves the great power this apparatus has of drawing and condensing the electricity.

Fourthly.

Fourthly. Where the electrometers are not sufficiently sensible to discover the quantities of excited electricity, those quantities may be readily explored by the condenser. For this purpose, rub those bodies with the metal plate of the condenser, which for this purpose must be naked, and if the plate be then presented to an electrometer, it will be found considerably electrified, although the body rubbed may have acquired little or no electricity. The quality, whether positive or negative, may easily be ascertained, since the electricity of the metal plate must be the contrary of that body on which it was rubbed. Mr. Cavallo made use of this method to discover the electricity of many bodies. But still a better method may be used, in case the bodies to be examined cannot easily be adapted to the metal plate, viz. The metal plate being laid on the imperfect conducting plane, the body to be tried is rubbest against, or repeatedly stroaked upon it, which done, the plate is taken up and examined by an electrometer. If the body tried is leather, a string, cloth, velvet, or other imperfect conductor of the like sort, the plate will certainly be found electrified, and incomparably more by this means than if it were stroaked by the same bodies, whilst standing insulated in the air. In short, by either of those methods you will obtain electricity from

from bodies which could hardly be expected to give any, even when they are not very dry. Indeed, coals and metals excepted, every other body will afford ſome electricity. Electricity may often be obtained by ſtroaking the plate with the naked hand.

The metal plate has a much greater power to retain electricity when it lies upon a proper plane, as mentioned in the foregoing experiments, than when quite inſulated.

It is eaſy to comprehend, that where the capacity of holding electricity is greateſt, there the intenſity of the electricity is proportionably leſs, for it will then require a greater quantity to raiſe it to a given degree of intenſity; ſo that the *capacity* is inverſely as the *intenſity*; by which we mean, that endeavour, by which the electricity of an electrified body tends to eſcape from all parts of it; to which tendency or endeavour, the electrical phænomena of attraction and repulſion, and eſpecially the degree of elevation of an electrometer, correſpond.

That the *intenſity* of electricity muſt be inverſely proportioned to the *capacity* of the body electrified, will be clearly exemplified by the following experiment.

EXPERIMENT CLXXXI.—Take two metal rods of equal diameter, the one a foot, the other five feet long; let the firſt be electrified till the index of the electrometer riſes to 60°, then let it touch the other rod; and in that caſe it is evident, that the intenſity of the electricity being diffuſed between the two rods, will be diminiſhed as the capacity is increaſed; ſo that the index of the electrometer, which before was elevated to 60°, will now fall to 10°, viz. to one ſixth of the former intenſity. For the ſame reaſon, if the like quantity of electricity was communicated to a rod 60 feet long, it's intenſity would be diminiſhed to one degree; and on the contrary, if the electricity of the long conductor was contracted into the 60th part of that capacity, it's intenſity would be increaſed to 60.

Conductors of different bulk have not only different capacities for holding electricity, but alſo the capacity of the ſame conductor is increaſed and diminiſhed in proportion as it's ſurface is enlarged and contracted; as is ſhewn in Dr. Franklin's experiment of the can and chain, &c. from which it has been concluded, that the capacity of conductors is in proportion to their ſurface, and not to their quantity of matter.

This concluſion is true, but does not comprehend the whole theory, ſince even the extenſion

ſion contributes to increaſe the capacity. In ſhort, it appears from all the experiments hitherto made, that the capacity of conductors is not in proportion to the ſurfaces in general, but to the ſurfaces which are free, or uninfluenced by ſimilar or homologous atmoſpheres; and further, that the capacity of a conductor, neither altered in it's form or ſurface, is increaſed, when, inſtead of remaining quite inſulated, it is preſented to another not inſulated; and this increaſe is more conſpicuous, as the ſurfaces of the conductors are larger, and approach nearer to each other.

The above-mentioned circumſtances, by which the natural capacity of conductors is greatly augmented, has been overlooked, and therefore no advantage has hitherto been deduced from it. The following experiment will ſhew this increaſed capacity in the ſimpleſt manner.

EXPERIMENT CLXXXII.—Take the metal plate of an electrophorus, hold it by it's handle in the air, and electrify it ſo, that the index of an electrometer annexed to it may be elevated to 60°, then lower the plate by degrees to a table, or other plain conducting ſurface, the index will gradually fall from 60°, to 50°, 40°, 30°, &c. and yet the quantity of electricity in the plate remains the ſame, except it is brought ſo near the table as to occaſion a tranſmiſſion of the electricity from the former to the latter; at leaſt, it will remain as near the ſame, as the dampneſs of the air, &c. will permit. The decreaſe of intenſity is owing to the increaſed capacity of the plate, which is now not inſulated, or *ſolitary*, but *conjugate*, or communicating with another conductor: for let the plate be gradually removed from the table, the electrometer will riſe again to it's former ſtation, namely, to 60°; excepting the loſs that the air, &c. may have occaſioned during the experiment.

The reaſon of this phænomenon is eaſily derived from the action of electric atmoſpheres. The atmoſphere of the metal plate, which for the preſent I ſhall ſuppoſe electrified poſitively, acts upon the table, or other conductor, to which it is preſented; ſo that the electric fluid in the table retiring to the remoter parts of it, becomes more rare in thoſe parts which are expoſed to the metal plate, and this rarefaction increaſes the nearer the electrified metal is brought to the table; if the metal plate is electrified negatively, the contrary effects take place. In ſhort, the parts which are immerſed in the ſphere of action of the electrified plate, by contracting a contrary electricity, give the electricity of the metal plate an opportunity to expand itſelf, and will thus diminiſh it's inten-

ſity,

ſity, as is ſhewn by the depreſſion of the electrometer.

The two following experiments will throw more light upon the reciprocal action of the electric atmoſpheres.

EXPERIMENT CLXXXIII.—Electrify two flat conductors, either both poſitively or negatively, then bring them gradually towards each other, and it will appear, by two annexed electrometers, that the nearer they approach each other, the more their denſities will increaſe, as all elaſtic bodies re-act in proportion as they are acted on; which ſhews, that either of the two *conjugate* powers has a much leſs capacity to receive more fluid now, than when ſingly inſulated, and out of the influence of the other. This experiment explains, why the tenſion of the electric atmoſphere on an electrified conductor is greater when it is contracted into a ſmaller bulk; and alſo, why a long extended conductor will ſhew leſs intenſity than a more compact one, ſuppoſing their quantity of ſurface and electricity to be the ſame; becauſe the homologous atmoſpheres of their parts interfere leſs with each other in the former than in the latter caſe, and of courſe, as their action is leſs, the re-action is alſo leſs.

EXPERIMENT

EXPERIMENT CLXXXIV.—Electrify one of these flat conductors positively, the other negatively, and the effects will then be just the reverse of the preceding, viz. the intensity of their electricities will be diminished, because their capacities, or their power and facility of expanding, are increased the nearer the conductors come to each other.

Apply the explanation of this last experiment to that mentioned before, viz. the bringing the electrified metal plate towards a conducting plane, which is not insulated; for, as this plane acquires a contrary electricity, it follows, that the intensity of electricity in the metal plate must be diminished, and the annexed electrometer is depressed according as the capacity of the plate is increased, or as the density of it's atmosphere is diminished; and consequently the plate in that situation is capable of receiving a greater quantity of electricity.

This will be rendered still clearer by the following experiment.

EXPERIMENT CLXXXV.—Insulate the conducting plane whilst the other electrified plate is upon it, and afterwards separating them, both the metal plate and conducting plane, which may be called the inferior plane, will be found electrified,

fied, but poffeffed of contrary electricities, as may be afcertained by electrometers.

If the inferior plane is infulated firft, and then the electrified plate is brought over it, then the latter will caufe an endeavour in the former to acquire a contrary electricity, which the infulation prevents from taking place; hence the intenfity of the electricity of the plate is not diminifhed, at leaft the electrometer will fhew a very little, and almoft imperceptible depreffion, which fmall depreffion is owing to the imperfection of the infulation of the inferior plane, and to the fmall rarefaction and condenfation of the electric fluid, which may take place in different parts of the faid inferior plane. But if, in this fituation, the inferior plane be touched fo as to cut off the infulation for a moment, then it will acquire the contrary electricity, and the intenfity in the metal plate will be diminifhed.

If the inferior plate, inftead of being infulated, were itfelf a non-conducting fubftance, then the fame phænomena would happen, viz. the intenfity of the electrified metal plate laid upon it would not be diminifhed. This, however, is not always the cafe, for if the faid inferior non-conducting plane is very thin, and is laid upon a conductor, then the intenfity of the electrified metal plate will be diminifhed, and

it's

it's capacity will be increafed by being laid upon the thin infulating ftratum : as in that cafe, the conducting fubftance, which ftands under the non-conducting ftratum, acquiring an electricity contrary to that of the metal plate, will diminifh it's intenfity, &c. and then the infulating ftratum will only diminifh the mutual action of the two atmofpheres more or lefs, according as it keeps them at greater or fmaller diftances from each other.

The intenfity or electric action of the metal plate, which diminifhes gradually as it is brought nearer and nearer to a conducting plane not infulated, becomes almoft nothing when the plate is nearly in contact with the plane, the compenfation or natural ballance being nearly perfect. Hence, if the inferior plane only oppofes a fmall refiftance to the paffage of the electricity, (whether fuch refiftance is occafioned by a thin electric ftratum, or by the plane's imperfect conducting nature, as is the cafe with dry wood, marble, &c.) that refiftance, joined to the interval, however fmall, that is between the two plates, cannot be overcome by the weak intenfity of the electricity of the metal plate, which on that account will not dart any fpark to the inferior plane, (except it's electricity were very powerful, or it's edges not well rounded) and will rather retain it's electricity; so that being removed from the inferior plane, it's electrometer will nearly recover it's former height. Besides, the electrified plate may even come to touch the imperfectly conducting plane, and may remain in that situation for some time; in which case, the intensity being reduced almost to nothing, the electricity will accordingly pass but slowly to the inferior plane. But the case is different, if, in performing this experiment, the electrified metal plate touches the inferior plane edgewise, for then it's intensity being greater than when it is laid flat, as appears by the electrometer, the electricity easily overcomes the small resistances, and passes to the inferior plane, even across a thin stratum, because the electricity of one plane is ballanced by that of the other, only in proportion to the quantity of surface which they oppose to each other within a given distance; so that when the metal plate touches the other plane in flat and ample contact, it's electricity is not dissipated. This apparent paradox is clearly explained by the theory of electric atmospheres.

It is still more like a paradox, that neither touching the metal plate with a finger or piece of metal will deprive it of all it's electricity, while standing upon the proper plane; so that it generally leaves it so far electrified, that when ſeparated from the plane, it will give a ſpark. Indeed this phænomenon could not be explained on the ſuppoſition, that the finger or metal were perfect conductors. But, ſince we do not know of any perfect conductor, the metal or finger oppoſe a ſufficient reſiſtance to retard the immediate diſſipation of the electricity of the plate, which is in that caſe actuated by a very ſmall degree of intenſity, or power of expanſion; ſo that, ſuppoſe for inſtance, the piece of metal or finger touching the plate took off ſo much of it's electricity as to reduce the intenſity of the remainder to the 50th part of a degree, this remaining electricity would be then nothing; but when the plate, by being ſeparated from the inferior plane, has it's capacity ſo far diminiſhed as to render the intenſity of it's electricity 100 times greater, then the intenſity of that remaining electricity would become of two degrees or more, viz. ſufficient to afford a ſpark.

Having conſidered in what manner the action of electric atmoſpheres modifies the electricity of the metal plate in it's various ſituations, we ſhall now conſider the effects which take place when the electricity is communicated to the metal plate, whilſt ſtanding upon a metal plane. As the whole buſineſs has been proved in the preceding pages, it is eaſy to deduce the appli-

cations

cations from it: neverthelefs, it will be ufeful to exemplify it by an experiment.

EXPERIMENT CLXXXVI.—Suppofe a Leyden phial or a conductor, fo weakly electrified that it's intenfity is one half a degree, or even lefs; if the metal plate of the condenfer, when ftanding upon it's proper plane, was to be touched with that phial or conductor, it is evident, that either of them would impart to it a quantity of it's electricity, proportional to the plate's capacity, viz. fo much as fhould make the intenfity of the electricity of the plate equal to that of the electricity in the conductor or phial, viz. half a degree; but the plate's capacity, now it lies upon a proper plane, is above 100 times greater than if it ftood infulated in the air, or which is the fame thing, it acquires 100 times more electricity from the phial or conductor. It naturally follows, that when the metal plate is removed from the proper plane, it's capacity being leffened fo as to remain equal to the 100th part of what it was before, the intenfity of it's electricity muft become 50°, fince the intenfity of the electricity in the phial or conductor was half a degree.

If a fmall quantity of electricity, applied to the metal plate of the condenfer, enables it to give a ſtrong ſpark, it may be aſked, What would a greater quantity do? Why nothing more. Becauſe, when the electricity communicated to the metal plate is ſo ſtrong as to overcome the ſmall reſiſtance of the inferior plane, it will be diſſipated.

It is eaſy to underſtand, that if the metal plate of the condenſer can receive a good ſhare of electricity from a Leyden phial or ample conductor, however weakly electrified, it cannot receive any conſiderable quantity of it from a conductor of ſmall capacity; for this conductor cannot give what it has not, except it were continually receiving a ſtream, however ſmall, as is the caſe with an atmoſpherical conductor, or with the conductor of a machine which acts very poorly, but continues in action. In thoſe caſes it has been obſerved, that a conſiderable time is required before the metal plate has acquired a ſufficient quantity of electricity.

As an ample conductor, weakly electrified, imparts a conſiderable quantity of electricity to the metal plate of the condenſer, ſo when this plate is afterwards ſeparated from it's plane, the electricity in it appears much condenſed and vigorous; when the ſame plate contains a ſmall quantity of electricity, ſuch as cannot give a ſpark or affect an electrometer, that elec-

tricity

tricity may be rendered very confpicuous by communicating it to another fmall plate or condenfer.

Mr. Cavallo firft thought of this improvement, by reafoning on Mr. Volta's experiments. He made a fmall metal plate not exceeding the fize of a fhilling. This fecond condenfer is of great ufe in many cafes, where the electricity is fo fmall as not to be at all, or not clearly obfervable by one condenfer only, as has been fully proved. Sometimes the ufual metal plate of a condenfer acquires fo fmall a quantity of electricity, that being afterwards taken from the inferior plane, and prefented to an extremely fenfible electrometer, made by Mr. Cavallo, it did not affect it. In this cafe, if the faid plate, thus weakly electrified, was made to touch the other fmall plate properly fituated, and was afterwards brought near an electrometer, the electricity was then generally ftronger than was fufficient merely to afcertain it's quality.

Now, if by the help of both condenfers, the intenfity of the electricity has been augmented 1000 times, which is by no means an exaggeration, how weak muft then be the electricity of the body examined! how fmall the quantity of electricity that is produced by rubbing a piece of metal with one's hand! fince when it is condenfed denſed by both condenſers, and then communicated to an electrometer, it will hardly affect that inſtrument, and yet is ſufficient to afford conviction, that the metal can be electrified by the friction of a perſon's hand.

Before the diſcovery of the condenſer and Mr. Cavallo's very ſenſible electrometer, we were far from being able to diſcover ſuch weak excitations; whereas, at preſent, we can obſerve a quantity of electricity, incomparably ſmaller than the ſmalleſt obſervable at thoſe times.

CHAP.

CHAP. XII.

OF ATMOSPHERICAL ELECTRICITY.

IT is now univerſally acknowledged by every philoſopher, that the electric fluid is diſſeminated through the whole atmoſphere: it is alſo known, that the motion of this fluid is reſtrained when it acts in denſe air, but it moves with the greateſt liberty in a vacuum or rarified air, as in an exhauſted receiver. Therefore at a great height, where the air is equally, if not more rarified than in our receivers, it's motion muſt be exceeding free, and hence capable of the greateſt effects: becauſe it can be moved from one place to another with extreme eaſe and rapidity, and in great quantities; and if, as many philoſophers believe, the electric fluid is that ether or ſubtil matter which fills the intervals between the planets, how great muſt be the force of an agent which fills theſe immenſe ſpaces! Be this as it will, we know that the upper ſtrata of air are filled with this fluid, and that it moves there freely.

Again, we know that water, whether in ſubſtance or in vapour, is a conductor of electricity; that in proportion as air is loaded with it, it refifts lefs the motion and diffufion of the elec-tric fluid: confequently, if vapour rifes to a great height, it becomes a conductor and canal of communication between this immenfe refer-voir, this ocean of free electric fluid, and the entire mafs of our globe. If then this fluid is more reftrained at one part of our globe, than it is in correfponding parts of the higher regions, the vapours will be the medium to reftore the equilibrium. But this equilibrium will not laft long, for it is natural to fuppofe this immenfe fluid fubject to a flux and reflux, currents, &c. which will alter it's local denfity. Thus alfo this fluid, which is contained in our globe, can-not be long uniformly fpread through it's mafs, as there are ten thoufand agents, which will either accumulate or rarify it: confequently va-pour will fcarce ever rife without ferving as a vehicle to maintain the equilibrium between our globe and the fluid in the higher regions of the atmofphere.

This theory is fo natural a confequence of the moft immediate and certain principles of electri-city, that it feems almoft fuperfluous to confirm it by the phænomena which it explains. It is the only one that accounts for the following fact, that vapours never rife to a great height without producing the moft terrible meteors. All con-

fiderable

ſiderable volcanic productions are accompanied with lightning. The fire which riſes from the earth ſeems to light that of heaven. The column of vapour which proceeds from the bowels of a volcano is continually traverſed by lightning,* which ſometimes ſeems to proceed from the higher regions, ſometimes from the column itſelf. Hail, which neceſſarily ſuppoſes the aſcenſion of vapour to a conſiderable height, is always accompanied with electricity. The aurora borealis is alſo electrical; it's light ſeems to be produced by the electric fluid, at the inſtant it is condenſed in paſſing in the columns of elevated vapour.

Waterſpouts, whirlwinds, and even earthquakes, are in a great meaſure the effects of torrents of the electric matter, attracted from the higher regions by torrents of vapour. In a word, can the electricity of the clouds be attributed to a more natural or probable cauſe ?†

For the ſubject of this chapter we are principally indebted to P. Beccaria, who has for many years accurately obſerved the various changes in the electricity of the atmoſphere,

 and

* The younger Pliny obſerved theſe lightnings in the eruption which killed his uncle. Sir William Hamilton has alſo obſerved them ſeveral times.

† Sauſſure's Eſſais ſur l'Hygrometrie, p. 275.

and their relation to the other phænomena of the weather. His apparatus was admirably well adapted for this purpofe, and fuperior to any thing that we are at prefent acquainted with, for intimating eafily and at all times the electricity of the air. It not being at firft fufpected, that electricity was fo intimately blended with every operation of nature, as it is now known to be, the labourers in this part are of courfe very few; the principal are P. Beccaria, Mr. Ronayne, and Mr. Cavallo.

I have extracted and methodized the refults of the obfervations made by P. Beccaria, introducing occafionally thofe made by others, that the reader might be in poffeffion of the moft material facts, and excited to inveftigate and purfue with attention this delicate and important fubject; for, indeed, little certainty can be expected from any fyftem of meteorology, where the action of the principal agent is not particularly confidered and attended to.

The apparatus ufed by P. Beccaria, for inveftigating the electricity of the atmofphere, was an iron wire, which he terms an exploring wire, one hundred and thirty-two feet long. It was fixed at one end to a pole raifed over the chimney, the other end was faftened to the top of a cherry-tree. The extremities of the wire

were

were inſulated, and covered with a ſmall umbrella of tin. Another wire was brought from this, (through a thick glaſs tube, coated with ſealing-wax) into the room; by which means, continual information of the ſtate of the electricity in the exploring wire was obtained. He connected with this wire a ſmall ſlip of metal, on each ſide of which was a ſmall pith ball, one line diameter; the balls were ſuſpended by ſilk threads, ſixteen lines long.

Air-balloons will probably enable us to diſcover with certainty the electricity of the different ſtrata of the atmoſphere. Mr. de Sauſſure has already made the experiment with a balloon made of taffety, containing two hundred cubic feet of air, and which was raiſed by the heat from the flame of ſpirit of wine: with this, in cloudy but calm weather, he obtained a ſtrong poſitive electricity.*

The electricity, in ſerene weather, generally makes each of the balls diverge about ſix lines; when it is very ſtrong, they will diverge fifteen or twenty degrees from the metal plate; when weak, the divergence is very ſmall.

In ſerene weather, the wire, after being

 touched,

* Faujas de St. Fond, Deſcription des Experiences Aeroſtatiques, tom. II. p. 271.

touched, will take a minute or longer before it again ſhews ſigns of electricity; though, at other times, it will become electrified in the ſpace of a ſecond.

The electricity during ſerene weather is always poſitive. There are few inſtances in which it is negative, and then it is brought over by the wind from ſome part of the atmoſphere, (perhaps very diſtant from the place of obſervation) where there is either fog, ſnow, rain, or clouds. The whole ſeries of obſervations, which P. Beccaria has made, confirm this poſition. He ſeems to have met with only three or four inſtances to the contrary.

Dr. Franklin has obſerved, that the clouds are ſometimes negative, which is certainly true; becauſe they will at times abſorb, at and through the apparatus, a large and full bottle of poſitive electricity, of which the apparatus could not have received and retained the hundredth part. And it is eaſy to conceive, how a ſtrongly charged large poſitive cloud may reduce ſmaller clouds to a negative ſtate.

The electricity of the atmoſphere is very much connected with the ſtate of the air, as to moiſture and dryneſs; ſo that it is neceſſary to attend to the hygrometer, in order to form a proper judgment of the different degrees of electricity at different times. That invented by Mr. Coventry, which is made of hatters' paper, will anſwer beſt; it is very ſenſible, abſorbs moiſture ſoon, and parts with it eaſily. Comparative obſervations may alſo be made with it. It is alſo neceſſary to place a thermometer near the hygrometer, to aſcertain what quantity of moiſture the air can keep in ſolution with a given degree of heat: though this object will more probably be obtained by obſerving accurately the quantity of moiſture evaporated from a given ſurface at different times. It is alſo to be obſerved, that the different degrees of denſity in the air will affect the quantity of moiſture which is retained in the air.

The moiſture in the air is the conſtant conductor of the atmoſpheric electricity during clear weather; and the quantity of electricity is proportioned to the quantity of moiſture which ſurrounds the exploring wire; except there is ſo much as to leſſen the exactneſs of the inſulation of the wire and of the atmoſphere. In a dry ſtate of the air, it will ſometimes be above a minute before the balls will manifeſt any electricity after the wire has been touched; though in a damper ſtate, a ſecond will ſcarce elapſe before rapid oſcillations of the balls may be ob-

ſerved

ferved between the finger and the plate of brafs to which they are affixed.*

The electricity, when the weather clears up, is always pofitive. When the weather is clearing up, and becomes dry quickly, the electricity rifes to a great degree of intenfity, and affords frequent opportunities for repeating the obfervations. It fometimes happens, that the electricity, caufed by the clearing up of the weather, continues in it's ftate of intenfity for a long while; and alfo, after being interrupted, it begins afrefh. Thefe accidents feem to be owing to the electricity being brought over by the wind from great diftances.

P. Beccaria fays, that whenever he obferved that the thick low clouds which were over his head began to break, and the rare even clouds, which are above the former, became dilated, that the rain ceafed, and the balls diverged with pofitive electricity, he always wrote down CERTAIN TENDENCY TO CLEAR WEATHER.

Prior Ceca fays, that a ftrong pofitive electricity

* In making obfervations on the electricity of the atmofphere in clear weather, it is effential to repeat them very frequently; i. e. to obferve the velocity with which the electricity rifes after it has been annihilated; which P. Beccaria generally eftimated by the number of feconds elapfed before the balls began to manifeft their electricity.

tricity after rain is an indication that the weather will continue fair for ſeveral days. If the electricity is weak, it is a ſign that the fair weather will not laſt the whole day, but that it will ſoon be cloudy, and even rain.

If, when the ſky grows clouded over the place of obſervation, and a high cloud is formed, without any ſecondary clouds under it, and that it is not an extenſion of a cloud which drops rain elſewhere, either no electricity takes place, or it is poſitive.

If the clouds which are gathering are ſhaped like locks of wool, and keep moving firſt nearer to, and then ſeparating from each other; or, if the general cloud which is forming lies very high, and is ſtretched downwards like deſcending ſmoke, then poſitive electricity commonly takes place, which is more or leſs ſtrong in proportion to the quickneſs with which this cloud forms; and it foretels the greater or leſs quantity and velocity of the rain or ſnow which is to follow.

When a thin, even, and extenſive cloud is forming, which darkens the ſky, and turns it into a grey colour, a ſtrong and repeated poſitive electricity takes place; but in proportion as the gathering of the cloud ſlackens, this electricity leſſens, or even fails. On the contrary,

trary, if the rare extenſive cloud is gradually formed of ſmaller clouds, like locks of wool, which are continually joining to, and parting from each other, the poſitive electricity commonly continues.

Low and thick fogs (eſpecially when as they riſe the air above them is free from moiſture) carry up to the exploring wire an electricity which will give ſmall ſparks repeatedly, and produce a divergence of the balls from 20° to 25°, or even 30°. If the fog grows ſluggiſh, and continues round the exploring wire, the electricity ſoon fails; but if it continues to riſe, and another cloud ſucceeds, it electrifies again the wire, though leſs than before. Sky-rockets ſent through ſuch thick, low, and continued fogs, often afford ſigns of electricity. P. Beccaria, under any one of the circumſtances above deſcribed, never met with an inſtance of negative electricity; except perhaps once, when he ſent a ſky-rocket, to which a ſtring was fixed, through a low thick fog; though he had afterwards every reaſon to think, that he had miſtaken A FALSE LITTLE STAR FOR A TRUE ONE.

Mr. Ronayne obſerved, that the air in Ireland was generally electrified in a fog, and even in a miſt, and that both day and night, but principally in winter; ſeldom in ſummer, except from

from poſitive clouds, or cool fogs. The electricity of the air in a froſt or fog is always poſitive. He ſays, that he has often obſerved, during what ſeemed the paſſing of one cloud, ſucceſſive changes from negative to poſitive, and from poſitive to negative.

N. B. Moſt fogs have a ſmell very like an excited glaſs tube.

Mr. Henly has ſhewn, that fogs are more ſtrongly electrified in, or immediately after a froſt, than at other times; and that the electricity in fogs is often the ſtrongeſt ſoon after their appearance.

Whenever there appears a thick fog, and at the ſame time the air is ſharp and froſty, that fog is ſtrongly electrified poſitively.

Though rain is not an immediate cauſe, yet he is inclined to think, it was always a remote conſequence, of electricity in the atmoſphere; and he generally found, that in two or three days after he had diſcovered the air to be ſtrongly electrified, we had rain, or other falling weather.

If, in clear weather, a low cloud, which moves ſlowly and is conſiderably diſtant from any other, paſſes over the wire, the poſitive electricity generally grows very weak, but does not become negative; and when the cloud is gone, it returns to it's former ſtate. When many whitiſh clouds, like locks of wool, keep over the wire, ſometimes uniting with, and then ſeparating from each other, thus forming a body of conſiderable extent, the poſitive electricity commonly increaſes. In all the above circumſtances the poſitive electricity never changes to a negative one.

The clouds which leſſen the electricity of the exploring wire are thoſe which move; though thoſe that are low ſeem alſo to have the ſame effect.

Of the Diurnal Atmospherical Electricity.

In the morning, when the hygrometer indicates a degree of dryneſs equal to, or little leſs than that of the preceding day, an electricity takes place before the ſun riſes; which is manifeſted by junctions, adheſions, or even a divergence of the balls, and is proportioned to the dryneſs of the air, and the ſmallneſs of it's difference from that of the preceding day. If this ſtate of dryneſs does not obtain, no diſcernible electricity will be perceived before, or even for a little while after, the riſing of the ſun. As the air is generally damp in the night, electricity is ſeldom obſerved before the ſun riſes. During three months obſervations, P. Beccaria found the electricity before the ſun roſe only eighteen mornings; and from the whole of his numerous obſervations it appears, that the appearance of electricity in winter before ſun-riſe is more frequent that in the ſummer, eſpecially if the dampneſs from hoar-froſt is prevented from affecting the apparatus.

In the morning, as the ſun riſes higher, the electricity, whether it began before ſun-riſe or only after, gradually increaſes. This gradual increaſe of the morning electricity begins ſooner, if the hygrometer continues after ſun-riſe to indicate a greater degree of increaſing dryneſs. The intenſity and the riſe of the electricity (after it has been annihilated by touching the exploring wire) laſts in ſerene days, in which no impetuous wind takes place, and the hygrometer is ſtationary at the higheſt degree it has attained that day, till the ſun draws near the place of it's ſetting. When the ſun is near ſetting, and in proportion as the hygrometer abſorbs the moiſture, the intenſity of the daily electricity leſſens.

Though the hygrometer may indicate equal degrees of dryneſs at twelve o'clock, in different days, yet the electricity will appear ſooner after being deſtroyed on ſome days than on others;

and this is in a great meaſure proportioned to the increaſe of heat. The electricity moreover commences on ſuch days later in the morning, and falls ſooner in the evening.

The friction of winds againſt the ſurface of the earth is not the cauſe of atmoſpheric electricity. Impetuous winds leſſen the intenſity of the electricity in clear weather. If they are damp, they leſſen it's intenſity in proportion to the diminution they cauſe in the exactneſs of the inſulation both of the wire and atmoſphere.

OF THE ELECTRICITY PRODUCED BY THE EVENING DEW.

In cold ſeaſons, if the ſky is clear, little winds and a great degree of increaſing dryneſs, an electricity of conſiderable intenſity ariſes after ſun-ſet, as ſoon as the dew begins. The *frequency* of ſuch electricity is moreover greater than that of the *daily* electricity, and it vaniſhes ſlowly.

In temperate or warm ſeaſons, if the ſame circumſtances as above take place, an electricity intirely ſimilar to the former ariſes as ſoon as the ſun has ſet; only it's intenſity is not ſo conſtant; it begins with greater rapidity, and ends ſooner.

If,

If, under the above circumſtances reſpectively, the general dryneſs of the air happens to be leſs, the electricity that riſes in the evening, when the dew begins, is leſs in proportion to the diminutions of the exactneſs of the inſulation of both the exploring wire and the atmoſphere; but correſpondently to the greater quantity of dew, the frequency of the electricity is greater.

The electricity of dew ſeems to depend on the quantity of dew, and to follow in it's various changes, proportions ſimilar to thoſe which take place between the electricity of calm mild rain, and that of rainy and ſtormy weather, and varies alſo according to the ſeaſons.

As rain, ſhowers, the Aurora Borealis, and the zodiacal light, have a tendency to appear for ſeveral ſucceſſive days with the ſame characteriſtic accidents, ſo the electricity of dew ſeems to have as it were an inclination to appear for ſeveral evenings ſucceſſively with the ſame characters.

EXPERIMENT CLXXXVII.—Let the air in a well-cloſed room be electrified; that is to ſay, the moiſture and other vapours diffuſed in it: then let a bottle, filled with water colder than the air in the room, and inſulated on a tube of glaſs, be raiſed pretty high in this room. Care muſt be taken to preferve the infulation of the glafs, with warm cloths. The electric figns that will arife in two threads fufpended to fuch bottle, will exactly reprefent the electricity of dew; and they will exhibit the different manner after which this electricity takes place, according as the electrified vapours in the room are more or lefs rare; as the difference between the heat of the air in the room, and that of the water in the bottle is lefs or greater, and the infulation of the bottle is more or lefs exact.

In a thunder-ftorm Mr. Ronayne obferved, that the flafhes would caufe fudden changes. Sometimes the electricity would be extended, fometimes diminifhed; at other times increafed, and fometimes even changed to the contrary again, though none was perceived before; it would come on fuddenly with a flafh of lightning. A large thunder-cloud, when it darkens the hemifphere, does not produce fo much electricity as a branch of it, or even as a common fhower; that a ftorm does not go in a regular current of the wind, but obliquely and zig-zag; viz. it rains in that region from whence the ftorm is to proceed.

EXPERIMENTS AND OBSERVATIONS ON ATMOSPHERICAL ELECTRICITY, BY MR. CAVALLO.

Theſe were principally made with an electrical kite, which will collect electricity from the air at any time. The power of this inſtrument reſides in the ſtring. The beſt method of making the ſtring is by twiſting two threads of common twine with one of that copper thread which is uſed for trimming: a ſchoolboy's kite with this ſtring anſwers the purpoſe as well as any other. When a kite conſtructed in this manner was raiſed, Mr. Cavallo ſays he always obſerved the ſtring to give ſigns of electricity, except once; the weather was warm, and the wind ſo weak, that the kite was raiſed with difficulty, and could hardly be kept up for a few minutes: afterwards, when the wind increaſed, he obtained as uſual a ſtrong poſitive electricity.

If this kite was raiſed at a time when there was any probability of danger from the great quantity of electricity, Mr. Cavallo connected one end of a chain with the ſtring, and let the other end fall on the ground, and placed himſelf alſo on an inſulating ſtool. Except the kite is raiſed in a thunder-ſtorm, there is no great danger that the operator will receive a ſhock. Although he raiſed his kite hundreds of of times without any precaution whatever, he ſeldom received even a few ſlight ſhocks in the arms. But it is not adviſeable to raiſe it while ſtormy clouds are over-head. This is alſo leſs neceſſary, as the electricity of the atmoſphere may then be eaſily obſerved by other means.

When the kite was raiſed, he often introduced the ſtring through a window into a room of the houſe, and faſtened it by a ſtrong ſilk lace to a heavy chair in the room. Fig. 78, A B repreſents part of the ſtring of the kite which comes within the room, C the ſilk lace, D E a ſmall prime conductor, which, by means of a ſmall wire, is connected with the ſtring of the kite; F a quadrant electrometer, fixed upon an inſulating ſtand, and placed near the prime conductor; G a glaſs tube about 18 inches long, gn a ball and wire of braſs, which are fixed to the glaſs tube. This ſmall inſtrument is uſeful to determine the quality of the electricity, when it is not ſafe to come near the ſtring. This is effected by touching the ſtring with the wire, which takes a ſufficient quantity from it to aſcertain thereby the quality of the electricity, either by the attraction and repulſion of light balls, or the appearances of the electric light: or it may be aſcertained by a Leyden phial, which will retain a charge for a conſiderable time; and then the kite need not be

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kept up any longer than is neceſſary to charge the phial, by which the quality will be ſhewn even at ſome days diſtance.

If a charged phial is carefully kept from any of thoſe means by which it is known to be diſcharged, it will retain it's charge for a long time. On this principle the above-mentioned phial is conſtructed; the bottle is coated in the uſual manner; the uncoated part of the glaſs is covered with wax, or elſe well varniſhed; a glaſs tube, which is open at both ends, is cemented into the neck of this phial, having a piece of tin-foil connected with it's loweſt extremity, which touches the inſide non-electric coating. A glaſs handle is fixed to the ball on the wire which paſſes into the foregoing glaſs tube; the wire is of a proper length to touch the tin-foil which is at the bottom of the tube. Charge this bottle in the uſual manner, and then take out the wire from the glaſs tube by means of the glaſs handle. This may be done without diſcharging the phial; and, as the fire cannot now eſcape eaſily, the charge of a phial may be preſerved for many weeks.

Fig. 80 repreſents a very ſimple inſtrument (contrived by Mr. Cavallo) for making experiments on the electricity of the atmoſphere, and which, on ſeveral accounts, appears to be the beſt for the purpoſe. A B is a common jointed fiſhing rod, without the laſt or ſmalleſt joint: from the extremity of this rod proceeds a ſmall glaſs tube C, covered with ſealing-wax, a cork D is fixed at the end of it, from which an electrometer with pith balls is ſuſpended. H G I is a piece of twine faſtened to the other extremity of the rod, and ſupported at G by a ſmall ſtring F G. At the end of the twine T a pin is faſtened, which, when puſhed into the cork D, renders the electrometer E uninſulated. When the electricity of the atmoſphere is obſerved with this inſtrument, thruſt the pin T into the cork D, and hold the rod by the lower end A; place it out of a window at the upper part of the houſe, raiſing the end of the rod with the electrometer, ſo as to make an angle of 50 or 60 degrees with the horizon. Keep the inſtrument in this ſituation for a few ſeconds, then pull the twine at H, and the pin will be diſengaged from the cork D; which operation cauſes the ſtring to drop in the dotted ſituation K L, and leaves the electrometer inſulated, and electrified with an electricity contrary to that of the atmoſphere. This being done, you may draw the electrometer into the room, and examine the quality of the electricity, without obſtruction either from wind or darkneſs.

Fig.

Fig. 81 is an electrometer for rain, contrived by Mr. Cavallo. A B C T is a ſtrong glaſs tube, about two feet and a half long, having a tin funnel D E cemented to it's extremity, which funnel defends part of the tube from the rain. The outſide ſurface of the tube from A to B is covered with ſealing-wax, and ſo is the part of it which is covered by the funnel. F D is a piece of cane round which braſs wires are twiſted in different directions, ſo as to catch the rain eaſily, and at the ſame time to make no reſiſtance to the wind. This piece of cane is fixed into the tube, and a ſmall wire proceeding from it goes through the tube, and communicates with the ſtrong wire A G, which is thruſt into a piece of cork, faſtened to the end A of the tube. The end G of the wire A G is formed into a ring, from which a ſenſible pith ball electrometer is to be ſuſpended. This inſtrument is faſtened to the ſide of a window frame, where it is ſupported by ſtrong braſs hooks at C B; which part of the tube is covered with a ſilk lace, in order to adapt it better to the hooks. The part F L is out of the window, with the end F elevated a little above the horizon. The remaining part of the inſtrument comes through a hole in one of the lights in the ſaſh, within the room, and no more of it touches the ſide of the window than the part C B. When it rains, eſpecially in paſſing ſhowers, this inſtrument is frequently electrified; and by the divergence of the electrometer, the quantity and quality of the rain may be obſerved without any danger of a miſtake. With this inſtrument, in rainy weather, Mr. Cavallo has been able to charge a ſmall coated phial at the wire A G. It ſhould be fixed in ſuch a manner, that it may be eaſily taken off from the window, and replaced again, as occaſion requires; as it will be neceſſary to clean it often, particularly when a ſhower of rain is approaching.

DESCRIPTION OF A SMALL PORTABLE ATMOSPHERICAL ELECTROMETER, INVENTED BY MR. CAVALLO.

The principal part of this inſtrument is a glaſs tube C D M N, cemented at the bottom into the braſs piece A B, by which part the inſtrument is to be held when uſed for the atmoſphere; and it alſo ſerves to ſcrew the inſtrument into it's braſs caſe A B O, fig. 76. The upper part of the tube C D M N is ſhaped tapering to a ſmall extremity, which is intirely covered with ſealing-wax; into this tapering part a ſmall tube is cemented; the lower extremity, being alſo covered with fealing-wax, projects a fmall way within the tube CDMN; into this fmaller tube wire is cemented, which, with it's under extremity, touches the flat piece of ivory H, faftened to the tube by means of a cork; the upper extremity of the wire projects about a quarter of an inch above the tube, and fcrews into the brafs cap E F, which cap is open at the bottom, and ferves to defend the waxed part of the inftrument from the rain, &c.

I M and K N are two narrow flips of tin-foil, ftruck to the infide of the glafs C D M N, and communicating with the brafs bottom A B. They ferve to convey that electricity, which, when the balls touch the glafs, is communicated to it, and, being accumulated, might difturb the free motion of the balls.

To ufe this inftrument for artificial electricity, electrify the brafs cap by an electrified fubftance, and the divergence or convergence of the balls of the electrometer, at the approach of an excited electric, will fhew the quality of the electricity. The beft manner to electrify this inftrument is, to bring excited wax fo near the cap that one or both of the corks may touch the fide of the bottle CDMN, after which they will foon collapfe and appear unelectrified. If now the wax is removed,

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they will again diverge, and remain electrified positively.

When this electrometer is to be ufed to try the electricity of the fogs, air, clouds, &c. the obferver is to do nothing more than to unfcrew it from it's cafe, and hold it by the bottom A B to prefent it to the air a little above his head, fo that he may conveniently fee the balls P, which will immediately diverge if there is any electricity; i. e. whether pofitive or negative may be afcertained, by bringing an excited piece of fealing-wax or other electric towards the brafs cap E F.

General Laws deduced from the Experiments performed with the Electrical Kites.

1. The air appears to be electrified at all times. It's electricity is conftantly pofitive, and much ftronger in frofty than in warm weather; but it is by no means lefs in the night than in the day time.

2. The prefence of the clouds generally leffens the electricity of the kite: fometimes it has no effect upon it, and it very feldom increafes it.

3. When it rains, the electricity of the kite is generally negative, and feldom pofitive.

4. The

4. The Aurora Borealis ſeems not to affect the electricity of the kite.

5. The electrical ſpark taken from the ſtring of the kite, or from any inſulated conductor connected with it, eſpecially when it does not rain, is ſeldom longer than a quarter of an inch, but it is exceedingly pungent. When the index of the electrometer is not higher than 20°, the perſon who takes the ſpark will feel the effects of it in his legs; it appears more like the diſcharge of an electric jar, than the ſpark taken from the prime conductor of an electrical machine.

6. The electricity of the kite is in general ſtronger or weaker, according as the ſtring is longer or ſhorter; but it does not keep any exact proportion to it. For inſtance; the electricity brought down by a ſtring of an hundred yards may raiſe the index of the electrometer to 20°, when with double that length of ſtring the index of the electrometer will not go higher than 25°.

7. When the weather is damp, and the electricity is pretty ſtrong, the index of the electrometer, after taking a ſpark from the ſtring, or preſenting the knob of a coated phial to it, riſes ſurpriſingly quick to it's uſual place, but in dry or warm weather it riſes exceedingly ſlow.

It appears, from the obſervations which have been made on the electricity of the atmoſphere,

that

that nature makes great uſe of this fluid in promoting vegetation.

1. In the ſpring, when plants begin to grow, then temporary electrical clouds begin to appear, and pour forth electric rain. The electricity of the clouds and of the rain continues to increaſe, till that part of the autumn in which the laſt fruits are gathered.

2. It is this fluid which ſupplies common fire with that moiſture, by the help of which it actuates and animates vegetation: it is the agent that collects the vapours, forms the clouds, and is then employed to diſorder and diſſipate them in rain.

3. From the ſame principle may be explained the proverb, that *No watering gives the country ſo ſmiling a look as rain.* The clouds of rain, by extending their electric atmoſphere to the plants, diſpoſe the pores of the latter to receive with greater facility the water which is impregnated with this penetrating and dilating fluid. Beſides, it is natural to ſuppoſe, that the poſitive electricity, which continually prevails in ſerene weather, will contribute to promote vegetation, ſince this has been found to be the effect of even artificial electricity.

OF THE IMPERFECTIONS OF METEOROLOGY, SO LONG AS BAROMETRICAL, THERMOMETRICAL, AND HYGROMETRICAL OBSERVATIONS ARE NOT ACCOMPANIED WITH THE REGULAR OBSERVATION OF THE ELECTRICITY OF THE ATMOSPHERE, OF THE ELECTRICITY OF RAIN, SNOW, MISTS, AND AQUEOUS METEORS IN GENERAL. BY MR. ACHARD.

As it is now clearly aſcertained, that electricity is a cauſe of various meteorological phænomena, it is rather ſurpriſing that philoſophers have not perceived the abſolute neceſſity of joining an inſtrument, by which obſervations may be made on the electricity of the atmoſphere, to thoſe which indicate it's weight, heat, and humidity.

Without conſidering in this place the different proofs of the influence of electricity on meteors, it will be ſufficient to remark, that we cannot attain to an adequate knowledge of any phænomena, occaſioned by the concurrence of various cauſes, without being acquainted with them all; for if any one is neglected, it will be abſolutely impoſſible thoroughly to explain the phænomena. If electricity is not the ſole cauſe of ſeveral meteorological appearances, it is undoubtedly concerned more or leſs in their formation; ſo that by neglecting to obſerve it, as well as the barometer, &c. we loſe the fruits of other, even very exact, meteorological obſervations.

The influence of electricity on vegetation is proved by a ſet of obſervations made by different philoſophers; but it evidently appears, that the botanical meteorological obſervations alone will never be ſo uſeful as might be expected, till we unite thoſe made by an inſtrument which will indicate the electric ſtate of the atmoſphere, to thoſe made with other inſtruments. It is owing to this cauſe, perhaps, that it is impoſſible to draw any concluſion from the botanical meteorological obſervations of Meſſrs. Gautier and Duhamel, which were continued from 1751 to 1769.

Mr. Achard has had an opportunity of making a few obſervations, but they were ſufficient to convince him of the intimate connection that ſubſiſts between the formation of the moſt part of meteors, and atmoſpherical electricity.

To diſcover if the atmoſphere was electrical, he made uſe of a pair of light pith balls which were attached to a reſinous rod. This electrometer, from it's ſimplicity, is almoſt preferable to any other for merely difcovering that electricity exifts in the atmofphere.

During the month of July, 1778, Mr. Achard obferved daily the electricity of the atmofphere in the morning, at noon, and in the evening, with a pair of fmall pith balls, which were placed above the roof of the houfe, above 40 feet high, and fufficiently diftant from buildings, trees, &c. During the whole time there were only 10 days which gave no figns of electricity; 17 days, including the foregoing 10, in which he could obferve no electricity in the morning, though it became very fenfible at noon, and was very much increafed towards the fetting of the fun. Every other day he found the air electrical during the whole day, but always ftrongeft a little before fun-fet, a fhort time after which it began again to diminifh.

If in ferene weather the fky became fuddenly cloudy, the electrometer indicated continual changes in the electricity of the atmofphere; fometimes increafing, then difappearing, then re-appearing; in which cafe it had generally changed from pofitive to negative, or *vice verfa*. In windy weather he found it difficult to obferve with the electrometer, on account of the continual motion of the balls. It feemed to vary confiderably when the air was heavy, but not windy. When the weather was very calm, and the ſky without clouds, the electrometer did not alter in the leaſt, except towards ſun-ſet, when it increaſed in a ſmall degree.

It is remarkable, that in thoſe days in which he obſerved no electricity in the air, there was no dew at night; while on the other nights, it fell in greater or leſs quantities. He does not think thoſe obſervations are ſufficient to determine, that the dew is occaſioned by electricity, but it may, he thinks, be fairly inferred, that the elevation and fall of the dew is obſtructed or promoted by the electricity of the air. It is eaſy to point out in what manner electricity may produce the effect. Let us ſuppoſe the air to be either poſitively or negatively electrified, but the ſurface of the globe where we are not to be ſo; the aqueous and volatile parts of the vegetables exhaled by the rays of the ſun, and ſuſpended in the air, will become electric by communication. The air cooling by the abſence of the ſolar heat, will not, after the ſetting of the ſun, retain the aqueous particles with the ſame force; and theſe being attracted by the non-electric bodies which are on the ſurface of the earth, their ſuperficies will be covered with dew. Again, let us ſuppoſe that the ſurface of the earth is electrical, but that the air is not electrical, and the

the effect will be similar to the preceding case. If the air and the earth are both electrified, but with contrary powers, the attraction will be stronger and the dew more abundant; but no dew will fall if they are both possessed of the same power, and in the same degree. It is known, that the dew does not fall with the same facility upon all bodies, and that electric bodies are those on which it falls with the greatest abundance. This fact admits of an easy explanation, if we suppose electricity to be the cause of the dew; for the electric bodies do not readily receive electricity from the medium which surrounds them; there is, therefore, always a greater difference between the electricity of the air and that of the electrics which are placed in it, than between the electricity of the air and the conducting bodies which it envelopes. Now it is in the ratio of this difference that the power of electric attraction acts, and consequently these bodies ought to be covered more abundantly with dew.

As electricity is often, if not always, the cause of dew, no one will doubt the necessity of attending to it in the botanical meteorology, as every one is acquainted with the influence of dew on the growth of vegetables.

In the Phil. Tranf. for 1773, are obfervations on the electricity of fogs, which prove that they are generally electrical. Mr. Achard has made feveral obfervations, the refults of which correfpond entirely with thofe, for he conftantly found that the air was more or lefs electrified by a fog. Twice he obferved, that in the fpace of a few minutes the fog ceafed altogether, and fell in form of a fine rain; and though it was very thick, difappeared in about feven minutes. It is alfo very probable that rain is occafioned by electricity; and of this we fhall be convinced, if we confider the attractions and repulfions that the terreftrial or atmofpheric electricity muft occafion, as well between the furface of the globe and the vapours contained in the air, as between the particles of vapour which always neceffarily tend to difperfe or unite the aqueous particles which fwim in the atmofphere, and to bring them nearer, or carry them farther from the earth.

Having proved the neceffity of combining obfervations on the electricity of the atmofphere with other meteorological obfervations, Mr. Achard proceeds to defcribe the properties requifite in a good atmofpherical electrometer, the want of which accounts for the neglect and fupinenefs of philofophers on this fubject.

NECESSARY

NECESSARY REQUISITES IN AN ATMOSPHERICAL ELECTROMETER.

1. It ſhould be eaſy in it's uſe.

2. It ſhould not only indicate that the air is electrical, but in what degree.

3. It is neceſſary that we may learn whether it is poſitive or negative.

4. That the obſerver ſhould be in no danger in ſtormy weather.

5. That it be portable.

The number of difficulties which oppoſe the conſtruction of an inſtrument which will unite all theſe advantages, is very conſiderable. The greateſt is to inſulate the metal which receives the electricity from the air, ſo that rain may not eſtabliſh a communication between it and the earth, and that the inſulation is ſufficiently perfect to prevent too quick a diſſipation of the electricity received by the metal. Mr. Achard does not pretend that he has ſurmounted all theſe difficulties, but after ſeveral trials he has contrived an inſtrument ſufficiently portable, eaſy to obſerve with, and that without danger.

DESCRIPTION OF THE PORTABLE ATMOSPHERICAL ELECTROMETER, CONTRIVED FOR THE PURPOSES ALREADY MENTIONED.

This inſtrument is compoſed of a hollow and truncated cone of tin, whoſe upper end is open, and which is cloſed at bottom by a plate of the ſame metal. This plate is covered, in the inſide of the cone, with a layer of roſin two inches thick: to the lower ſurface of this layer of roſin a tube of tin is cemented, which, when it is placed on a wooden pedeſtal, ſupports the cone in ſuch a manner, that the great baſe is horizontal, and turned downwards; the roſin inſulates the cone perfectly, and, when the latter becomes electric, prevents the loſs of it's electricity by tranſmiſſion. The cone muſt be high enough, and it's inferior baſe muſt exceed far enough in diameter, it's ſuperior extremity, to prevent the rain, even though it ſhould fall in an oblique direction, from wetting, either in it's fall, or by rebounding from the pedeſtal, the lower ſurface of the roſin-layer, with which the bottom of the truncated cone is internally covered: otherwiſe the cone would ceaſe to be inſulated, and the electrometer would be changed into a conductor.

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On the truncated part of the cone Mr. Achard faſtens a ſquare iron branch, on which he places a thermometer and two electrometers; the one very light, and thus capable of being ſet in motion by ſmall degrees of electricity; the other heavier, and which, conſequently, only riſes when the electricity becomes too ſtrong to be meaſured by the light electrometer. Beſides theſe two electrometers, Mr. Achard tied to the iron bar a thread, which indicates, by it's riſing, the ſmalleſt degrees of electricity: the whole is incloſed in a receiver of glaſs, open above and below; the baſe of this receiver is alſo inſulated with roſin, that it may not derive any electricity from the tin cone; the remaining ſpace of the upper part of the receiver, between the bar of metal, which paſſes through it, and the glaſs, is likewiſe filled with roſin, to prevent the communication of electricity to the receiver; to preſerve this roſin from rain, which, by moiſtening it, would form a communication between the receiver and the bar, it is covered over with a glaſs funnel, through which the bar paſſes, and which hinders the rain from falling on the roſin. This receiver is alſo indiſpenſably neceſſary to prevent the action of the wind upon the electrometers, which would render the accurate obſervation of them impoſſible. At the end of the metal bar, which paſſes through the receiver, hollow tin pipes may be placed, of a ſmall diameter, to render them as light as poſſible, and they may be raiſed to the height of 10, 20, or 30 feet. The upper end of the pipe terminates in an iron point, extremely ſharp and well gilt; the gilding is neceſſary to hinder the point, which muſt be always even and ſmooth, from contracting ruſt. With reſpect to the elevation that it may be proper to give to the tin-pipe, this muſt vary with the height of the buildings or trees in the different places where obſervations are made; for the height of the pipe muſt always exceed, at leaſt by ſix feet, the elevation of all the bodies that are near it. Mr. Achard joins a thermometer to this machine, which may be obſerved at the ſame time, and be the means, perhaps, of diſcovering the relations, if any there be, between electricity and the temperature of the air. A barometer and hygrometer may, with facility, be added to this inſtrument for the ſame purpoſe.

In order to know whether the electricity of the air be poſitive or negative, Mr. Achard ſuſpends a ball of cork, by a linen thread, on the wire which communicates with the iron bar, and which paſſes through the roſin, with which the baſe of the truncated cone is covered. The wire muſt be of ſuch a length, that bodies poſitively or negatively electrified may be commodiouſly brought near the cork-ball, which is ſuſpended on it; and it is according as theſe bodies attract or repel the ball, that the obſerver learns whether the electricity, which the inſtrument has received from the air, be poſitive or negative.

That the obſerver may be in no danger from ſudden accumulations of electricity, which ſometimes happen, Mr. Achard faſtens to the baſe of the pedeſtal an iron bar, which not only communicates with, but even enters into, the ground, ſeveral feet deep. This bar, whoſe upper part terminates in a round knob or ball, muſt be only at the diſtance of an inch from the cone. When the electrical fluid is ſo accumulated that the inſtrument can no longer contain it, it will diſcharge itſelf againſt this metal bar, which will conduct it under ground. The ſame thing would happen, if the lightning fell upon the inſtrument, and the obſerver would be in no ſort of danger, even at the diſtance of a few feet. When the inſtrument is placed in a garden, this method of forming a communication with the ground is ſubject to no inconveniency; but if it ſhould be judged proper to employ the inſtrument in a houſe, (which may be done by making the tin pipe paſs through a hole in the roof, and placing the inſtrument in a garret) the manner above-mentioned of forming it's communication with the earth would not be ſo eaſily executed: in this caſe, the communication muſt be effected by means of a bar of metal deſcending from the garret to a depth of ſome feet under ground; and for greater ſecurity againſt the too great proximity of a thunder-ſtorm, it would be proper to place the metallic bar in contact with the cone of tin: thus the inſtrument would become a real conductor, which, inſtead of expoſing the houſe to danger, would, on the contrary, preſerve it from all the accidents that are occaſioned by lightning.

When the inſtrument is placed in a garret, or on the platform of a houſe, no inconvenience is to be apprehended from aſcending dews; but when it is placed in a garden, the dew adheres to the roſin which covers the truncated baſe of the cone, and forming thus a communication between the cone and the earth, makes the inſtrument loſe the electricity with which it may have been charged. To prevent this accident, it is neceſſary to pave the ground on which the inſtrument is placed, and THAT in ſuch a manner, that the pavement may extend itſelf on all ſides, at leaſt two or three feet beyond the circumference

cumference of the lower baſe of the cone: the riſing of the dew, which by adhering to the roſin might damage the inſtrument, will be thus effectually prevented.

When the air is electrical, it muſt neceſſarily communicate it's electricity to the vapours which it contains. This is evident from the formation of lightning, which is not produced by the diſcharge of the electrical matter of the air, but by that of the vapours which float in the atmoſphere. Hence it follows, that rain, ſnow, hail, miſt, and dew, muſt be very often electric. As it appears to Mr. Achard a matter of great conſequence to know and obſerve exactly the electricity of thoſe meteors, he has conſtructed a machine that is adapted to diſcover both it's nature and degree. This machine is compoſed of a truncated tin cone, cloſed at the top, open at bottom, and inſulated upon a pedeſtal, like that of the machine employed to meaſure the electricity of the air. In the center of the upper truncated part of the cone, Mr. Achard fixes an iron bar terminated by a ball; he covers the whole with an inſulated glaſs receiver, high enough to have it's ſummit at the diſtance of three inches from the ball which terminates the iron bar, to which he faſtens a very SENSIBLE electrometer, and alſo a linen thread to diſcover

the

the ſmalleſt degrees of electricity. As this inſtrument is but little elevated, and has no pointed extremity, it is not eaſily charged with the electricity of the air, which at ſuch a degree of proximity to the earth is always imperceptible; but rain, ſnow, hail, miſt, and dew, if they are electrical, will render it alſo electrical by falling upon the cone; the degree of electricity is aſcertained by the electrometer, which is under the receiver; and in order to know whether it be poſitive or negative, the obſerver has only to employ the method indicated above, in our account of the inſtrument uſed to meaſure the electricity of the air. Beſides the uſe of this inſtrument in diſcovering the electricity of aqueous meteors, it may ſtill ſerve farther purpoſes: it may be highly uſeful to compare it with the atmoſpherical electrometer, in order to diſcern the true principle of the electricity with which it is charged, and to ſee whether it proceeds immediately from the air, or from the heterogeneous bodies that are ſuſpended in the atmoſphere; for the atmoſpherical electrometer may alſo become electrical by rain, ſnow, hail, or miſt; and the comparing theſe two inſtruments is the only method that occurs to Mr. Achard by which we can know, whether it receives it's electricity directly from the air, or by the interven-

tion

tion of bodies (indued with a CONDUCTING power) which are diffused in it. If, during rain, hail, snow, or mist, the atmospherical electrometer is ELECTRICAL, while THAT which indicates the electricity of aqueous meteors is NOT so, we may conclude, with certainty, that the electricity of the former proceeds only from the air; if, on the contrary, they are both electrical, it must then be inquired, whether they be so in the same degree; if this be the case, it is only to the rain or snow, &c. that the electricity must be attributed. I need not observe, (concludes Mr. Achard) that when there is neither rain, snow, hail, or mist, the atmospherical electrometer will always indicate the electricity of the air.

CHAP. XIII.

ON THE DIFFUSION AND SUBDIVISIONS OF FLUIDS BY ELECTRICITY.

WE are chiefly indebted to the Abbé Nollet for what is known on the ſubject of this chapter, which was inveſtigated by him with incredible induſtry and patience. I have only ſubjoined the principal reſult of his experiments, and muſt refer the reader, for a more ample account, to the Abbé's own writings, or Dr. Prieſtley's Hiſtory of Electricity.

Electricity augments the natural evaporation of fluids; ſince, excepting mercury and oil, all the others which were tried ſuffered a diminution that could not be aſcribed to any other cauſe than electricity.

It increaſes the evaporation of thoſe fluids moſt, which naturally tend to evaporate readily. Volatile ſpirits of ſal-ammoniac loſt more than ſpirits of wine, this more than water, &c.

Electricity acts ſtrongeſt upon the fluids, when the veſſels which contain them are non-electrics. The evaporation was greateſt in the moſt open veſſels, but did not increaſe in proportion to their

their apertures. It does not make any liquor evaporate through the pores either of metal or glaſs.

To extend theſe principles further, the Abbé made a great variety of experiments on electrified capillary tubes, and found, that the ſtream would be ſub-divided, but it is not ſenſibly accelerated, if the tube is not leſs then one tenth of an inch diameter in the inſide.

Under this diameter, if the tube is wide enough to let the fluid run in a ſtream, electricity will accelerate it's motion in a ſmall degree.

If the tube is ſo far capillary that the water only iſſues from it in drops, the electrified jet becomes a continued ſtream; it will even be divided into ſeveral ſmaller ones, and it's motion is conſiderably accelerated; the ſmaller the diameter of the tube, the greater is the acceleration. When the ſurface is wider than one tenth of an inch, electricity ſeems rather to retard the motion of the fluid.

From ſome very accurate experiments made by Mr. de Sauſſure with his new hygrometer, it appears, that the foregoing theory, which aſſerts that electricity always promotes evaporation, is only true under certain reſtrictions. It increaſes the evaporation from thoſe bodies which are ſuperſaturated, but does not occaſion any evaporation in thoſe which do not contain a ſuperabounding quantity of water.

EXPERIMENT CLXXXVIII.—Fig. 77 repreſents a metal phial, to which a capillary tube is adapted, which will only permit water to paſs through it in interrupted drops. Fill the pail with water, and ſuſpend it from the prime conductor, then turn the cylinder, and the water will paſs through the tube in a continued ſtream; this will ſeparate into other ſtreams, that will appear luminous in the dark.

EXPERIMENT CLXXXIX.—Suſpend one pail from a poſitive conductor, and another from a negative one, ſo that the end of the tubes may be about three or four inches from each other, and the ſtream proceeding from one will be attracted by that which iſſues from the other, and form one ſtream, which will be luminous in the dark.

If the pails are ſuſpended on two poſitive, or two negative conductors, the ſtreams will recede from each other.

EXPERIMENT CXC.—Place a metal baſon on an inſulating ſtand, and connect it with the prime conductor; then pour a ſmall ſtream of water into the baſon, which in the dark will have a beautiful appearance, as the ſtream will be divided into a great number of lucid drops.

EXPERIMENT CXCI.—Dip a ſponge in water, and then ſuſpend it from the conductor: the water, which before only dropped from it, will now fall faſt, and appear in the dark like fiery rain.

EXPERIMENT CXCII.—Hold a pail, which is furniſhed with ſeveral capillary tubes placed in various directions, near an electrified conductor, and the water will ſtream out of thoſe jets near the conductor, while it will only drop at intervals from thoſe which are oppoſite to it.

EXPERIMENT CXCIII.—The knob of a charged jar will attract a drop of water from a ſaucer, &c. This drop, the moment the bottle is removed from the ſaucer, aſſumes a conical ſhape, and if it is brought near any conducting ſubſtance, it is driven forcibly away in ſmall ſtreams, which are luminous in the dark.

It appears by this experiment, that the electric fire not only tends to ſeparate the particles of water, and to diſſipate them into vapour as common fire, but that it effects this with uncommon rapidity.

EXPERIMENT CXCIV.—Difcharge a battery through a drop of water, previoufly placed on the knob of one of it's bottles; the whole will be inftantly exploded into vapour; the fparks will be much longer than common, and more compact.

Beccaria obferves, that by fending a difcharge to a greater or lefs diftance, through one or more drops of quickfilver, the difcharge diffufes itfelf into drops, and drives them into vapour; part of it rifing into the air in the form of fmoke, the other part remains on the glafs.

EXPERIMENT CXCV.—A drop of water hanging from the condenfing ball of an electrified conductor, will ftretch towards water placed in a cup under it, lengthening and fhortening itfelf according to the force of the electricity.

EXPERIMENT CXCVI.—Place a drop of water on the prime conductor, turn the machine, and long zig-zag fparks may be taken from it; the drop will take a conical figure; the body that receives the fpark will be wetted, and the fpark will be confiderably longer than can be obtained from the conductor without the water.*

EXPERIMENT

* Nicholfon's Introduction to Philofophy.

EXPERIMENT CXCVII.—Stick a piece of ſealing-wax on the conductor, in ſuch a manner that it may be eaſily ſet on fire by a taper; while it is flaming turn the cylinder, the wax will become pointed and ſhoot out an almoſt inviſible thread into the air, to the length of a yard and more. If the filaments that are thrown out by the wax are received on a ſheet of paper, the paper will be covered by them in a very curious manner, and the particles of the wax will be ſo far ſubdivided as to reſemble fine cotton. To faſten the piece of wax conveniently to the conductor, ſtick it firſt on a ſmall piece of paper, then twiſt the end of the paper ſo as to fit one of the holes which are made in the prime conductor; when it is thus placed, it may be readily fired by a taper.

EXPERIMENT CXCVIII.—Inſulate a fountain made by condenſed air, and which emits only one ſtream; electrify the fountain, and the ſtream will be ſeparated into a great number; theſe will diffuſe themſelves equally over a large ſpace of ground. By laying a finger upon the conductor, and taking it off again, the operator may command either the ſingle ſtream or the divided one, at pleaſure.

EXPERIMENT CXCIX.—Electrify two ſmall inſulated fountains with the different electric powers; the ſtreams of both will be diſperſed into very minute particles, which will run together at the top, and come down in heavy drops, like a ſhower of rain.

CHAP. XIV.

OF THE ELECTRIC LIGHT IN VACUO.

EXPERIMENT CC.

TAKE a tall dry receiver, and inſert in the top, with cement, a wire with a rounded end, then exhauſt the receiver, and preſent the knob of the wire to the conductor, and every ſpark will paſs through the vacuum in a broad ſtream of light, viſible the whole length of the receiver, moving with regularity, unleſs it is ſolicited and bent out of it's way by ſome non-electric, then dividing itſelf into a variety of beautiful rivulets, which are continually dividing and uniting in a moſt pleaſing manner. If the veſſel is graſped by the hand, at every ſpark a pulſation is felt, like that of an artery, and the fire bends itſelf towards the hand. This pulſation is even felt at ſome diſtance from the receiver, and in the dark, a light is ſeen between the hands and the glaſs. The ſtreams of light paſs ſilently through the receiver, becauſe the air is removed, by whoſe vibration ſound is produced.

From ſome experiments made ſeveral years ſince by Mr. Wilſon, with an excellent air-pump

of

of Mr. Smeaton, he obferved, that very fmall differences of air occafioned very material differences in the luminous effects produced by the electric fluid; for when all the air was taken out of the receiver, which this pump at that time was capable of extracting, no electric light was vifible in the dark. Upon letting in a little air by a ftop-cock, a faint electric light was vifible, and by letting in a little more air increafed the light, which again decreafed on letting in more air; till at laft, on admitting great quantities, it intirely vanifhed. By this experiment it appeared, that a certain limited quantity of air was neceffary to occafion the greateft luminous effect.

EXPERIMENT CCI. — Fig. 82 reprefents an exhaufted receiver, ftanding on the plate of an air-pump, *a b* an electrified wire difcharging a ftream *b c* of the electric fluid on the plate of the air-pump. If the ftratum of air on the outfide of the receiver be leffened by the application of the finger to the receiver, and by this means an opportunity be given to the fluid on the outfide to efcape, the fluid within will be impelled to that part, as at *d e f*. It has been inferred from this experiment, that no repulfive power exifts between the particles of the electric fluid; becaufe, if it was in itfelf really elaftic, or endowed

endowed with a repulſive power of it's own, it is not probable it could paſs in an uninterrupted ſtream, as at *b c*, when the reſiſtance was taken off; it would then ſpread wider, and diſplay it's elaſtic power.

It is more conſiſtent, ſays Dr. Watſon, to ſuppoſe, that the repulſion of theſe particles, which is ſeen in the open air, is occaſioned by the reſiſtance of the air, and not by any natural tendency of the electricity itſelf.

By conſidering the experiments made with the electric fluid IN VACUO, we attain a clear idea of the reſiſtance the air continually makes to it's paſſage, and ſee that the divergence of it's rays is not to be attributed to an imaginary repulſion, but to the reſiſtance of the ambient air, for the divergence ceaſes, and the rays unite, when this reſiſtance is removed.

EXPERIMENT CCII.—Before the air was exhauſted from the receiver, if the wire at the top of it was electrified, a diverging bruſh proceeded from it, about an inch long, but little of the fluid paſſing off, and even that little requiring a ſtrong impulſive force to puſh it forward. On exhauſting the receiver the following changes took place: firſt, the rays of the bruſh became longer; ſecondly, the rays diverged lefs, were fewer in number, and the fize of the remaining rays was increafed; thirdly, they all united at laft, and formed a continued column of light, from the wire to the plate of the air-pump.

From this experiment it is clear, that the air is the agent by which, with the affiftance of other electrics, we are able to communicate electricity to electrics, as well as non-electrics; for when this is removed, the fluid pervades the vacuum, and flies off to a confiderable diftance.

EXPERIMENT CCIII.—To diftinguifh with great accuracy the changes in the form and length of the electric fpark when it is paffing through a receiver, the air of which is more or lefs rarified; fix a ball to the rod, let another proceed from the plate of the air-pump; the balls are to be placed about one inch from each other. When the vacuum is good, a fingle uniform ray, of a purple colour, paffes from one ball to the other; but in proportion as the air is admitted, the ray acquires a quivering motion, which indicates that a refiftance to it's motion then begins, and this interruption is followed by a divifion of the ray or ftream; the ray now acquires a more vivid light; and, laftly, it becomes the common fpark, which is emitted with greater or lefs facility, in proportion to the power of the machine, and the refiftance of the air.

EXPERIMENT CCIV.—Prefent a thin exhaufted flafk, fimilar to that reprefented at E, fig. 49, but without any coating on the outfide, to the conductor, and the bottle will be luminous from end to end, and when taken from the conductor, will continue luminous, moving in various curvilinear directions for a confiderable time, flafhing at intervals in a manner which very much refembles the Aurora Borealis. The light may be revived by paffing the flafk through the hand. The ftroke of the fluid againft the glafs is very fenfibly heard and felt in this experiment.

The flexuous motions of the electric fluid in an exhaufted receiver may, in fome degree, be produced at pleafure. By wetting the outfide of the receiver, the fire will follow the direction of the wetted line, as the refiftance is now leffened on one fide; and the fire can adhere and accumulate itfelf on the infide of the receiver, becaufe, by means of the dampnefs, it can expel a portion from the outfide.

This experiment may be exhibited very pleafingly, by making a Torricellian vacuum in a glaſs tube about three feet long, and then ſealed hermetically. Hold one end of this tube in the hand, and apply the other to the conductor, and immediately the whole tube will be illuminated from end to end, and will continue ſo for a conſiderable time after it is removed from the conductor, flaſhing at intervals for many hours.

EXPERIMENT CCV.—Screw on a ball, of about an inch diameter, to the rod of the plate of the collar of leather of an air-pump; place this on a tall receiver; connect the exterior part of the rod with the conductor; place ſome cylindrical pieces of metal on the plate of the pump, then exhauſt the receiver in part, and electrify the rod at intervals, and luminous jets of fire like fulminating meteors will fly from the ball to the cylinders of metal.

EXPERIMENT CCVI.—Another beautiful appearance may be produced in the dark, by inſerting a ſmall Leyden phial into the neck of a tall receiver, ſo that the outward coating may be expoſed to the vacuum. Exhauſt the receiver, and then charge the phial, and at every ſpark which paſſes from the conductor to the inſide, a flaſh of light is ſeen to dart from every part of the external ſurface of the jar, ſo as to fill the receiver.

receiver. Upon making the difcharge, the light is feen to return in a clofe body.

EXPERIMENT CCVII.—A very perfect vacuum for the paffage of the electric fluid may be made by a double barometer, or long bent tube of glafs filled with mercury and inverted, each leg ftanding in a bafon of mercury; the bent part of the tube above the mercury forms a complete vacuum. If a bottle is difcharged through this fpace, the light appears uniform through the whole fpace, but is moft vivid when the difcharges are ftrong. Dr. Watfon infulated this apparatus, and then made one of the bafons of mercury communicate with the conductor, and touched the other with a non-electric; the electric fluid pervaded the vacuum in a continued flame, without any divergence: when one of the bafons was connected with the infulated cufhion, the fire appeared to pervade the vacuum in a different direction.

EXPERIMENT CCVIII.—Fig. 83 reprefents a glafs tube, fuch as is generally ufed for barometers; on the end *b* a fteel cap is cemented, from which a wire and ball *c d* proceed into the tube. Fill this tube with quickfilver, and then, by fending up a large bubble of air, and repeatedly inverting the tube, free the quickfilver and iron ball

ball from air, according to the ordinary mode of filling barometers; then place a ſmall drop of æther on the quickſilver, and put the finger on the end of the glaſs tube, and then inſert the end *f* in a baſon of quickſilver, taking care not to remove the finger from the end of the tube, till the end is immerged half an inch under the ſilver. When the finger is removed, the quickſilver will deſcend, and the æther will expand itſelf, leſſen the vacuum, and depreſs the mercury in the tube; now preſent the metallic top of the tube to a large charged conductor, and a beautiful green ſpark will paſs from the ball to the quickſilver. By admitting a ſmall quantity of air into the vacuum, an appearance ſomething ſimilar to a falling ſtar is obtained. I am indebted for this valuable experiment to Mr. Morgan, of the Equitable Aſſurance Office.

EXPERIMENT CCIX.—Place the braſs cap of a well exhauſted receiver, at about half an inch from the prime conductor, ſo that when the machine is in action, ſparks may paſs from the conductor to the braſs cap of the receiver. Mr. Cavallo, in relating the circumſtances attending an experiment of this kind made by him, obſerves, that when the receiver was exhauſted, the ſpark paſſed from the cap to the plate of the

pump

pump through the receiver, illuminating it's whole cavity; that the vacuum became a better conductor of electricity in proportion as it was more perfect, and that the electric light was more equally diffused, but it was by no means faint when the receiver was exhausted to the utmost. The light changed according as the receiver was more or less exhausted. The appearances were as follows.

Degree of Rarefaction, as shewn by the Gage.	Appearances of the Electric Light within the Receiver.
Air rarified 40 times.	Light in large, long, but divided streams.
70	Fine diffused light of a white colour.
80 100 400	Beautiful diffused light inclining to red or purple, and filling the whole receiver.
When the gage shewed the utmost degreee of exhaustion,	A diffused light filled equally the receiver; it had hardly any reddish hue.*

See

* Phil. Transf. vol. lxxiii. part ii. p. 451.

See alſo EXPERIMENT 112, 113, 121, 122, of this Eſſay, for further obſervations on the appearance of the electric light IN VACUO.

CHAP.

CHAP. XV.

OF MEDICAL ELECTRICITY.

THE Abbé Nollet ſays, that he received more pleaſure when he diſcovered that the motion of fluids in capillary tubes and the inſenſible tranſpiration of animated bodies were augmented by electricity, than by any other diſcovery he had made; becauſe they ſeemed to promiſe ſuch abundant advantages to mankind, when properly applied by a ſkilful hand. But how much would this pleaſure have been augmented, if he had lived to ſee his hopes realized, and this branch of electricity obtain the ſame medical certainty as the bark in intermittents?

It is true, that like every other ſimple medicine which has proved beneficial to mankind, electricity met with much oppoſition from the intereſted views of ſome, and the ignorance of others; has been treated with contempt, and injured by miſplaced caution. I ſhall recommend to thoſe who thus oppoſe it, not to condemn a ſubject of which they are ignorant, but to hear the cauſe before they paſs ſentence; to take ſome pains to underſtand the nature of electricity; to learn to make the electrical machine act well, and then apply it for a few weeks to ſome of thoſe diſorders in which it has been adminiſtered with the greateſt ſucceſs; and there is no doubt but they would ſoon be convinced, that it deſerves a diſtinguiſhed rank in medicine, which is the offspring of philoſophy.

The ſcience of medicine and it's practitioners have been reproached with the inſtability and fluctuations of practice; at one time cold as the ice at Zembla, at another hot as the Torrid Zone; that they are led by faſhion, and influenced by prejudice. On this ground it has been predicted, that however great the benefits which may be derived from electricity, it would ſtill only laſt for the day of faſhion, and then be conſigned to oblivion. I muſt confeſs, that I cannot be of this opinion, nor eaſily led to think a ſet of men, whoſe judgment has been matured by learning and experience, will ever neglect an agent, which probably forms the moſt important part of our conſtitution. Electricity is an active principle, which is neither generated nor deſtroyed; which is every where, and always preſent, though latent and unobſerved; and is in motion by night and day, to maintain an equilibrium that is continually varying. To give

give one inſtance, among many, it has been ſhewn, that the rain that deſcends in a ſtorm is ſtrongly impregnated with electricity, and thus brings down what the heated vapours carried up into the air, till the deficiency of the earth is ſupplied from the ſuperfluity of the heavens. A variety of other cauſes concur to vary continually the equilibrium of this fluid; as the perpetual inteſtine and oſcillatory motion, which contributes ſo much towards carrying on the operations of nature. Further, if a particular portion of this fluid is diſtributed to every ſubſtance, then every alteration of it's capacity, which is continually changing by heat or cold, muſt move or operate on it.

As heat, or fire in action, is the firſt mover in the animal machine, and the chief active principle during it's exiſtence, and as electricity exhibits ſo many phænomena, which cannot be diſtinguiſhed from thoſe of fire, we are naturally led to conceive high ideas of the importance of this fluid to medicine. Though the vital ſtate of it is not to be eſtimated by the degree of heat, abſtractedly conſidered, becauſe the degree of heat only aſcertains the quantity which is acting in a peculiar manner.

It is known that this vivifying principle haſtens the vegetation of plants. Myrtle-trees, which were electrified, budded ſooner than others of the ſame kind and ſize, and in the ſame green-houſe. Seeds, daily electrified, have ſhot up, and grown more in three or four days than others of the ſame kind, and alike in all other circumſtances, have done in eleven or twelve days. In the ſame manner Mr. Achard has ſhewn, that it may be uſed as a ſupplement for heat, to hatch the chicken from the egg. The ſuppoſition of an ingenious writer is by no means improbable, that the vegetating power which is operating during the whole year in ever-greens, may ariſe from theſe trees having more reſin in their compoſition, than thoſe whoſe leaves fall in autumn, by which they are enabled to attract and retain thoſe juices which give them their continual verdure, and ſupply, in ſome degree, the abſence of ſolar heat. This may be inferred from their natural properties, and is confirmed by the ſtrong electric power poſſeſſed by their leaves. The ſame writer thinks, that the fluid collected in our electrical experiments is only thoſe ſolar rays that have been diſperſed in, and are arreſted by the earth; an idea which is ſtrongly corroborated by the obſervations made on atmoſpherical electricity, and by the deductions which have been made from the relative affinities of fire, light, and heat.

The agency of this fluid, and it's existence in animated nature, has been fully proved by the experiments that have been made on the Torpedo and the Gymnotus Electricus; for the similitude established between the electrical fluid of the Torpedo and that of nature at large, is such, that, in a physical sense, they may be considered as precisely the same. Mr. Hunter has well observed, says Sir J. Pringle, and I think he is the first who has made the observation, that the magnitude and number of the nerves bestowed on those electric organs in proportion to their size, must appear as extraordinary as their effects; and that, if we except the important organs of our senses, there is no part, even of the most perfect animal, which, for it's size, is more liberally supplied with nerves than the Torpedo: nor yet do these nerves of the electric organs seem necessary for any sensation that can belong to them: and with respect to action, Mr. Hunter observes, that there is no part of any animal, however strong and constant it's action may be, which enjoys so large a portion of them. If then it be probable, that these nerves are unnecessary for the purpose either of sensation or action, may we not conclude, that they are subservient to the formation, collection, and management of the electric fluid? especially, as it appears from

from Mr. Walſh's experiments, that the will of the animal commands the electric powers of it's organs. If theſe reflections are juſt, we may with ſome probability foretel, that no diſcovery of conſequence will ever be made by future phyſiologiſts concerning the nature of the nervous fluid, without acknowledging the lights they have borrowed from the experiments of Mr. Walſh upon the living Torpedo, and the diſſection of the dead animal by Mr. Hunter.*

A variety of curious facts clearly evince, that the electric fire is eſſentially connected with the human frame, and is continually exerting it's influence upon it. Add to this the eaſe with which the natural equilibrium is deſtroyed, and we may readily conceive, that any alteration in the quantity or intenſity of action of this powerful fluid will produce correſponding changes in the habit or health of the body: the following is a remarkable inſtance of the agency of the fluid in the human frame, and of the eaſe with which it is put in action. Mr. Brydone mentions a lady, who, on combing her hair in froſty weather in the dark, had ſometimes obſerved ſparks of fire to iſſue from it; this made him think

* Sir John Pringle's Diſcourſes, p. 84.

think of attempting to collect the electrical fire from hair alone, without the affiftance of any other electrical apparatus. To this end, he defired a young lady to ftand on wax, and comb her fifter's hair, who was fitting in a chair before her; foon after fhe had begun to comb, the young lady on the wax was furprifed to find her whole body electrified, and darting out fparks of fire againft every object that approached her. Her hair was ftrongly electrical, and affected an electrometer at a confiderable diftance. He charged a metallic conductor from it, and in the fpace of a few minutes collected a fufficient quantity of fire to kindle common fpirits, and, by means of a fmall jar, gave many fmart ftrokes to all the company.

Mr. Cavallo obtained, by means of a fmall condenfing plate, very fenfible figns of electricity from various parts of his own body, and the head of almoft any other perfon.

When the difcoveries in this fcience, fays Mr. Brydone, are further advanced, we may find, that what we call fenfibility of nerves, and many other difeafes, which are known only by name, are owing to the bodies being poffeffed of too large or too fmall a quantity of this fubtle fluid, which is perhaps the vehicle of all our feelings. It is known, that in damp and hazy weather,

when

when this fire is blunted and abſorbed by the humidity, it's activity is leſſened, and what is collected is ſoon diſſipated; then our ſpirits are more languid, and our ſenſibility is leſs acute. And in the fierce wind at Naples, when the air ſeems totally deprived of it, the whole ſyſtem is unſtrung, and the nerves ſeem to loſe both their tenſion and elaſticity, till the north-weſt wind awakens the activity of the animating power, which ſoon reſtores the tone, and enlivens all nature, which ſeemed to droop and languiſh in it's abſence: nor can this appear ſurpriſing, if it is from the different ſtate of this fire in the human body, that the ſtrictum and laxum proceeds, and not from any alteration in the fibres themſelves, or their being more or leſs braced up, (among which bracers cold has been reckoned one) though the muſcular parts of an animal are more braced when they are hot, and relaxed when they are cold.

Mr. Jalabert and Profeſſor Sauſſure, when paſſing the Alps, were caught among thunder-clouds, and found their bodies full of electrical fire; ſpontaneous flaſhes darting from their fingers, with a crackling noiſe, and the ſenſations they felt were the ſame as when ſtrongly electrified by art. It ſeems pretty evident, that thoſe feelings were owing to their bodies containing

taining too great a ſhare of electrical fire; and it is not improbable, that many of our invalids owe their feelings to the oppoſite cauſe.

The perpetual electricity of the atmoſphere is no longer a problem: the exiſtence and continual agency of it in that maſs of air which ſurrounds our globe has been aſcertained by numerous clear and deciſive experiments, and it ſeems by no means improper to infer, that this fluid cannot exiſt in the atmoſphere without exerting a certain influence on all the beings contained in it, and principally on organized bodies, among which man holds the higheſt rank.

EXPERIMENT CCX.—Paſs the charge of a large jar, or battery, from the head to the back of a mouſe; this, if the ſhock is ſufficiently ſtrong, will kill the animal. After it's death, make the diſcharge in the ſame manner, and the fluid will paſs viſibly over the body, and not through it; evincing, that the power or medium which tranſmitted the ſhock through the animal, is loſt with it's life. This experiment is taken from Mr. Cavallo's treatiſe on medical electricity. It's importance is ſelf-evident, and it certainly merits a further inveſtigation by thoſe who are acquainted with the animal œconomy, as well as electricity.

The following experiment ſhews, that the electric fluid paſſes through that ſeries of muſcles which form the ſhorteſt paſſage for it, and whoſe conducting power, or electric capacity, is moſt favourable to it.

Experiment ccxi.—Let A graſp a Leyden phial with his right hand, and touch, with a braſs rod held in his left hand, the naked right foot of B; let the left foot of B communicate by a braſs rod with the right foot of C; let D with his right hand hold the left ear of C, and touch the knob of the bottle with his left hand: A will feel the ſhock in the muſcles of the right hand and arm, of the thorax, and of the left hand and arm; B will feel the commotion in the muſcles of his right foot, right leg and thigh, and thoſe which are connected with the left thigh, leg, and foot, while C will perceive it in that ſeries which goes from the leg to the ear by which he communicates with D. The action of the fluid on the human body in the ſhock, is the ſame when it paſſes through ſimilar parts with the ſame denſity. It's action is more extenſive when the fire is denſeſt, and therefore moſt intenſe when it meets with any reſiſtance.

Aſſiſted by a ſurgeon, Beccaria made ſeveral experiments upon the effects produced by electricity on the muſcles in the left leg of a cock. The muſcles were ſtrongly contracted when a ſhock was paſſed through them, and the contraction was always accompanied by a ſudden and proportional ſwelling of the muſcles, excepting at the part where the membrane is inſerted, which ſeparates one muſcle from another, which was always depreſſed. The membrane which inveſted that part of the muſcle through which the fluid paſſed, became dry and wrinkled, and a vapour aroſe from that part; when one muſcle was contracted, a general contraction took place in thoſe that were contiguous to it, and they were a little convulſed after the ſhock.

In another inſtance, where the muſcle was relaxed and parted from the thigh, on paſſing the ſhock through it the muſcle contracted itſelf, and was drawn back into it's natural place, and could not be again diſplaced but by force; a circumſtance which ſtrongly manifeſts the power of electricity to give tone to a flaccid fibre. Indeed, when we conſider, ſays a very ſenſible writer, that the muſcles have been brought into action by the electric fire; that it has rendered palſied limbs plump, and reſtored a power of action and motion to many, whofe palfies did not arife from the fpinal marrow; is it not a convincing proof, that the vital fire is the caufe of mufcular motion, and that this is the fame with that which is collected by the electrical machine?*

As the fcience of medicine knows of no fpecific, fo we are not to fuppofe, that electricity will triumph over every diforder to which it is applied. It's fuccefs will be more or lefs extenfive, according to the difpofition of the fubject, and the talents of thofe who direct it; it cannot therefore appear furprifing, that many diforders have been refractory to it's powers, and others have only yielded in a fmall degree; or, that the progrefs of the cure has often been ftopped by the impatience, or prejudice, of the difeafed: but at the fame time, it muft be acknowledged, that even in it's infancy, when it had to combat againft fear, prejudice, and intereft, it's fuccefs was truly great: we have furely then the higheft reafon to expect a confiderable increafe of fuccefs, now that it is cultivated and promoted by profeffional men of the firft merit.

EXPERIMENT

* Dr. Cullen fays, that electricity, when properly applied, is one of the moft powerful ftimulants that can be ufed to act upon the nervous fyftem of animals.

EXPERIMENT CCXII.—This experiment ſhews, that the electric powers may be put in action by heat and cold. It was originally made by Mr. Canton. He procured ſome thin glaſs balls, of about an inch and a half diameter, with ſtems or tubes, about eight or nine inches in length, and electrified them, ſome poſitively on the inſide, others negatively, and then ſealed them hermetically; ſoon after he applied the naked balls to his electrometer, and could not obſerve the leaſt ſign of their being electrical; but holding them at the fire, at the diſtance of five or ſix inches, they became ſtrongly electrical in a ſhort time, and more ſo when they were cooling. Theſe balls would, every time they were heated, give the electric power to, or take it from other bodies, according to the plus or minus ſtate of it within them. Heating them frequently diminiſhed their power, but keeping one of them under water a week did not in the leaſt impair it. The balls retained their virtue above ſix years. The tourmalin and many other precious ſtones are alſo known to acquire electricity by heat. The tourmalin has always at the ſame time a poſitive and negative electricity; one ſide of it being in one ſtate, the other in the oppoſite. Theſe powers may be excited by friction and

by

by heat; nay, even by plunging it in boiling water.

EXPERIMENT CCXIII.—Inſulate a ſenſible mercurial thermometer, and place the bulb between two balls of wood, one affixed to the conductor, the other communicating with the ground, and the electric fluid, in paſſing between the two balls, will raiſe the mercury in the thermometer conſiderably. With a cylinder of about ſeven inches and a half in diameter, the fluid paſſing from a ball of lignum vitæ to a ball of beech, and thence to the ground, elevated the quickſilver in the thermometer, from 68° to 110°, repeatedly to 105. The thermometer was raiſed from 68° to 85°, by the fluid paſſing from a point of box to a point of lignum vitæ; from 67° to 100°, from a point of box to a ball of box; from 66° to 100°, from a ball of box to a braſs point; from 69° to 100°, from ball to ball; the bulb of the thermometer covered with flannel.

Mr. Morgan, in his examination of Dr. Crawford's Theory of Heat, was the firſt perſon who proved, that the mercury in the thermometer might be raiſed by electricity.

The public have long expected, that ſome ſyſtem of the application of Medical Electricity

would

would be produced; but the gentlemen, into whofe hands the chief practice has fallen, know the fallacy of fyftems too well to hazard any which is not built on experience.

In a fhort courfe of lectures which were read on this fubject lately by Mr. Birch, fomething like a fyftem was thrown out for the confideration of future electricians. The application of electricity to medicine was divided into three forms; namely, the fluid, the fpark or friction, and the fhock. The firft mode he confidered to act as a fedative, the fecond he ranked under the title of a ftimulant, and the laft as a deobftruent. As the diftinctions were the refult of many experiments and much obfervation, they may fafely be adopted for the prefent. That gentleman being now engaged in the practice of a great hofpital, where his electrical experiments have already gained fome reputation, we may hope the fcience will be more univerfally diffufed, and being taught under the cautious eye of public fcrutiny, we may truft it's merits will foon give it an eftablifhed rank in the art of healing.

From hence we may perceive, that in medicine, electricity is applicable to palfies, rheumatifms, intermittents; to fpafm, obftruction, and inflammation. In furgery it has confider-

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able ſcope for action; where contractions and ſprains, tumours, particularly of the glandular ſort, waſting of the muſcles, and other incidents, form a catalogue of viſible diſeaſes as diſtreſſing to the ſight of others as to the patients themſelves. The gout, and the ſcrophula, or king's evil, two diſeaſes which have tormented mankind, and been the diſgrace of medicine to the preſent time, are ranked among thoſe to which this remedy is applicable; and in the commencement of the complaints, I am informed, has been wonderfully ſucceſsful. To remove ill-placed fits of the gout, it ſhould ſeem to be a more rational application than any medicine, for it applies directly to the ſeat of the diſeaſe, with a power and rapidity unknown in phyſic, and perfectly manageable at diſcretion; and, as it is a remedy which applies to the underſtanding as well as to the feelings, I ſhould think it better worth the attention and contemplation of men of liberal education, than the compounding a medicine, in which they place little faith, or applying a plaiſter, in which they have none at all.

The ſucceſs of electricity, in relieving the ſufferings of mankind, has been conſiderably promoted, and it's operations rendered more rapid, ſenſible, and efficacious, by applying it in different

different manners and quantities to the human frame. The modes formerly uſed were the ſhock, ſpark, and ſometimes, though very ſeldom, ſimple electrification. Theſe modes are now varied, and their number augmented. The ſtream of the electric fluid may, without a ſhock, be made to paſs through any part of the body; it may alſo be thrown upon, or extracted from any part, and it's action in each caſe varied, by cauſing the fluid to paſs through materials which reſiſt it's paſſage in different degrees; it may be applied to the naked integuments, or to the ſkin covered with different reſiſting ſubſtances; and it's power may be rarified or condenſed, confined to one ſpot, or applied in a more diffuſive manner, at the diſcretion of the operator.

THE APPARATUS NECESSARY FOR THIS PURPOSE IS SIMPLE, AND CONSISTS OF THE FOLLOWING ARTICLES:

1. An electrical machine, with an inſulated cuſhion, properly conſtructed to afford a continued and ſtrong ſtream of the electrical fluid. (The machine repreſented in the plate which faces the title-page of this Eſſay, is the kind which Mr. Birch recommended to medical practitioners in his lectures.)

2. A ſtool with inſulating feet, or rather an arm chair fixed on a large inſulating ſtool. The inſide part of the back of the chair ſhould move on a hinge, that it may occaſionally let down to electrify conveniently the back of the patient: the arms of the chair ſhould alſo be made longer than uſual.

3. A Leyden bottle with an electrometer.

4. A pair of large directors, with glaſs handles, and wooden points.

5. A few glaſs tubes of different bores, ſome of them with capillary points.

To theſe may be added, an univerſal diſcharger on a large ſcale, a pair of ſmall directors with ſilver wires, and a pair of inſulating forceps.

Fig. 93 repreſents the directors; the handles are of glaſs. A is a braſs wire with a ball on it's end. The wire of one is bent, for the more conveniently throwing the electric fluid on the eye, &c. The balls may be unſcrewed from the wires, and the wooden point B ſcrewed in it's place, or the pointed end of the braſs wire may be uſed. The directors ſhould always be held by that extremity of the glaſs handle which is fartheſt from the braſs, and care ſhould be taken that the heat of the hand does not make them moiſt.

L and M, fig. 84, reprefent glafs tubes, through which fmall wires are made to pafs, to convey the fluid directly to the ear or throat.

Fig. 88 reprefents another glafs tube, of a larger fize, the end of which is capillary; a fmall quantity of rofe water, or any other fluid, is to be poured into this tube; then connect it with the prime conductor by a wire; turn the cylinder, and a fubdivided, gentle and refrefhing ftream of this fluid may be thrown on the patient.

Fig. 86 reprefents the electric forceps: fome gentlemen think it is a very convenient inftrument for communicating a fhock. It's ufe is evident from an infpection of the figure.

Fig. 85 is the medical bottle, furnifhed with an electrometer, to limit the force of the fhock, and enable the operator to give a fucceffive number of them of the fame force. C is a bent piece of glafs, on the upper part of which is cemented a brafs focket D, furnifhed with a fpring tube E; the wire F moves in this tube, fo that the ball G may be fet at a convenient diftance from the ball H. The end I of the bent piece of glafs is alfo furnifhed with a fpring tube, which flides upon the wire K, communicating with the infide of the bottle.

To ufe this bottle, place the ball H in contact with the conductor, or connect them together by by a wire, and then charge it in the usual manner. Now, if a wire proceeds from the ball L to the outside coating, the bottle will be discharged whenever the fluid has acquired sufficient force to pass through the space of air between the two balls; consequently the shock is stronger in proportion as the distance between the two balls is increased.

It is obvious, that when the electrometer is thus connected, it acts in the same manner as a common discharging rod, and forms the communication between the outside and the inside of the bottle; with this difference only, that the distance of the end which is to communicate with the inside may be limited and regulated.

It has been found more convenient, to separate the electrometer from the bottle, and apply it to the conductor: see in the frontispiece to this Essay, where *a*, *b*, represents the electrometer, *c*, *d*, the Leyden bottle, suspended at a small distance from it; a glass tube *e*, *f*, is fixed in this bottle, a small part of the lower end of which is coated; two wires pass through the brass ball C on the top of this tube, one of which goes down to the bottom of the exterior bottle, and touches it's internal coating, the other only goes to the coating of the tube: these wires may be removed at pleasure. The bottle is to be suspended

pended to the conductor by the ring, and a chain or wire is to be fixed to the hook *d*, at the bottom.

Fig. 119, pl. V. reprefents the bottle director, which is hollow and coated like a common bottle, acting in all refpects like one, but is convenient from it's fhape and fome other circumftances in giving fmall fhocks.

The handles of the directors fhould be carefully dried, as alfo the bent piece of glafs C, and thofe parts of the bottle which are above the coating. It is likewife neceffary to prefs the ends of the directors againft the part, to convey the fhock more readily.

Fig. 87 reprefents an univerfal difcharger upon a large fcale, with a patient fitting between the two pillars, one ball refting at A, the other being placed at B. The convenience of this apparatus is obvious, from an infpection of the figure; for as the joints have both an horizontal and vertical motion, and the wires pafs through two fpring fockets, they may therefore be placed in any direction, and the balls fixed in any required fituation. Hence, by connecting one wire with a pofitive conductor, and the other with a negative one; or one with the bottom of a Leyden bottle, and the other with the electrometer; the fhock or ftream may be conveyed to any part, with the greateſt facility. It is alſo evident, that a perſon may, by means of the two joints of this ſimple apparatus, electrify himſelf with eaſe, (or any patient, conveniently) without the aſſiſtance of any other perſon; that is, he may turn the machine with one hand, while he is receiving the fluid, or the ſhock, by means of this univerſal diſcharger. But this may alſo be readily effected, by faſtening a wire to one of the conductors, and pinning the other end of it to one extremity of the part through which you intend to paſs the ſhock, or convey the fluid; then connect a director with the other conductor, and hold it to the other extremity of the part. If the ſituation is ſuch as to occaſion the wires to touch the table, paſs a ſmall glaſs tube over them, which will prevent a diſſipation of the fire.

ELECTRICITY MAY BE APPLIED MEDICALLY IN THE FOLLOWING DIFFERENT MODES.

Firſt, By merely placing the patient in an inſulated chair, and connecting him with the prime conductor; when the machine is in action, he will be filled with the electric fluid, which will be continually diſſipated from the points and edges of his cloaths: and though the effects of this are probably too ſlow to be rendered very advan-

advantageous, yet a ſedentary perſon might perhaps derive ſome benefit from ſitting in an inſulated chair, having before him an inſulated table; the chair to be connected with the ball of a large charged jar or battery, by which means a ſmall quantity of the fluid will be continually paſſing through thoſe innumerable capillary veſſels, on the right ſtate of which our health ſo much depends.

2. BY THROWING THE FLUID UPON, OR EXTRACTING IT FROM A PATIENT, BY MEANS OF A WOODEN POINT.

This may be effected in a twofold manner: 1ſt, By inſulating the patient, and connecting him either with the cuſhion or the poſitive prime conductor, the operator preſenting the point. 2nd, Let the patient ſtand upon the ground, and the wire of the director be connected either with the poſitive or negative parts of the machine. The ſenſation produced by the fluid when acting in this manner, is mild and pleaſing, reſembling the ſoft breezes of a gentle wind; generating a genial warmth, and promoting the ſecretion and diſſipation of tumors, inflammations, &c.

3. By

3. By the Electric Friction.

Cover the part to be rubbed with woollen cloth or flannel. The patient may be feated in an infulated chair, and rubbed with the ball of a director that is in contact with the conductor: or he may be connected with the conductor, and rubbed with a brafs ball which commnnicates with the ground. The friction thus produced is evidently more penetrating, more active, and more powerful, than that which is communicated by the flefh brufh; and there is, I apprehend, very little fear of being thought too fanguine, if I affert, that this, when ufed but for a few minutes, will be found more efficacious than the other, after feveral hours application.—Electricity applies here with peculiar propriety to fpafm, pleurify, and fome ftages of the palfy, and in every cafe anfwers the end of bliftering where the difcharge is not wanted, being the moft fafe and powerful ftimulant we know.

4. By

4, By taking strong Sparks from the Patient.

Here, as in every other caſe, the operator may connect the ball of the director with the poſitive or negative conductor, or he may connect the patient with either of theſe and the ball with the ground; now it is clear from what has been already laid down, that if the director be connected with the poſitive conductor, the fluid is thrown upon the patient, if with the cuſhion the fluid is extracted from him. Let the patient be inſulated, and the action is in ſome meaſure reverſed; if he is joined to the negative conductor or cuſhion, he will receive a ſpark from a perſon ſtanding on the floor; but if he communicates with the poſitive conductor, he will give the ſpark to the perſon on the ground.

5. By causing a Current of the Electric Fluid to pass from one Part of the Body, and thus confining and concentrating it's Operation without communicating the Shock.

Place the patient in an inſulated chair, and touch one part of the body with a director, joined to a poſitive conductor; then with a braſs ball communicating with the ground, touch another part, and when the machine is in action the fluid will paſs through the required part, from the conductor to the ball; the force of the ſtream will be different according to the ſtrength of the machine, &c. Or connect one director with the cuſhion and the other with the poſitive conductor, and apply theſe to the part through which the fluid is to paſs, and when the machine is in action the electricity will paſs from one ball to the other. It is not neceſſary to inſulate the patient in this caſe.

6. By the Shock.

Which may be given to any part of the human body, by introducing that part of the body into the circuit which is made between the outſide and inſide of the bottle. This is conveniently effected, by connecting one director by a piece of wire with the electrometer, and the other with the outſide of the bottle; then hold the directors by their glaſs handles, and apply the balls of them to the extremity of the parts through which

which the ſhocks are to be paſſed. The force of the ſhock, as we have already obſerved, is augmented or diminiſhed by increaſing or leſſening the diſtance between the two balls, which muſt be regulated by the operator to the ſtrength and ſenſibility of the patient. When the little bottle with the glaſs tube is uſed as a common bottle, both wires are to be left there, and the ſhock is communicated by two directors, one connected with the bottom, the other with the top by means of the electrometer. (See the plate facing the title-page of this Eſſay.) The operator will often find himſelf embarraſſed in giving ſmall ſhocks, the fluid paſſing from the conductor to the ball of the electrometer, inſtead of going through the circuits he deſires: when this happens, which may be known by the chattering noiſe of the ſpark in paſſing to the electrometer, the reſiſtance formed to the diſcharge is ſo great, that the fluid cannot force it's way through the circuit; to remedy this, and leſſen the reſiſtance, paſs two metallic pins through the cloathing, ſo that they may be in contact with the ſkin, which will leſſen the reſiſtance and conduct the fluid.

7. BY A SENSATION BETWEEN A SHOCK AND THE SPARK, WHICH DOES NOT COMMUNICATE THAT DISAGREEABLE FEELING ATTENDING THE COMMON SHOCK.

This is effected by taking out the long wire from the fmall medical bottle, and leaving the fhorter one which is connected with the tube in it's place, the directors to be connected and ufed as before. In leffening this vibratory fhock the electrometer may be drawn to a much greater diftance; for the rapidity with which the charge of the bottle fends forward the charge of the tube, is fufficient to overcome the refiftance of a large body of air. The effect of this fpecies of fhock, if it may be called one, is to produce a great vibration in the mufcular fibres, without inducing that pungent fenfation which the fhock effects. It is therefore applicable to fome ftages of palfy and rheumatifm; it may alfo ferve as an artificial means of exercife.

8. BY THE BOTTLE DIRECTOR.

Infulate the patient, and place the ball *g* in contact with him, by which means this director is is charged. Now if a wire is conveyed from the bottom of this to the top of another director, the bottle director, fig. 119, plate V. will be difcharged whenever the ball *b* is brought in contact with the patient, fo that by bringing it down with rapidity any number of fmall fhocks may be procured in a minute. Or connect the infulated patient with the top or infide of a large charged jar, and then this apparatus ufed in the foregoing manner will difcharge, from the large jar at each fpark, it's own contents, and by repetition difcharge the whole jar; thus a number of fhocks may be given without continually turning the machine, or employing an affiftant.

9. By passing the whole Fluid contained in the Leyden Phial through a diseased Part without giving the Shock.

Connect a director, by means of a wire, with the ball of a Leyden jar; charge the jar either completely or partially, and then apply the ball or point of the conductor to the part intended to be electrified, and the fluid which was condenfed in the phial will be thrown on the part in a denfe flow ftream, attended with a pungent fenfation, which produces a confiderable degree of warmth. If a wire that communicates with the ground is placed oppoſite to the end of the director, the paſſage of the fluid will be rendered more rapid, and the ſenſation ſtronger. Or inſulate the patient, connect him with the top of a jar, charge this, and then apply a metal wire or piece of wood to the part through which you mean to make the fluid paſs. It is obvious, that in this caſe the circuit between the inſide and the outſide of the jar is not completed, therefore the ſhock will not be felt. The condenſed fluid paſſes in a denſe ſlow ſtream through the required part, while the outſide acquires a ſufficient quantity from ſubſtances near it to reſtore the equilibrium.

It is in all caſes moſt adviſable to begin with the more gentle operations, and proceed gradually to increaſe the force, as the ſtrength and conſtitution of the patient, or the nature of the diſorder requires. The ſtream from a wooden point, a wooden ball, or braſs point, may be firſt uſed; ſparks, if neceſſary, may then be taken, or ſmall ſhocks given.

In rheumatic caſes, the electric friction is generally uſed. If the pains are local, ſmall ſhocks may be given. To relieve the tooth-ach, very ſmall ſhocks may be paſſed through the tooth; or, cover the part affected with flannel,

and

and rub it with a director, communicating with the machine.

In inflammations, and other diſorders of the eyes, the fluid ſhould be thrown from a wooden point: the ſenſation here produced is that of a gentle cooling wind; but, at the ſame time, it generates a genial warmth in the part affected.

In palſies, the electric friction and ſmall ſhocks are adminiſtered. Streams of the fluid ſhould always be made to paſs through the affected part.

The only treatiſe we have yet had from the Faculty, on the ſubject of Medical Electricity, is a pamphlet intitled, "Conſiderations on the Efficacy of Electricity in removing Female Obſtructions," by Mr. Birch; to whom I am indebted for a variety of important obſervations and practical remarks on the different branches of electricity; and if it's merits were to be confined to this diſeaſe alone, (in which it may be reckoned a ſpecific) it would be intitled to the attention of practitioners; but we have reaſon to expect much more from it, ſince the prejudices of the Faculty ſeem removed, and the practice is becoming more general every day.

CHAP.

CHAP. XVI.

Miscellaneous Experiments and Observations.

THE diſpute concerning the preferable utility of pointed or knobbed conductors, for ſecuring buildings from lightning, occaſioned the ſetting up a more magnificent apparatus than had ever appeared before. An immenſe conductor was conſtructed, at the expence of the Board of Ordnance, and ſuſpended in the Pantheon, under the direction of Mr. Wilſon. It conſiſted of a great number of drums covered with tin-foil, which formed a cylinder of about 155 feet in length, and more than 16 inches in diameter; and to this vaſt conductor were occaſionally added 4800 yards of wire. The electric blaſt from this machine fired gun-powder in the moſt unfavourable circumſtances, namely, when it was drawn off by a ſharp point. The method of doing it was as follows: upon a ſtaff of baked wood a ſtem of braſs was fixed, which terminated in an iron point at the top; this point was put into the end of a ſmall tube of India-paper, made ſomewhat in the form of a cartridge,

tridge, about an inch and a quarter long, and two tenths of an inch in diameter, when the cartridge was filled with common gun-powder unbruifed; a wire, communicating with the earth, was then faftened to the bottom of the brafs ftem. The charge of the great cylinder being continually kept up by the motion of the wheel, the top of the cartridge was brought very near the drums, fo that it frequently touched the tin-foil with which they were covered. In this fituation, a fmall, faint, luminous ftream was frequently obferved between the top of the cartridge and the metal. Sometimes this ftream would fet fire to the gun-powder the moment it was applied; at others, it would require half a minute or more before it took effect. This difference in time was fuppofed to be owing to fome fmall degree of moifture in the powder, or the paper.

Gun-powder may alfo be fired by a ftream from a large charged Leyden jar, in the following manner:

EXPERIMENT CCXIV.—Fix a fmall cartridge on a metallic point, which is fitted to a wooden or glafs handle; make a communication from the wire to the ground, then prefent the cartridge to the knob of the phial, and the gun-powder will be fired by the paſſage of the electric ſtream through the cartridge. Tinder, or touch-wood, placed in a metal cup, may be lighted by paſſing the ſtream from the inſide of the jar through them, as in the foregoing experiment, without completing the circuit.

As it therefore appears, that the electric fluid, when it moves through bodies, either with great rapidity, or in great quantities, will ſet them on fire, it is ſcarce diſputable, that this fluid is the ſame with the element of fire.

EXPERIMENT CCXV.—To fire the ſmall electrical cannon, charge it with gun-powder in the uſual manner, then fill the ivory touch-hole with gun-powder, ram it well down, and puſh the braſs pin down, ſo that the end of it may be near the bottom of the hole; make a communication between the outſide of a large charged jar or battery and the body of the cannon, by placing one end of the diſcharging rod on the pin which paſſes down the touch-hole, and bring the other end to the knob of the jar, and the diſcharge will fire the powder.

EXPERIMENT CCXVI.—Fig. 89 is a perſpective view of the powder-houſe; the ſide of the roof next the eye being omitted, that the inſide may be be more conveniently ſeen. The front of this model is fitted up like the thunder-houſe, and is uſed in the ſame manner; the ſides of the houſe, the back, and fore-front, are joined to the bottom by hinges; the roof is divided into two parts, which are alſo faſtened by hinges to the ſides; the building is kept together by a ridge on the roof; when the roof is blown up, it will fall down with the ſides, the back, and fore-front. To uſe this model, fill the ſmall tube *a* with gun-powder, and ram the wire *c* a ſmall way in the tube, then connect the hook *e* with the bottom of a large jar or battery; when the jar is charged, form a communication from the hook *d* to the top of the jar; the diſcharge will fire the powder, and the exploſion of the gun-powder will throw off the roof, and the ſides, the fore and back fronts will then all fall down.

Fig. 90 repreſents a wooden pyramid, deſigned to ſhew the experiments which are made with the thunder-houſe, and is uſed in the ſame manner. When the piece *a* is thrown out by the diſcharge, the upper part of the pyramid falls down.

EXPERIMENT CCXVII.—Fix the ladle I, fig. 33, into a hole at the end of the conductor. Place a broad piece of camphor in the ladle, ſet the upper ſurface of the camphor on fire, let it burn ſome time, then extinguiſh it, and put the machine in action; the upper ſurface of the camphor will throw out a variety of ſmall ſhoots, and have the appearance of an imperfect vegetation, which is ſoon diſperſed in the air if the machine is continued in action, but will laſt ſome time if the electrization is ſtopped as ſoon as the ſhooting of the camphor has taken place.

EXPERIMENT CCXVIII.—Wrap ſome looſe cotton, which has been previouſly rolled in fine powder of yellow reſin, round one of the balls of a diſcharging rod, and hold the other end to the outward coating of a charged jar; then bring the knob with the reſin towards the ball of the jar, and the exploſion will fire the reſin, and this will communicate the flame to the cotton.

Fig. 91 repreſents the inflammable air lamp, invented by Mr. Volta. A is a glaſs globe to contain the inflammable air, B a glaſs baſon, or reſervoir, to hold water; D is a cock, which is to form occaſionally a communication between the reſervoir of water B, and that of air A; the water paſſes into the latter through the metal pipe *g g*, which is fixed to the upper part of the reſervoir refervoir A; as *s* is a fmall cock, to cut off, or open a communication with, the air in the ball, and the jet K. N is a fmall pipe to hold a piece of wax taper, L a brafs pillar, on the top of which is a brafs ball; *a* is a pillar of glafs, furnifhed at top with a focket; a wire *b* flides in this focket, a ball is fcrewed on to the end of the wire. F is a cock, by which the ball A is filled with inflammable air, and which afterwards ferves to confine the air and the water that falls from the bafon B into the ball A.

To ufe this inftrument, after having filled the refervoir A with pure inflammable air, and the bafon with water, turn the cocks D and S, and the water which falls from the bafon B will force out fome of the inflammable air, and caufe it to pafs through the jet K into the air. If an electric fpark is made to pafs from the brafs ball *m* to the brafs ball *n*, the inflammable jet, which paffes through the pipe K, will be fired. To extinguifh the lamp, fhut firft the cock S, and then the cock D.

To fill the refervoir A a with inflammable air, which is to be made in the ufual manner, and with the ufual apparatus, having previoufly filled A with water, place the foot R under water, on a board or ftool in a large tub of water, that the bent glafs tube, through which the inflammable

air

air paffes, may pafs commodioufly under the foot of the lamp; when the air has nearly driven out all the water, turn the cock F, and the apparatus is ready for ufe. This inftrument is convenient to preferve a quantity of inflammable air ready for any occafional experiment, as charging the inflammable air piftol, &c. It is alfo convenient to light a candle for œconomical purpofes, as the fmalleft fpark from an electrophorus, or a fmall bottle, is fufficient to fire the air.

A fmall battery of inflammable air piftols is occafionally made, that affords confiderable amufement; as either one piftol, or the whole together, may be fired at the pleafure of the operator.

The following experiment was made by Mr. Kinnerfly with his electrical thermometer, which is defcribed in page 48 of this Effay.

EXPERIMENT CCXIX.—Having put fome tinged water into the large tube, he placed the two wires within the tube in contact, and paffed a large charge of electricity from above thirty fquare feet of coated glafs, which produced no rarefaction in the air, and fhewed that the wires were not heated by the fire paffing through them. When the wires were about two inches afunder, the charge of a three-pint bottle, darting from one to the other, rarefied the air very evidently. The charge of a jar, which contained about five gallons and a half, darting from wire to wire, occafioned a very confiderable expanfion in the air; and the charge of a battery of thirty fquare feet of coated glafs would raife the water in the fmall tube quite to the top: upon the coalefcing of the air, the column of water inftantly fubfided, till it was in equilibrio with the rarefied air; then gradually defcending as the air cooled, fettled where it ftood before. By carefully obferving at what height the defcending water firft ftopped, the degree of rarefaction might be eafily difcovered.

EXPERIMENT CCXX.—Take a glafs tube, about four inches long, one quarter of an inch in diameter, and open at both ends; moiften the infide of the tube with oil of tartar per deliquium, then fix two pieces of cork into the ends of the tube, and pafs a wire through each cork, fo that the ends of the wires which are within the tube may be about three quarters of an inch afunder. Connect one wire with the outfide coating of a large jar, and form a communication from the other to the ball of the jar, fo as to pafs the difcharge through the tube; repeat this feveral

times,

times, and the oil of tartar will very often give manifeſt ſigns of cryſtalization.*

EXPERIMENT CCXXI.—Charge a Leyden phial, (the top of which is cemented into the bottle) place it upon an inſulated ſtand, and then take hold of it by the ball, and preſent the coated ſurface towards the condenſing ball of a prime conductor while the cylinder is charging, and a large bruſh and ſpark will paſs between the coating of the bottle and the ball of the conductor, from four to twelve inches and upwards in length.

EXPERIMENT CCXXII.—Take ſome of the powder of Canton's phoſphorus, and by means of a little ſpirit of wine, ſtick it all over the inſide of a clean glaſs phial, then ſtop the bottle, and keep it from the light. To illuminate this phoſphorus, draw ſeveral ſtrong ſparks from the conductor, keeping the phial about two or three inches from the ſparks, ſo that it may be expoſed to their light; the phial will afterwards appear lúminous, and remain ſo for a conſiderable time.

EXPERIMENT

* Cavallo on Medical Electricity, p. 117.

EXPERIMENT CCXXIII.—Cut out in paſteboard, or ſoft wood, the figure of a creſcent or any of the planets; cover this equally with the white of an egg beat up till it is quite ſmooth, over which ſift the phoſphorus through a fine lawn ſieve, then let it dry, and blow off all that is not fixed by the egg. To make the experiment, place the object in the communication between two directors, and diſcharge the jar, when the whole will become beautifully luminous; care muſt however be taken to hold the directors at a little diſtance above the phoſphorus, for if it paſſes through it, the whole of the powder in the track of the fluid will be torn off.

Place a ſmall key on the phoſphorus, and diſcharge a Leyden phial over the phoſphorus, and then throw the key off from it, and when it is exhibited in the dark, the form of the key and all it's wards will be perfectly ſeen.

As the experiments on phoſphorus are in themſelves exceedingly curious, and appear to me to be intimately connected with the nature of electricity, I hope I ſhall not be thought to have deviated too far from the ſubject of this Eſſay, by introducing ſome experiments of Mr. Wilſon on this ſubject; the more ſo, as the producing the priſmatic colours is by no means difficult, as little more is required than a few oyſter-ſhells, and a good fire of any kind. For, if thoſe ſhells are thrown careleſsly into the middle of the fire, and continued there for a proper time, (which may be for ten minutes, a quarter, half, or three quarters of an hour, according to the thickneſs and compactneſs of the ſhells, and the degree of fire they are expoſed to) they will exhibit lively priſmatic colours, after they are removed from the ſun into the dark ſuddenly, and the eyes have been previouſly prepared a little to receive them. Mr. Wilſon excited alſo the light of theſe ſhells with electricity in the following manner.

EXPERIMENT CCXXIV.—He placed upon a metal ſtand, which was rounded at top, and about half an inch in diameter, a prepared ſhell, that would exhibit the priſmatic colours very lively on the upper ſurface of this ſhell, and near the middle, where the colour-making parts predominated, he brought the end of a metal rod, and then connected the two metals properly with the coatings of a charged phial, in order to diſcharge the fluid. In this circuit there was left, deſignedly, an interval of about three inches, unoccupied by metal, and next one ſide of the glaſs; the diſcharge was made by completing the circuit

cuit with metal where the interval was left. The ſhell, at that inſtant, was lighted up to an exceeding great advantage, ſo that all the colours appeared perfectly diſtinct, and in their reſpective places, anſwering to their different colour-making parts. Theſe colours continued viſible ſeveral minutes, and when they ceaſed to appear, a white purpliſh light occupied their places, which laſted for a conſiderable time. And notwithſtanding this experiment was repeated with the ſame and other ſhells, the colours continued in their reſpective places, and nearly of the ſame degree of brilliancy; excepting, that in or near thoſe parts where the exploſion took place a few ſcales were driven off.

EXPERIMENT CCXXV. — Which proves, that bodies of the ſame nature, but of different volumes and different maſſes, are charged with electrical matter only in proportion to their ſurface, without any influence or concurrence of their maſſes in this caſe.

The following experiment, which we ſhall give in Mr. Achard's own words, ſeems to decide this queſtion, on which philoſophers have entertained very different opinions.

I electrified (ſays he) a cylindrical, hollow braſs conductor, ſeven inches long, and one and a half in diameter: when it had acquired forty degrees of electricity, I drew from it a ſpark, with a conductor of hollow braſs, of ſeven inches long, and one and a half in diameter, which weighed eight ounces, and was carefully inſulated. The firſt conductor loſt fifteen degrees of it's electricity. I repeated the ſame experiment, when the conductor had thirty degrees of electricity, and then it loſt ten degrees. Finally, when the conductor had twenty degrees of electricity, it loſt only ſeven by it's inſtantaneous contact with the ſame cylinder. After having filled this cylinder with lead, which produced an addition of five pounds to it's weight, and conſequently to it's maſs, I repeated the ſame experiments, and obtained from them the very ſame reſults.

This is followed by other experiments, which are a further confirmation of Mr. Achard's opinion.

Theſe experiments ſhew, 1ſt, That bodies of an equal ſurface, but different in maſs, when they are placed in the ſame circumſtances, are charged with an equal quantity of electrical matter; and 2dly, That bodies equal in maſs, but different in extent of ſurface, when they are placed in ſimilar circumſtances, are charged with an unequal quantity of electrical matter,

and

and that the body, whoſe ſurface is larger, receives more than that whoſe ſurface is leſs. Therefore, it is in proportion to their ſurfaces, and not to their maſs, that bodies are charged with a greater or leſs quantity of the electrical fluid.

Before theſe experiments were made, it had been obſerved, that the extreme ſubtility, and, in moſt caſes, inviſibility of the electric fluid, render all reaſoning about it's motion precarious. It is however incredible, that this fluid, ſhould paſs through the very ſubſtance of metallic bodies, and not be retarded by their ſolid particles. In thoſe caſes, where the ſolid parts of metals are evidently penetrated, i. e. when wires are exploded, there is a manifeſt reſiſtance, for the parts of the wire are ſcattered about with violence in all directions.

The like happened in Dr. Prieſtley's circles, made on ſmooth pieces of metal. Part of the metal was alſo diſperſed and thrown off, for the circular ſpots were compoſed of little cavities. If therefore the fluid was diſperſed throughout the ſubſtance, and not over the ſurface of the metal, it is plain, that a wire, whoſe diameter is equal to one of thoſe circular ſpots, ought alſo to have been deſtroyed by an exploſion of equal ſtrength ſent through it; whereas a wire, whoſe

diameter

diameter is equal to one of thofe fpots, would without injury conduct a fhock much greater than any battery hitherto conftructed could give. It is moft probable, therefore, that though violent flafhes of electricity, which act alfo as fire, will enter into the fubftance of metals and confume them, yet it immediately difperfes itfelf over their furface, without entering their fubftance any more, till being forced to collect itfelf into a narrow compafs, it again acts as fire.

In many cafes the electric fluid will be conducted very well by metals reduced to a mere furface. A piece of white paper will not conduct a fhock, without being torn to pieces, as it is an electric fubftance; but a line drawn on it with a black-lead pencil will fafely convey the charge of feveral jars. It is impoffible we can think, that the fire here paffes through the SUBSTANCE or the black lead ftroke; it muft run over it's furface; and if we confider fome of the properties of metals, we fhall find that there is great reafon to fuppofe, that their conducting power lies in their furface.

Fig. 92 reprefents a fmall glafs tube, ftopped at one end with a piece of cork; *k* is a wire which paffes through a piece of cork, fitted into the other end of the tube; the upper part of the wire is furnifhed with a brafs ball; the end of the

the wire within the tube is bent at right angles to the reſt of the wire.

EXPERIMENT CCXXVI.—Take out the upper cork and wire; pour ſome ſallad oil into this tube, and then fit in the cork, and puſh down the wire, ſo that the end of it may be near or rather below the ſurface of the oil; preſent the ball towards a prime conductor, holding the finger or any other non-conductor oppoſite the bent end of the wire, and when a ſpark paſſes from the conductor to the braſs ball, another will paſs from the end of the wire, and perforate the glaſs; the oil will be curiouſly agitated.

This experiment appears more beautiful when it is made in the dark. After the firſt hole is made, turn the end of the wire round towards another part of the glaſs tube, and a ſecond hole may be made in the ſame manner. This experiment was communicated to me by the Rev. Mr. Morgan, of Norwich, who has carried it much farther, by filling ſmall bottles with cement, and then paſſing the ſhock in a ſimilar mode through them. The perforation may be made with water in the tube inſtead of oil.

Mr. Lullen produces very conſiderable effects by paſſing the ſhock through wires that were inferted in tubes filled with oil. The fpark appears larger in it's paffage through oil, than when it paffes through water.

Mr. Vilette filled a difh of metal with oil, and when he had electrified the difh, he plunged a needle into the oil, and received a very ftrong fpark as foon as the point of it came within a fmall diftance of the difh. A fmall cork ball being made to fwim in this oil, upon the approach of the thick end of the ftalk of a lime, it plunged to the bottom, and immediately rofe up again.

Analogous to this experiment of Mr. Morgan are fome obfervations of Dr. Prieftley, who conftantly found, that whenever he had covered the fractured place of a jar with any kind of cement or varnifh, it always broke at the place where the cement terminated; there the glafs was perforated, and a new fracture was made, which had no communication with the former. The jar always broke at the firft charge, generally before it had received half it's charge. Struck with this phænomenon, the Doctor proceeded to try the experiment on a jar which was not broken, and whofe ftrength he had previoufly afcertained by repeated difcharges: he took off a little of the outfide coating, and put on the glafs a patch of cement, about an inch in diameter, then drawing

drawing the coating over it, he charged the jar; but before it had received half it's charge, it burſt by a ſpontaneous exploſion, not indeed at the termination, but at the middle of the patch of cement, where the glaſs was thinneſt. He covered another entirely with cement, and it broke near the bottom, where the glaſs is generally thickeſt. A jar that was covered entirely both inſide and outſide with cement, and then coated with tin-foil, burſt at the very firſt attempt to charge it.

EXPERIMENT CCXXVII.—The magic picture is a COATED pane of glaſs, proper to anſwer the purpoſe of the Leyden experiment; over the coating on one ſide is paſted a picture, on the other ſide a piece of white paper is paſted, ſo as to cover the whole glaſs; it is then put into a frame, with the picture uppermoſt, and a communication is formed from the tin-foil of the under ſide to the bottom rail of the frame of the picture, which rail is covered with tin-foil.

Lay the picture on the table, with the print uppermoſt, and a piece of money on it; let a chain fall from the conductor to the print, turn the cylinder, and the plate of glaſs will ſoon be charged; now take hold of the picture by the top rail, and let another perſon take hold

 of

of the bottom rail, and endeavour to take off the piece of money; in doing this they will receive a ſhock, and generally fail in the attempt.

EXPERIMENT CCXXVIII.—Put a quantity of braſs duſt into a coated jar, and when it is charged invert it, and throw ſome of the duſt out, which will be ſpread in an equable and uniform manner on any flat ſurface, and fall juſt like rain or ſnow. May it not be queſtioned, ſays an ingenious writer, whether water, falling from the higheſt region of the clouded atmoſphere, would not meet the earth in much larger drops, or in cataracts, if the coaleſcing power of the drops was not counteracted by their electric atmoſpheres?

EXPERIMENT CCXXIX.—Place a piece of ſmoking wax-taper on the prime conductor; turn the cylinder; the volume of ſmoke will become more contracted, and it's motion upward accelerated. Take off the electricity of the conductor, and ſuſpend a pair of pith balls over it, and about five feet diſtance from it, turn the machine, and in a few ſeconds the balls will open half an inch; remove the taper, and the balls will not ſeparate.

This

This experiment, therefore, clearly evinces, that ſmoke is a conductor of electricity.

EXPERIMENT CCXXX.—Take a round board, well varniſhed, and lay on it a chain in a ſpiral form; let the interior end of the chain paſs through the board, and connect it with the coating of a large jar; fix the exterior end to a diſcharging rod, and then diſcharge the jar; a beautiful ſpark will be ſeen at every link of the chain. The illuminations to be produced by a chain are capable of an infinite variety of modifications.

EXPERIMENT CCXXXI.—Place ſpots of tin-foil at equal diſtances from each other, on a piece of bent glaſs, and let the ends of the glaſs be furniſhed with braſs balls, and a glaſs handle be fixed to the middle of the bent glaſs. The inſtrument will ſerve as a diſcharger, and at the ſame time exhibit, at each ſeparation of the tin-foil, the electric light.

I made ſeveral of theſe luminous diſcharging rods, many years ſince, in order to ſhew, that the electric fluid iſſues from the negative and poſitive coating of each diſcharge, agreeable to the idea conveyed by Mr. Atwood's experiments; ſee Exp. 120, 121, 122, of this Eſſay. But I ſoon found, that the circuit of a diſcharging rod was not ſufficiently extenſive for the purpoſe.

EXPERIMENT CCXXXII.—Fig. 98 repreſents ſeveral ſpiral tubes, placed round a board; a glaſs pillar is fixed to the board, and on this pillar is cemented a metal cap, carrying a ſmall ſteel point; a braſs wire, furniſhed with a ball at each end, and nicely ballanced, is placed on this point: place the middle of this wire under a ball proceeding from the conductor, ſo that it may receive a continued ſpark from the ball, then give the wire a rotative motion, and the balls in revolving will give a ſpark to each ball of the ſpiral tube, which will be communicated from thence to the board; forming, from the brilliancy of the light and it's rapid motion, a very pleaſing experiment.

All theſe experiments on the interrupted ſpark may be pleaſingly and beautifully varied, and the ſpark made to appear of different colours, at the pleaſure of the operator.

EXPERIMENT CCXXXIII.—Suſpend a light cork ball, which is covered over with tin-foil or gold-leaf, by a pretty long ſilk thread, ſo as juſt to touch the knob of a charged jar placed on a table; it will be firſt attracted and then repelled to

ſome

ſome diſtance, where, after a few vibrations, it will remain at reſt. If a lighted candle is now placed at ſome diſtance behind it, ſo that the flame of the candle may be nearly as high as the knob of the phial, the cork will inſtantly be agitated, and, after ſome irregular motions, will deſcribe a curve round the knob of the phial, and this it will continue to do for ſome time.

Fig. 96 and 97 repreſent an electrometer, nearly ſimilar to that contrived by Mr. Brooke. The two inſtruments are ſometimes combined in one, or uſed ſeparately, as in theſe figures. The arms F H f k, fig. 97, when in uſe, are to be placed as much as poſſible out of the atmoſphere of a jar, battery, prime conductor, &c. The arm F H and the ball K are made of copper, and as light as poſſible. The diviſions on the arm F H are each of them exactly a grain. They are aſcertained at firſt by placing grain weights on a braſs ball which is within the ball L, (this ball is an exact counterballance to the arm F H and the ball K when the ſmall ſlide r is at the firſt diviſion) and then removing the ſlide r till it, together with the ball K, counterballances the ball L and the weight laid on it.

A, fig. 69, is a dial-plate, divided into 90 equal parts. The index of this plate is carried once round, when the arm B C has moved through

through 90 degrees, or a quarter of a circle. That motion is given to the index by the repulſive power of the charge acting between the ball D and the ball B.*

The arm B C being repelled, ſhews when the charge is increaſing, and the arm F H ſhews what this repulſive power is between two balls of this ſize in grains, according to the number the weight reſts at when lifted up by the repulſive power of the charge: at the ſame time the arm B C points out the number of degrees to which the ball B is repelled; ſo that by repeated trials, the number of degrees, anſwering to a given number of grains, may be aſcertained, and a table formed from theſe experiments, by which means the electrometer, fig. 96, may be uſed without that of fig. 97.

Mr. Brooke thinks that no glaſs, charged (as we call it) with electricity, will bear a greater force, than that whoſe repulſive power, between two balls of the ſize he uſed, is equal to ſixty grains; that in very few inſtances it will ſtand ſixty grains weight; and he thinks it hazardous to go more than forty-five grains.

Hence, by knowing the quantity of coated ſurface, and the diameter of the balls, we may be enabled to ſay, ſo much coated ſurface, with a repulſion

* Phil. Tranſ. vol. 82, p. 384.

a repulſion between balls of ſo many grains, will melt a wire of ſuch a ſize, or kill ſuch an animal, &c.

Mr. Brooke thinks, that he is not acquainted with all the advantages of this electrometer; but that it is clear, it ſpeaks a language which may be univerſally underſtood, which no other will do; for though other electrometers will ſhew whether a charge is greater or leſs, by an index being repelled to greater or ſmaller diſtances, or by the charge exploding at different diſtances, yet the power of the charge is by no means aſcertained: but this electrometer ſhews the force of the repulſive power in grains; and the accuracy of the inſtrument is eaſily proved, by placing the weights on the internal ball, and ſeeing that they coincide with the diviſions on the arm F H, when the ſlide is removed to them.

Mr. Achard has ſhewn clearly, that if the ſcale of an electrometer is divided into equal parts, (degrees for example) the angle at which the index is held ſuſpended by the electric repulſion will not be a true meaſure of the repulſive force; to eſtimate which truly, he demonſtrates that the arc of the electrometer ſhould be divided according to a ſcale of arcs, the tangents of which are in arithmetical progreſſion.

OBSERVATIONS AND EXPERIMENTS MADE BY DR. PRIESTLEY ON THE EFFECTS OF ELECTRICITY ON DIFFERENT ELASTIC FLUIDS.

EXPERIMENT CCXXIV.—To change the blue colour of liquors, tinged with vegetable juices, red. The apparatus for this purpoſe is ſeen in fig. 94. A B is a glaſs tube, about four or five inches long, and one or two tenths of an inch diameter in the inſide; a piece of wire is put into one end of the tube, and fixed there with cement; a braſs ball is placed on the top of this wire; the lower part of the tube from *a* is to be filled with water, tinged blue with a piece of turnſole or archal. This is eaſily effected, by ſetting the tube in a veſſel of the tinged water, then placing it under a receiver on the plate of the air-pump; exhauſt the receiver in part, and then, on letting in the air, the tinged liquor will riſe in the tube, and the elevation will be in proportion to the accuracy of the vacuum; now take the tube and veſſel from under the receiver, and throw ſtrong ſparks on the braſs ball from the prime conductor.

When Dr. Prieſtley made this experiment, he perceived, that after the electric ſpark had been

been taken, between the wire *b* and the liquor at *a*, about a minute, the upper part of it began to look red; in two minutes it was manifeftly fo, and the red part did not readily mix with the liquor. If the tube was inclined when the fparks were taken, the rednefs extended twice as far on the lower fide as on the upper. In proportion as the liquor became red, it advanced nearer to the wire, fo that the air in which the fparks were taken was diminifhed; the diameter amounted to about one fifth of the whole fpace; after which, a continuance of the electrification produced no fenfible effect.

To determine, whether the caufe of the change of colour was in the air, or in the electric matter, Dr. Prieftley expanded the air in the tube, by means of an air-pump, till it expelled all the liquor, and admitted frefh blue liquor in it's place; but after this, electricity produced no fenfible effect on the air or on the liquor; fo that it was clear, that the electric matter had difcompofed the air, and made it depofit fomething of an acid nature. The refult was the fame with wires of different metals. It was alfo the fame when, by means of a bent tube, the fpark was made to pafs from the liquor in one leg, to the liquor in the other. The air thus diminifhed was in the higheft degree noxious.

In paſſing the electric ſpark through different elaſtic fluids, it appears of different colours. In fixed air, the ſpark is very white; in inflammable and alkaline air, it appears of a purple or red colour. From hence we may infer, that the conducting power of theſe airs is different, and that fixed air is a more perfect non-conductor than inflammable air.

The ſpark was not viſible in air from a cauſtic alkali, made by Mr. Lane, nor in air from ſpirit of ſalt; ſo that they ſeem to be more perfect conductors of electricity than water, or other fluid ſubſtances.

The electric ſpark, taken in any kind of oil, produces inflammable air. Dr. Prieſtley tried it with ether, oil of olives, oil of turpentine, and eſſential oil of mint, taking the electric ſpark in them without any air to begin with; inflammable air was produced in them all.

Dr. Prieſtley found, that on taking a ſmall electric exploſion for an hour, in the ſpace of an inch of fixed air, confined in a glaſs tube one tenth of an inch diameter, when water was admitted to it, only one fourth of the air was imbibed. Probably the whole would have been rendered immiſcible in water, if the electrical operation had been continued a ſufficient time.

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The electric ſpark, when taken in alkaline air, appears of a red colour; the electric exploſions, which paſs through this air, increaſe it's bulk; ſo that, by making about 200 exploſions, in a quantity of it, the original quantity will be ſometimes increaſed one fourth. If water is admitted to this air, it will abſorb the original quantity, and leave about as much elaſtic fluid as was generated by the electricity, and this elaſtic fluid is a ſtrong inflammable air.

Dr. Prieſtley found, when the electric ſpark was taken in vitriolic acid air, that the inſide of the tube in which it was confined was covered with a blackiſh ſubſtance. He ſeems to think, that the whole of the vitriolic acid air is convertible into this black matter, not by means of any union which it forms with the electric fluid, but in conſequence of the concuſſion given to it by the exploſion; and that, if it be the calx of the metal which ſupplied the phlogiſton, it is not to be diſtinguiſhed from what metal, or indeed from what ſubſtance of any kind, the air had been extracted.

Dr. Prieſtley made 150 exploſions of a common jar in about a quarter of an ounce meaſure of vitriolic acid air from copper, by which the bulk was diminiſhed about one third, and the remainder ſeemingly not changed, being all abforbed by water. In the courfe of this procefs, the air was carefully transferred three times from one veffel to another; and the laft veffel, in which the explofions were made, was, to all appearance, as black as the firft; fo that the air feems to be all convertible into this black fubftance.

Thinking this diminution of the vitriolic acid air might arife from it's abforption by the cement, with which the glafs tubes employed in the laft experiment were clofed, he repeated it with the air from quickfilver, in a glafs fyphon confined by quickfilver, and the refult was the fame.

That this matter comes from the vitriolic acid air only, and not from any combination of the electric matter with it, will appear from the following experiment.

He took the fimple electric fpark from a conductor of a moderate fize, for the fpace of five minutes without interruption, in a quantity of vitriolic acid air, without producing any change in the infide of the glafs; when immediately after, making in it only two explofions of a common jar, each of which might be produced in lefs than a quarter of a minute with the fame machine in the fame ftate, the whole of the infide of the tube was completely covered with the black matter. Now had the electric matter

formed

formed any union with the air, and this black matter had been the reſult of that combination, all the difference that would have ariſen from the ſimple ſpark or the exploſion, could only have been a more gradual, or a more ſudden formation of that matter.

A large phial, about an inch and a half wide, being filled with this air, the exploſion of a very large jar, containing more than two feet of coated ſurface, had no effect upon it; from which it ſhould ſeem, that in theſe caſes, the force of the ſhock was not able to give the quantity of air ſuch a concuſſion as was neceſſary to decompoſe any part of it.

He had generally made uſe of copper, but afterwards he procured this air from almoſt every ſubſtance from which it could be obtained; the electric exploſion taken in it produced the ſame effect. But, as ſome of the experiments were attended with peculiar circumſtances, he briefly mentions them, as follows.

When he endeavoured to get vitriolic acid air from lead, putting a quantity of leaden ſhot into a phial containing oil of vitriol, and applying only the uſual degree of heat, a conſiderable quantity of heat was produced; but afterwards, though the heat was increaſed till the acid boiled, no more air could be got. He imagined therefore,

fore, that in this caſe the phlogiſton had, in fact, been ſupplied by ſomething that had adhered to the ſhot. However, in the air ſo produced, he took the electric exploſion; and in the firſt quantity he tried, a whitiſh matter was produced, almoſt covering the inſide of the tube; but in the ſucceeding experiments, with air produced from the ſame ſhot, or from ſomething adhering to it, there was leſs of the whitiſh matter; and at laſt, nothing but black matter was produced, as in all the other experiments. Water being admitted to this air, there remained a conſiderable reſiduum, which was very ſlightly inflammable.

Vitriolic acid air is eaſily procured from ſpirit of wine, the mixture becoming black before any air is yielded. The electric exploſion taken in this air alſo produced the black matter.

The experiments made with ether ſeem to throw moſt light upon this ſubject, as this air is as eaſily procured from ether as any other ſubſtance, containing phlogiſton. In the air procured by ether the electric exploſion tinged the glaſs very black, more ſo than in any other experiment of the kind; and, when water had abſorbed what it could of this air, there was a reſiduum in which a candle burned with a lambent blue flame. But what was moſt remarkable in this experiment was, that beſides the oil of

vitriol

vitriol becoming very black during the procefs, a black fubftance, and of a thick confiftence, was formed, which fwam on the furface of the acid.

It is very poffible, that the analyfis of this fubftance may be a means of throwing light upon the nature of the black matter, formed by electric explofions, in vitriolic acid air, as they feem to refemble one another very much.

The electric fpark or explofion, taken in common air, confined by quickfilver in a glafs tube, covers the infide of the tube with a black matter, which, when heated, appears to be pure quickfilver. This, therefore, may be the cafe with the black matter into which he fuppofed the vitriolic acid air to be converted by the fame procefs, though the effect was much more remarkable than in the common air. The explofion will often produce the diminution of common air in half the time that fimple fparks will do it, the machine giving the fame quantity of fire in the fame time: alfo, the blacknefs of the tube is much fooner produced by the fhocks than by the fparks. When the tube confiderably exceeds three tenths of an inch in diameter, it will fometimes become very black, without there being any fenfible diminution of the quantity of air.

EXPERIMENT

EXPERIMENT CCXXXV.—This curious experiment was made by Mr. Marſham, originally with a view to melt wires with a ſmall Leyden bottle. The effects are curious, and ſeem to open a new field for inveſtigating the force and direction of the electric fluid. He fixed a ſmall piece of wax upon the outſide coating of the Leyden bottle; the head of a ſmall needle was ſtuck in the wax, ſo as to be at right angles to the coating; oppoſite to the point of this needle, and at half an inch diſtance, another needle was fixed, by being forced through the bottom of a chip box; this was connected with the diſcharging rod by a wire. On diſcharging the bottle, the needle with the wax was driven from the coating of the bottle, and fixed into the box oppoſed to it. The diſtance between the needles was then increaſed to two inches and a half, which was the greateſt ſtriking diſtance. The head of the needle, which was fixed to the bottle, was evidently melted in two or three places. If the charge was ſtrong, and the wax was not ſtuck faſt to the coating of the bottle, both the wax and the needle would be driven ſome inches from the bottle. On placing a ball of wax on the point of each needle, and paſſing the diſcharge through them, the ball was thrown from that connected with the bottle full

two

two feet. Repeating this again, he could not produce the ſame effect.

Mr. Marſham now fixed the needle, oppoſed to that on the bottle, with wax on a braſs plate. On paſſing the charge through them, when the needles were half an inch diſtance from each other, the needle was thrown ſix inches from the braſs plate, while the other remained in it's ſituation. On increaſing the diſtance, the effects were the ſame, till it came to one inch and a half, when neither were thrown off. In many inſtances, both were thrown off, leaving the wax behind them.

The needles in all theſe experiments paſſed through the wax, ſo as to touch the coating of the bottle and the braſs plate; both the coating and plate were beautifully fuſed at each exploſion.

Mr. Marſham then ſubſtituted ſmall pieces of putty inſtead of wax; when on making the diſcharge with the points, at only three-eighths of an inch, the needle was driven from the bottle, and the putty forced up the needle. The points were then placed as near each other as was poſſible; when, on making the diſcharge, the putty of both needles was blown to pieces, and the needle thrown at a conſiderable diſtance;

 the

the braſs plate was alſo curiouſly melted, and the bottle broke.

EXPERIMENT CCXXXVI.—Cut a piece of India or thin paper into the ſhape of an iſoſceles triangle, whoſe ſides are about two inches long, breadth two tenths of an inch; then erect a braſs ball of two or three inches diameter, on a braſs wire one ſixth of an inch diameter, and two feet ſix inches long, on the prime conductor; electrify the conductor, and then bring the obtuſe end of the pieces of paper within the atmoſphere of the ball, and let it go, and the paper will revolve round the ball and often round it's own axis. This pleaſing and exceeding curious experiment was communicated to me by the ingenious Mr. J. Gamble, of Pembroke-Hall, Cambridge.

EXPERIMENT CCXXXVII.—Electrify two pieces of ſwan's down, one negatively, and the other poſitively; they will then float in the air, and may be eaſily driven about by bottles charged with contrary electricity; when brought near together, they will attract each other, meet with rapidity, their fibres will collapſe, and they will then fall to the ground, repreſenting in miniature what may be ſuppoſed often to happen in the higher regions of the atmoſphere.

EXPERIMENT

EXPERIMENT CCXXXVIII.—Insulate a Leyden phial, and connect a set of electrical bells with the inside of the phial, and another set with the outside; charge the phial, and then touch the set of bells connected with the inside; these will cease ringing, and the other set will begin to ring; now touch these, and then the set connected with the inside will ring; and so on alternately till the bottle is discharged. Thus illustrating, in a pleasing manner, the received theory of the Leyden phial.

A distinct apparatus is often fitted up for the performing of this experiment: or it may be shewn by means of the apparatus represented fig. 49, pl. III. which can easily be applied to a great variety of purposes, and is sufficient for explaining most part of the phænomena relative to the Leyden phial, besides being very convenient for several pleasing experiments.

On the Analogy between the Production and Effects of Electricity and Heat, and also between the Power by which Bodies conduct Electricity and receive Heat; with the Description of an Instrument to measure the Quantity of the Electrical Fluid, which Bodies of a different Nature will conduct when placed in the same Circumstances. By Mr. Achard.*

The production of heat is similar to that of electricity.

Every kind of friction produces heat and electricity. It may be objected to this, that in order to render the analogy perfect, it would be necessary that the friction of every body should produce electricity, which appears contrary to experience, as metals and other conducting substances do not become electrical, but by the contact of electric bodies, and that the immediate friction of these substances will not render them electrical.

To this it may be answered, that when an electric body is excited by friction against a non-electric,

* Memoirs de l'Academie de Berlin, for 1779.

non-electric, the laſt, if it is inſulated, gives as ſtrong ſigns of electricity as thoſe of the electric itſelf. This electricity is not communicated by the electric, ſince it is of an oppoſite kind: negative, if the electric is poſitive; and the contrary.

This obſervation proves, not only that the conducting bodies become electrical by friction, as well as electric bodies, but alſo, that to produce electricity, it is neceſſary that the equilibrium between the electricity of the rubbing bodies ſhould be deſtroyed; if each ſubſtance is equally adapted to receive and tranſmit the electrical fluid, it is clear, that the equilibrium of the fluid between them cannot be deſtroyed; becauſe, that at the inſtant one receives from the other any given quantity, it will, by it's elaſticity, be again divided between them: we may therefore conclude,

1. That the electricity produced by the friction of two bodies is greater, in proportion to the increaſe of the difference between the conducting power of thoſe bodies.

2. That where two bodies are equally adapted to receive and tranſmit the electric fluid, they give no ſign of electricity; not becauſe they cannot become electrified by friction, but becauſe the electricity, which is diſturbed by the friction,

is at the ſame time reſtored, on account of the facility with which it penetrates each ſubſtance. For a reaſon nearly ſimilar, electrics, when rubbed together, do not appear electrified.

It ſeems therefore, that we may conclude from this theory, which is founded on fact, that in all caſes, and whatever is the nature of the ſubſtance, the friction always produces electricity; and when the effect is not ſenſible, it is only becauſe electricity is loſt as ſoon as produced.

That there are no ſubſtances, that are rubbed againſt a body, which tranſmit the electric fluid with greater or leſs difficulty, but what give ſigns of electricity: that metals are as electrical by themſelves as glaſs and wax.

That as friction always, and in all caſes, produces electricity, there is a perfect analogy between the production of heat and electricity.

THE EFFECTS, WHICH ARE PRODUCED BY ELECTRICITY, ARE SIMILAR TO THOSE PRODUCED BY HEAT.

Heat dilates all bodies. The action of the electric fluid on the thermometer ſhews it's dilating power alſo; and if we do not generally perceive it, it is becauſe the force with which bodies

cohere

cohere together, exceeds the dilating power of electricity.

Heat promotes and accelerates vegetation as well as germination: Electricity, whether positive or negative, does the ſame.

Electricity, as well as heat, accelerates evaporation.

Heat and electricity accelerate the motion of the blood.* Leſt fear, conſtraint, or the attention to the experiment, might accelerate the pulſe, and thus be attributed to electricity, Mr. Achard made the experiment on a dog when aſleep, and always found, that the number of pulſations was increaſed when the animal was electrified.

The experiment made by Mr. Achard on the eggs of a hen, and by others on the eggs of moths, proves that electricity, as well as heat, favours the developement of thoſe animals. The electric fluid, in common with fire, will throw metals into fuſion.

If ſubſtances, with equal degrees of heat, touch each other, the heat is diffuſed uniformly between them. In the ſame manner, if two bodies with

* This poſition has been much controverted, and it ſeems clear, from modern experiment, that ſimple electricity does not accelerate the pulſe.

with unequal degrees, or different kinds of electricity, touch each other, an equilibrium will be eſtabliſhed.

THERE IS AN EXACT ANALOGY BETWEEN THE FACULTY WITH WHICH BODIES CONDUCT THE ELECTRIC FLUID AND RECEIVE HEAT.

If bodies of different kinds, and of equal degrees of heat, are placed in a medium of a different temperature, they will all acquire, at the end of a certain time, the ſame degree of heat. There is a conſiderable difference, however, in the ſpace of time in which they acquire the temperature of the medium: ex. gr. metals take leſs time than glaſs, to acquire or loſe an equal degree of heat.

On an attentive examination of the bodies which receive and loſe their heat ſooneſt, when they are placed in mediums of different temperature, they will be found to be the ſame which receive and loſe their electricity with the greateſt facility. Metals, which become warm or grow cool the quickeſt, are the ſubſtances which receive and part with their electricity ſooneſt. Wood, which requires more time to be heated or cooled, receives and loſes electricity ſlower than metals. Laſtly, glaſs and reſinous ſubſtances,

ſtances, which receive and loſe ſlowly the electric fluid, acquire with difficulty the temperature of the medium which ſurrounds them.

If one extremity of an iron rod be heated red-hot, the other extremity, though the bar is ſeveral feet long, will become ſo warm in a little time that the hand cannot hold it; becauſe the iron conducts heat readily; but a tube of glaſs, only a few inches long, may be held in the hand, even while the other end is melting. The electric fluid, in the ſame manner, paſſes with great velocity from one end of a rod of iron to the other; but it is a conſiderable time before a tube of glaſs, at one end of which an excited electric is held, will give electric ſigns at the other.

Theſe obſervations prove, that ſeveral bodies that receive and loſe with difficulty their actual degree of heat, receive and loſe alſo with difficulty their electricity. To determine if this law is general, and what are the exceptions to it, will require a variety of experiments.

If we ſuppoſe two ſubſtances, one of which is electrified, but the other not, that the firſt has a known degree of electricity, and that the laſt, in touching it, deprives it of a given degree of electricity; this loſs of a part of it's electricity determines the faculty with which the body that touches it receives the electric fluid. Besides the figure and volume of this substance, the time the two bodies remain in contact will alter the quantity taken from the electrified substance; so that all other circumstances being the same, the property of bodies to deprive other bodies of their electricity, or, in other words, to conduct the electric fluid, is in the inverse ratio of the time necessary to make them lose an equal degree of electricity.

The instrument, which is represented fig. 95, is constructed on these principles, and with it the quantity of electricity that one body loses in a given time, when touched by another, may be accurately ascertained. A B is a very sensible ballance; at the extremity of each arm two very light balls of copper are affixed; C F D a divided semicircle, which is fastened to the cock which supports the axis of the ballance; the degrees may be pointed out by a needle, or by the arms of the ballance; the cock is fixed to a brass cap, which is cemented on the glass pillar G G, which is fixed to the board Q R S T; this pillar should be at least 18 inches high. U is a Leyden bottle; to the wire Z Z, which communicates with it's inside coating, three horizontal wires, V Z, X Z, and Z Y, are fixed; the ends of these wires are furnished with hollow brass

braſs balls; the bottle U is ſo fixed to the board, that when the beam is horizontal, the ball B touches exactly the ball X, as is repreſented in the figure.

K N is a metal lever, which turns upon an axis at I, ſo as to move freely in a vertical plane, which ſhould coincide with the bar V X; the lever K N is ſupported by a wooden pillar I H, which is fixed to the board Q R S T; at the end K of the lever is a ſcrew, to hold the ſubſtance on which the experiment is to be made; the upper end of this ſubſtance ſhould be turned into a convex form. A thread N O is tied to the end N of the lever; at O is a ſmall hook, on which a ball I is to be ſuſpended. The diſtance of the pillar I H from the bottle is to be ſo adjuſted, that when the end N is lowered, the body L may touch in one point the ball V; the proportion between the weight of the arms of the lever, the weight I, and the body L, and the length of the pillar I H to the thread N O, is to be ſuch, that when the ſubſtance L touches the ball V, at the ſame moment the ball P will touch the board Q R S T, and be diſengaged from the thread N O: the ſubſtance L will alſo at the ſame inſtant quit the ball V.

To uſe this inſtrument, connect the bottle U with the prime conductor by the ball Y, and form a communication by a wire from Y to the cap G; charge the bottle, and the ball X will repel the ball B; the angle of repulſion will be marked by the needle E F. Suppoſe this to be 20 degrees, and let L be brought, as before deſcribed, to touch V, it will abſorb a quantity of electricity proportionable to it's conducting power, and the ball B will fall in proportion to the quantity abſorbed, and the difference will be ſeen on the ſemicircle. Let the difference be five degrees; repeat the experiment, only ſubſtituting ſome other ſubſtance in the place of the body L; ſuppoſe that with this ſubſtance the diminution of the angle is 8 degrees, then is the conducting power of theſe two ſubſtances in the proportion of five to eight.

Fig. 106 repreſents an apparatus, to ſet a wire on fire by the electric exploſion in dephlogiſticated air. I am obliged to defer the deſcription and uſe of it to ſome future opportunity, as I have not had any time to try it's ſucceſs.

AN

ESSAY

ON

MAGNETISM.

ADVERTISEMENT.

THIS ſmall Eſſay is publiſhed to illuſtrate and exemplify ſome uſes of a Magnetical Apparatus, conſtructed in order to exhibit the general phænomena of Magnetiſm. It is extracted from a larger work, which is laid aſide for the preſent, as it is probable the public will ſoon be favoured with a treatiſe on this ſubject by Mr. CAVALLO.

AN

ESSAY

ON

MAGNETISM.

THOUGH the phænomena of the magnet have, for many ages, engaged the attention of natural philoſophers, not only by their ſingularity and importance, but alſo by the obſcurity in which they are involved; yet very few additions have been made to the diſcoveries of the firſt inquirers upon the ſubject. The powers of genius, which have been hitherto employed in proſecuting this ſubject, have not been able to frame an hypotheſis, that will account, in an eaſy and ſatisfactory manner, for all the various properties of the magnet, or point out the links of the chain which connect it with the other

other phænomena of the univerſe. Though it is certain, that both natural and artificial electricity will give polarity to needles, and even reverſe a given polarity; from whence it would appear, that there is a conſiderable affinity between the electric and magnetic fluid, but how it acts when producing magnetiſm, is entirely unknown.

It is known by the works of Plato * and Ariſtotle, that the ancients were acquainted with the attractive and repulſive powers of the magnet; but it does not appear, that they knew of it's pointing to the pole, or the uſe of the compaſs. As they were not acquainted with the true method of philoſophiſing, and contented themſelves with obſervation alone, their knowledge of nature was confined within very narrow limits, and did not afford any conſiderable advantage to ſociety. Modern philoſophers, by combining experiment with obſervation, ſoon extended the boundaries of ſcience, and diſ-

covered

* "A power reſembling that, which acts in the ſtone, "called by Euripides the magnet. For this ſtone does not "only attract iron rings, but impart to thoſe rings the power "of doing that very thing which itſelf does, enabling them "to attract other rings of iron; ſo that ſometimes may be "ſeen a very long ſeries of iron rings, depending as in a "chain one from another. But from that ſtone at the head "of them is derived the virtue, which operates in them "all." See Sydenham's tranſlation of the IO of Plato.

covered the polarity of the loadſtone, a property which in a manner conſtitutes the baſis of navigation, and gives being to commerce.

THE LOADSTONE, LEADING STONE, OR NATURAL MAGNET, is an iron ore or ferruginous ſtone, found in the bowels of the earth, generally in iron mines; of all forms and ſizes, and of various colours. It is endowed with the property of attracting iron; and of both pointing itſelf, and alſo enabling a needle, touched upon it, and duly poiſed, to point towards the poles of the world.

Loadſtones are in general very hard and brittle, and for the moſt part more vigorous in proportion to their degree of hardneſs. Conſiderable portions of iron may be extracted from them. Newman ſays, that they are almoſt totally ſoluble in ſpirit of nitre, and partially in the vitriolic and marine acids.

Mr. Kirwan ſays, that the magnet ſeems to contain a ſmall quantity of ſulphur, is often contaminated with a mixture of quartz and argill; it is poſſible, it may contain nickel, for this, when purified to a certain degree, acquires the properties of a magnet, but it's conſtitution has not as yet been properly examined.*

* Kirwan's Elements of Mineralogy, p. 271.

Artificial magnets, which are made of ſteel, are now generally uſed in preference to the natural magnet; not only as they may be procured with greater eaſe, but becauſe they are far ſuperior to the natural magnet in ſtrength, and communicate the magnetic virtue more powerfully, and may be varied in their form more eaſily, ſo that the natural magnet is now very little eſteemed, except as a curioſity.

The power of attracting iron, &c. poſſeſſed by the loadſtone, which is alſo communicable to iron and ſteel, is called MAGNETISM. It has been ſuppoſed, that iron and the loadſtone were the only two bodies which could be rendered magnetical; but it now appears, that nickel, when purified from iron, becomes more inſtead of leſs magnetic, and acquires, what iron does not, the properties of a magnet.†

A rod or bar, of iron or ſteel, to which a permanent polarity has been communicated, is called a MAGNET.

The points in a magnet which ſeem to poſſeſs the greateſt power, or in which the virtue ſeems to be concentrated, are termed THE POLES OF A MAGNET.

THE MAGNETICAL MERIDIAN is a vertical circle in the heavens, which interſects the horizon

* Ibid. p. 369.

rizon in the points to which the magnetical needle, when at reſt, is directed.

THE AXIS OF A MAGNET is a right line, which paſſes from one pole to the other.

THE EQUATOR OF A MAGNET is a line perpendicular to the axis of the magnet, and exactly between the two poles.

The diſtinguiſhing and characteriſtic properties of a magnet, are,

Firſt, It's attractive and repulſive powers.

Secondly, The force by which it places itſelf, when ſuſpended freely, in a certain direction towards the poles of the earth.

Thirdly, It's dip or inclination towards a point below the horizon.

Fourthly, The property which it poſſeſſes of communicating the foregoing powers to iron or ſteel.

AN HYPOTHESIS.*

Mr. Euler ſuppoſes, that the two principal cauſes, which concur in producing the wonderful properties of a magnet, are, firſt, a particular ſtructure of the internal pores of the magnets, and of magnetical bodies; and, ſecondly, an

* Lettres à une Princeſſe d' Allemagne.

external agent or fluid, which acts upon and paſſes through theſe pores. This fluid he ſuppoſes to be the ſolar atmoſphere, or that ſubtle matter called ether, which fills our ſyſtem.

Indeed, moſt writers on this ſubject agree in ſuppoſing, that there are corpuſcles of a peculiar form and energy, which continually circulate around and through a magnet; and that a vortex of the ſame kind circulates around and through the earth.

A magnet, beſides the pores which it has in common with other bodies, has alſo other pores conſiderably ſmaller, deſtined only for the paſſage of the magnetic fluid. Theſe pores are ſo diſpoſed as to communicate one with the other, forming tubes or channels, by which the magnetic fluid paſſes from one end to the other. The pores are ſo formed, that this fluid can only paſs through them in one direction, but cannot return back the ſame way; ſimilar to the veins and lymphatic veſſels of the animal body, which are furniſhed with valves for this purpoſe. So that the pores of the magnet may be conceived to be formed into ſeveral narrow contiguous tubes, parallel to each other, as at A B, fig. 99, through which the finer parts of the ether paſſes freely from A to B, but cannot return back on account of the reſiſtance it meets with at *a*, *a*,

b, *b*,

b, *b*, nor overcome the refiftance of the groffer ether, which occafions and continues the motion. For fuppofing the pole A of a magnet, filled with feveral mouths or open ends of fimilar tubes, the magnetic fluid, preffed by the groffer parts of the ether, will pafs towards B with an inconceivable rapidity, which is proportionable to the elafticity of the ether itfelf; this matter which, till it arrives at B, is feparated by the tubes from the more grofs parts, then meets with it again, and has it's velocity retarded, and it's direction changed; the ftream, reflected by the ether, with which it cannot immediately mix, is bent on both fides towards C and D, and defcribes, but with lefs velocity, the curves D E and C F e, and approaching by the curves *d* and *c*, falls in with the affluent matter *m m*, and again enters the magnet; and thus forms that remarkable atmofphere, which is vifible in the arrangement of fteel filings on a piece of paper that is placed over a magnet.

A SECOND HYPOTHESIS.*

1. That the earth is a large magnet.
2. That there is a fubtle fluid, called the magnetic

* Oeuvres de Franklin, tom. 1, p. 277.

netic fluid, which exifts in every kind of iron, is equally attracted by all it's parts, and equally diffeminated throughout it's fubftance, unlefs it is forced into an inequality by a power fuperior to the attraction of the iron.

3. That the natural quantity of magnetic fluid contained in a piece of iron, may be put in motion fo as to be more rarified in one part, and more condenfed in another; but it cannot be fo taken away by any known force, as to leave the whole mafs in a negative ftate with refpect to it's natural quantity; neither can any additional quantity be introduced fo as to put it in a pofitive ftate.

4. A piece of foft iron permits the magnetic fluid, which is contained in it's fubftance, to be put in motion by a fmall force, fo that, being placed in the direction of the magnetic meridian, it acquires immediately the properties of a magnet, it's magnetic fluid being drawn or pufhed from one extremity to the other, and continuing fo while it remains in the fame pofition, one of the ends becoming pofitively, the other negatively magnetic. The tranfient magnet lofes it's properties when it is laid in an eaft and weft fituation, the magnet returning to it's original fituation.

If

If the iron is hard as ſteel, it is more difficult to put the magnetic fluid in motion, it requires a ſtronger force than is exerted by the magnetiſm of the earth to move it, and when moved from one end to the other, it cannot eaſily return, and thus a ſteel bar requires a permanent magnetiſm.

6. A great heat opens the ſubſtance and ſeparates the parts of the bar, and thus gives a free paſſage for the magnetic fluid, which deſtroys it's magnetic properties.

7. A ſteel bar not magnetical, placed in the direction of the magnetic meridian and dip, and firſt heated and then ſuddenly cooled, while in this poſture, acquires a permanent magnetiſm; for while the bar was warm, the magnetic fluid contained in it was eaſily forced from one end to the other, by the magnetiſm of the earth, and was retained there by the contraction of the bar from cold.

8. Violent concuſſions of the ſteel bar placed as in the foregoing article, ſo ſeparate it's parts during the vibrations, as to ſuffer the magnetic fluid to be forced from it's ſituation by the magnetiſm of the earth, and is retained in it's altered ſituation by the cloſing of the pores when the vibrations ceaſe.

9. An electric ſhock dilating a needle for a

moment, gives it, for the foregoing reaſon, a magnetic virtue.

I. THERE IS A TENDENCY IN IRON AND A MAGNET TO APPROACH EACH OTHER, AND ATTACH THEMSELVES TOGETHER, AND THAT WITH SUCH FORCE, AS OFTEN TO REQUIRE A CONSIDERABLE WEIGHT TO SEPARATE THEM.

This curious property of the magnet was that by which it was firſt diſcovered, and by which it engaged the attention of the curious. Every ſubſtance which contains iron is more or leſs attracted by the magnet, with one exception, as Henchel, Gellert, and Brand aſſert, that the ſmalleſt quantity of antimony mixed with iron prevents it's being attracted by the magnet. Mr. Burgman uſed the following method to diſcover the ſubſtances which are attracted by the magnet, he placed the bodies which he intended to examine on pure water, or very pure mercury, either directly on the ſurface, or on a piece of paper, when on the approach of a ſtrong magnet they will be ſenſibly attracted, although the attraction could be diſcovered by no other method; in this way he found martial ſalts ſtrongly attracted by the magnet. Howbeit, in general,

general, iron, when involved in a coating of ſaline matter, is attracted leſs ſtrongly in proportion as it is more intimately united to the ſalts. The attraction of iron is ſtrongeſt when it is moſt deprived of oily, ſulphureous, and ſaline particles. Spirit of nitre poured on iron which is acting on a magnetic needle, will diminiſh it's action.

EXPERIMENT I.—Place a piece of iron on a cork, and put the cork into water, the piece of iron will be attracted by, and follow a magnet, in a pleaſing manner. The tendency between the magnet and the iron is reciprocal; for if the magnet be put on the cork, it will follow the iron, in the ſame manner as this followed the magnet.

On this principle many ingenious and entertaining pieces of mechaniſm have been contrived. Small ſwans ſwimming in the water have been made to point out the time of the day, &c.

EXPERIMENT II.—Place a magnet upon one of the braſs ſtands, and preſent one end of a ſmall needle towards it, holding the other end by a piece of thread, to prevent the needle fixing itſelf to the bar, and the needle will be pleaſingly ſuſpended in the air; the needle will remain ſuſpended, although a piece of paper, glaſs, braſs, &c. be introduced between the magnet and the needle.

Experiment iii.—Suſpend a magnet under the ſcale of a ballance, and counterpoiſe it by weights in the other ſcale, then preſent a piece of iron towards the magnet, it will immediately deſcend, and, if the iron is not placed at too great a diſtance, will adhere to it: now ſuſpend the iron under the ſcale inſtead of the magnet, then bring the latter towards it, and the iron will deſcend and adhere to the magnet.

Experiment iv.—Hold one end of the magnet at about half an inch from ſome ſteel filings, and theſe will fly to the magnet and form a kind of beard about the end of the magnet.

II. There are certain Points in a Magnet, in which it's Virtues seem as it were concentrated, which are called it's Poles.

Experiment v.—Let a magnet be placed on one of the braſs ſtands contained in the apparatus, and then try what number of iron balls it will ſuſtain at different parts; it will be found to ſupport

ſupport moſt near the ends, evincing that the magnetic power is exerted there with the greateſt force.

Take out the ſteel needle from between the two pillars *a b*, fig. 117, and place in it's ſtead the needle, one half of which is made of ſteel, the other half of braſs, the ſteel part of this needle is to be touched; on preſenting the ſouth end of a magnet to the end of the arch, this will repel the end of the needle to a certain degree, but on moving the magnet progreſſively forwards, the needle will gradually fall down till it comes to Zero. If the magnet is moved further, the needle will be attracted.

To FIND THE POLES OF A MAGNET.

EXPERIMENT VI.—Let a magnet be placed under one of thoſe panes of glaſs which are contained in the bottom of the box; ſift ſome ſteel filings on this glaſs, and then ſtrike it gently with a key, in order to throw the glaſs into a vibratory motion; this will diſengage the filings, and they will ſoon be arranged in a pleaſing manner: thoſe parts of the magnet, from which the curves ſeem to take their riſe, and over which the filings ſeem to be almoſt erect, are the poles of the magnet: or roll the magnet or loadſtone in ſteel filings, which will adhere in a greater quantity, and more ſtrongly to thoſe parts that are near the poles; and thoſe particles which are over the poles will be perpendicular to the bar, the other particles will incline towards the poles. If a ſmall needle be placed in a glaſs ball and carried over the magnetic bar, it will ſtand perpendicular to the bar when it is over either of the poles, the various inclinations of a piece of ſteel, and at different parts of a magnet, may be pleaſingly obſerved by this little apparatus.

In this, as well as many other magnetical experiments, a mechanical force is evidently exerted, detaching the particles of iron from one ſituation, removing them to another, and then retaining them there with conſiderable force.

Experiment vii.—The poles of a magnet may be aſcertained with greater accuracy by means of the ſmall dipping needle, fig. 117; place this on a magnet, and move it backwards and forwards till the needle is perpendicular to the magnet, it will then point directly to one of the poles. When it is between the north and ſouth poles, ſo that their mutual actions ballance each other, the center of the needle will ſtand over what is called the equator of the magnet, and the needle

needle will be exactly parallel to the bar. If it is then removed towards either pole, it will be differently inclined according to it's diſtance from the poles.

EXPERIMENT VIII.—Hold a common ſmall ſewing needle (with ſome thread in it's eye) near a magnet for a few ſeconds, then bring it gradually towards the middle of a magnetic bar, and the powers of the magnet will ſo far counteract the force of gravity, as to keep it ſuſpended in the air, in a poſition which is nearly parallel to that of the magnet.

There is no magnetical attraction without polarity; it is conſequently abſurd to ſuppoſe, that a magnet may have a ſtrong attractive power, but a weak polarity, or directive power.

III. THE CONTRARY POLES OF TWO MAGNETS ATTRACT EACH OTHER.

THE NORTH POLES OF TWO MAGNETS, WHEN BROUGHT CONTIGUOUS, REPEL EACH OTHER. THE SOUTH POLES ALSO, WHEN BROUGHT NEAR, REPEL EACH OTHER.

Theſe phænomena are eaſily illuſtrated by a variety of pleaſing experiments.

EXPERIMENT

Experiment ix.—Sufpend on a point a touched needle, then prefent towards it's north pole the fouth pole of a magnet, and it will be attracted by, and fly towards it; prefent the other pole of the magnet, and the needle will fly from it.

Experiment x.—Strew a few fteel filings upon a pane of glafs, put either the north or fouth pole of one of the bars under the pane; the filings will rife upon the glafs as the magnet approaches. Bring the fame pole of the other bar directly over that under the glafs, and when it is at a proper diftance, the fteel filings will drop flat on the pane.

Experiment xi.—Fix two needles horizontally in two pieces of cork, and put them in water; if the poles of the fame name are placed together, they will mutually repel each other. If the poles of a contrary denomination are turned towards each other, they will be attracted and join.

Experiment xii.—Dip the north or fouth ends of two magnets in fteel filings, which will hang in clufters from the end of the bars; bring the ends of the bars towards each other, and the fteel filings on one bar will recede from thofe on the other. Dip the fouth pole of one magnet, and

and the north pole of the other, into ſteel filings, then let the ends be brought near to each other, and the tufts of filings will unite, forming ſmall circular arches.

IV. THE POWERS OR PROPERTIES OF A MAGNET MAY BE COMMUNICATED TO IRON OR STEEL.

To give a detail of the various proceſſes which have been ſuggeſted, for the touching or communicating the properties of the magnet to iron or ſteel, would alone fill a volume; I ſhall therefore only give an account of two general and good methods, which I preſume will be found adequate to every common purpoſe.

1. Place two magnetic bars A B, fig. 100, in a line with the north or marked end of one, oppoſed to the ſouth or unmarked end of the other, but at ſuch a diſtance from each other, that the magnet to be touched may reſt with it's marked end on the unmarked end of A, and it's unmarked end on the marked end of B; then apply the north end of the magnet D and the ſouth end of E to the middle of the bar C, the oppoſite ends being elevated as in the figure; draw D and E aſunder along the bar C, one towards A, the other towards B, preſerving the ſame

ſame elevation, remove D and C a foot or two from the bar when they are off the ends, then bring the north and ſouth poles of theſe magnets together, and apply them again to the middle of the bar C as before; repeat the ſame proceſs five or ſix times, then turn the bar, and touch the oppoſite ſurface in the ſame manner, and afterwards the two remaining ſurfaces, and by this means the bar will acquire a ſtrong fixed magnetiſm.

2. Place the two bars which are to be touched parallel to each other, and then unite the ends by two pieces of ſoft iron, called ſupporters, in order to preſerve, during the operation, the circulation of the magnetic matter; the bars are to be placed ſo that the marked end D, fig. 101, may be oppoſite the unmarked end B; then place the two attracting poles G and I on the middle of one of the bars to be touched, raiſing the ends ſo that the bars may form an obtuſe angle of 100 or 120 degrees; the ends G and I of the bars are to be ſeparated two or three tenths of an inch from each other. Keeping the bars in this poſition, move them ſlowly over the bar A B, from one end to the other, going from end to end about fifteen times. Having done this, change the poles of the bars,* and repeat the ſame operation

* That is, the marked end of one is always to be againſt the unmarked end of the other.

operation on the bar C D, and then on the opposite faces of the bars; the touch, thus communicated, may be farther increased, by rubbing the different faces of the bars with sets of magnetic bars, disposed as in fig. 102.

It seems, that in order to render steel magnetical, we must so dispose the pores that they may form contiguous tubes parallel to each other, capable of receiving the magnetic fluid, and then propagating and perpetuating it's motion, so that the magnetic stream may enter with ease, and be made to circulate through it with the greatest force: to this end, it is necessary to be particularly attentive in the choice of the steel which is to be touched; the grain should be equal, small, homogeneous, and without knots, that it may present a number of equal and uninterrupted channels to the fluid, from one end to the other: this is more immediately important in the choice of the steel for the needles of sea compasses, for if the steel is impure, or the mode of touching improper, the needle may have different poles communicated to it, which will more or less impede the action of the principal needle, according to their strength and situation.

The steel should be well tempered, that the pores may preserve for a long time the disposition they have received, and better resist those changes in their direction, to which iron and soft steel are liable. The difference in the nature of steel is exceeding great, as is easily proved by touching in the same manner, and with the same bars, two pieces of steel of equal size, but of different kind.

Steel, that is hardened, receives a more perfect magnetism than soft steel, though it does not appear that they differ from each other in any thing but the arrangement of the parts; perhaps the soft steel contains phlogiston in it's largest pores, while hardened steel contains it in the smaller. Iron, or steel, have very little air incorporated in their pores; when they are separated from the ore, they are exposed to a most intense degree of heat, and most of the changes to which they are afterwards submitted, are effected in a red hot state. A piece of spring-tempered steel will not retain as much magnetism as hard steel, soft steel still less, and iron scarce retains any. From some experiments of Mr. Musschenbroek, it appears, that when iron is united with an acid, it will not become magnetical; but if the acid is separated, and the phlogiston restored, it will become as magnetical as ever.

The dimensions and shape of a magnet will make a difference in it's force, therefore the bars to be touched, ſhould neither be too long nor too ſhort, but in proportion to the thickneſs; if they are too long, the paſſage of the magnetic matter coming out of one pole, and proceeding round the magnet to enter the other, will be impeded, and it's velocity leſſened. If they are too ſhort, the fluid, which comes out from one pole, will be repelled and thrown back by the other acting parts of the magnet, and thus be carried too far from the pole into which it ought to enter, and prevent the continued circulation of the magnetic matter. If they are too thin, then the number of pores are too few to receive a ſtream ſufficiently ſtrong to reſiſt the obſtacles in the external ſpace; while, if they are too thick, the ſtrait and regular direction of the channel is injured by the difficulty which takes place in the arrangement of the interior channels, as the magnetic matter has not ſufficient force to penetrate the ſteel to any conſiderable depth, and thus injures the circulation of the fluid.

All the pieces ſhould be well poliſhed; it is of the greateſt importance that the ends ſhould be flat and true, ſo as to touch, in as many points as is poſſible, the ends of ſoft iron which keep up the circulation. Inequalities on the faces, but principally near the poles, are to be avoided,

 as

as theſe occaſion irregularities in the circulation, and thus diminiſh it's velocity, which is one of the principal ſources of magnetic power.

While the bars are touching, the ends of ſoft iron ſhould be kept in conſtant contact with the bars, for a momentary ſeparation is ſufficient to deſtroy the effect of the operation, as the fluid will be inſtantly diſperſed in the air.

The operator ought not to ſtop longer on the firſt bar than is neceſſary to open the pores, and to arrange them magnetically, paſſing immediately to the other, to form an opening for the fluid which iſſues from the firſt.

It is moſt advantageous to turn the bar that is quitted, while the touching magnets are placed on the other; by this means, the ſtream that is to be excited will diſpoſe the channels of the firſt, and thus render the operation more efficacious; beſides, by only turning one bar at a time, the touching bars need never be totally removed during the whole operation, a circumſtance which will contribute to the ſtrength of the magnet.

The touching bars ſhould never be ſeparated but at the equator of the magnet; and their motion over the others ſhould be ſlow and regular.

The magnetic power of touching needles has been

been increafed by leaving them for fome time in linfeed oil.

It may contribute to the effects of the operation if the bars A and B, fig. 100, are placed in the direction of the magnetic meridian, and are inclined to the horizon in an angle equal to the dip of the needle.

The fixed power, thus communicated to a magnet, is impaired if it is laid amongft iron, or by ruft; it may be injured alfo by fire, as each of thefe circumftances will change, or confufe the direction of the magnetic ftream.

Place a fmall magnetic needle on the point of one of the fmall ftands, and put it between two magnetic bars, fo that the north end of the bar may be near the fouth end of the needle; the fmall needle will, without any apparent caufe, be thrown into a violent vibratory motion, and feem as it were animated, till it is faturated with magnetifm, when it will become quiefcent. The vibratory motion is probably occafioned by the irregularity of the impreffions it receives from the magnetic fluid, and the difficulty that fluids find in entering the needle.

All caufes, that are capable of making the magnetic fluid move in a ftream, will produce magnetifm in thofe bodies which are properly qualified to receive it.

If

If bars of iron are heated, and then cooled equally, in various directions, as parallel, perpendicular, or inclined to the dipping needle, the polarity will be fixed according to their poſition, ſtrongeſt when they are parallel to the dipping needle, and ſo leſs by degrees, till they are perpendicular to it, when they will have no fixed polarity; but if, upon cooling a bar of iron in water, the under end is conſiderably hotter than the upper, and the upper end is cooled firſt, it will ſometimes become the north pole, but not always. If iron, or ſteel, undergo a violent attrition in any one particular part, they will acquire a polarity; if the iron is ſoft, the magnetiſm remains very little longer than while the heat continues. Lightning is the ſtrongeſt power yet known in producing a ſtream of magnetiſm; it will, in an inſtant, render hardened ſteel ſtrongly magnetical, and invert the poles of a magnetic needle.

To make a magnetical bar with ſeveral poles, place magnets at thoſe parts where the poles are intended to be, the poles to be of a contrary name to thoſe required, and if a ſouth pole is fixed on one part, the two next places muſt have north poles ſet againſt them; conſider each piece between the ſupporters as a ſeparate magnet, and touch it accordingly.

EXPERIMENT

EXPERIMENT XIII.—Take a piece of iron wire and bend it into the form of a ſtaple, then touch the middle of the wire ſtaple with only one of the poles of a magnet, without moving it backwards or forwards; the place where the magnet touches the wire will be one pole, and the two ends the other pole.

EXPERIMENT XIV.—Take any number of ſmall ſteel bars, lay them end to end, and touch them while in this poſition; when you ſeparate them, there will be a north and a ſouth pole at every ſeparation. See a ſimilar experiment in the eſſay on electricity.

EXPERIMENT XV.—Touch a piece of iron wire, and then twiſt it about a large glaſs tube or any other cylindrical body, and the magnetic virtue will be ſo diſturbed, that in ſome parts it will attract, and in others repel the ſame pole of a magnetic needle.

To touch Horseshoe Magnets.

As theſe magnets from their form are capable of ſuſtaining great weights, and maintaining the circulation of the magnetic fluid, I ſhall deſcribe a convenient mode of touching them.

Place

Place a pair of magnetic bars againſt the ends of the horſeſhoe magnet, with the ſouth end of the bar againſt that end of the horſeſhoe, which is intended to be the north; and the north end of the other bar to that which is to be the ſouth. The contact or lifter of ſoft iron to be placed at the other end of the bars. In this ſituation the magnetic fluid which circulates through the bars will endeavour to force a paſſage through the horſeſhoe magnet, and thus facilitate the further communication of the magnetic virtue to the horſeſhoe magnet: to this end, rub the ſurfaces of the horſeſhoe with a pair of bars placed in the form of a compaſs, turning the poles properly towards the poles of the horſeſhoe magnet, being careful that theſe bars never touch the ends of the ſtrait bars, as this would diſturb the current of the magnetic fluid, and injure the operation. If the bars are ſeparated ſuddenly from the horſeſhoe magnet, it's force will be conſiderably diminiſhed; to prevent this, ſlip on the lifter or ſupport to the end of the horſeſhoe magnet, but in ſuch a manner, however, that it may not touch the bars; the bars may then be taken away, the ſupport ſlid to it's place, and left there to ſtrengthen the circulation of the fluid.

To

TO MAKE AN ARTIFICIAL LOADSTONE.

The late Dr. Gowin Knight poſſeſſed a ſurpriſing ſkill in magnetiſm, being able to communicate an extraordinary degree of attractive and repulſive power, and to alter or reverſe the poles at pleaſure; but as he refuſed to diſcover his methods, theſe curious and valuable ſecrets died with him. In the LXIXth volume of the Philoſophical Tranſactions, however, Mr. Benjamin Wilſon has given a proceſs, which diſcovers one of the leading principles of Dr. Knight's art; namely, his method of making artificial loadſtones.—To this end Dr. Knight provided himſelf with a ſufficient quantity of clean iron filings, he put them into a large tub more than one third filled with water, he then with great labour worked the tub to and fro for many hours together, that the friction between the grains of iron, by this treatment, might break off ſuch ſmaller parts as would remain ſuſpended in the water for a time. The obtaining theſe very ſmall particles in ſufficient quantity, ſeemed to him to be one of the principal deſiderata in the experiment. The water being by this means rendered muddy, he poured the ſame into a clean iron veſſel, leaving the filings behind, and when the water had ſtood long enough to become clear, he poured it out carefully, without diſturbing ſuch of the ſediment as ſtill remained, which now appeared reduced almoſt to an impalpable powder. This powder was afterwards removed into another veſſel, in order to dry it; but as he could not obtain a proper quantity thereof by this one proceſs, he was obliged to repeat the proceſs many times. Having at laſt procured a ſufficient quantity of this fine powder, the next thing was to make a paſte of it, and that with ſome vehicle that ſhould contain a ſufficient quantity of the phlogiſtic principle; for this purpoſe he uſed linſeed oil, and with thoſe two ingredients he made a puff paſte, and took particular care to knead it well before he moulded it into convenient ſhapes. This paſte was then put on wood or tiles at about a foot diſtance from a moderate fire; a great degree of heat frequently cracked the compoſition. The time for breaking or drying this paſte was about five or ſix hours, at which time they had generally attained a ſufficient degree of hardneſs; when this was done, he gave them the magnetic virtue in any direction he pleaſed, by placing them for a few ſeconds between his large

large magazine of artificial magnets, where they acquired ſuch force, that when any of their pieces were held between two of his beſt ten guinea bars, with it's poles purpoſely inverted, it immediately turned itſelf about to recover it's natural direction, which the force of thoſe very powerful bars were not able to counteract.

Ruſt of iron and common ſtone cemented together by any fat ſubſtance will alſo form an artificial loadſtone.

OF ARMED MAGNETS.

In a ſtrait loadſtone or magnet, the ſtream is carried back on all ſides in curved lines, but applying plates of ſoft iron to the poles of the magnet, the direction of the fluid is changed, and it is conducted, united, and condenſed at the feet to the armour, ſo that if the feet are connected by another piece of iron which is called the lifter, the ſtream proceeding from one pole will be carried by the lifter to the other, which cauſes it to adhere with conſiderable force.

The armour ſhould be made of ſoft homogeneous iron, well fitted to the ends of the magnets; it ſhould alſo be thicker in proportion as the diſtance of the poles from each other increaſes.

Experiment xvi.—Place an armed magnet under a glaſs plane which has been ſtrewed over with ſteel filings, and theſe will arrange themſelves in curves from one foot of the armour to the other.

Gaſſendi invented a peculiar kind of armour, which was formed by piercing a magnet in the direction of the axis, and placing a cylinder of iron in the hole, which augmented conſiderably the force of the magnet.

Experiment xvii.—Mr. Van Swinden applied to an artificial magnet B, fig. 106, which ſupported four ounces by it's north pole, another magnet b, ſo that it's north pole was almoſt half an inch from the pole which ſupported the weight, and this pole immediately ſupported ſeven ounces. Du Hamel, Le Maire, &c. have alſo made many curious experiments on this head.

Experiment xviii.—Apply a bar of iron M N, fig. 107, to one foot of an armed magnet, and it is ſupported; approach the iron lifter of the magnet, ſo that it may touch this bar and the armour, and the bar will fall.

Experiment xix.—Apply to the pole B, fig. 108, 108, a ſmall piece of iron, nearly as much as that foot of the armour will ſuſtain; let this piece of iron reach a little beyond the foot of the armour, then apply the lifter to the foot A, ſo that it may touch the piece of iron M, and the magnet will then ſupport a conſiderable addition of weight.

EXPERIMENT XX.—If one end of the armour of a magnet only juſt ſuſtains an iron ball, it will ſupport two or three balls, if the contrary pole of a magnet is brought near it.

EXPERIMENT XXI.—Place an armed magnet at the magnetic equator and ſome diſtance from a magnetic needle, and mark how much it makes it deviate from it's ſituation. Apply the contrary pole of another magnet to the end of the armed one, and the needle will be more ſtrongly attracted.

V. LET

V. LET AN IRON ROD BE EXACTLY BALLANCED AND SUSPENDED ON A POINT, SO AS TO REVOLVE IN A PLANE PARALLEL TO THE HORIZON; COMMUNICATE THE MAGNETIC VIRTUE TO THIS ROD, AND ONE EXTREMITY WILL BE ALWAYS DIRECTED TOWARDS THE NORTH.

EXPERIMENT XXII.—Place any of the untouched needles in the apparatus on a point, and it may be fixed, or will remain in any required ſituation; communicate the magnetic virtue to it, and it will no longer be indifferent as to it's ſituation, but will fix upon one, in preference to any other, one end pointing towards the north, the other towards the ſouth.

EXPERIMENT XXIII.—Float a magnet on water by means of cork, and it will place itſelf in the direction of the magnetic meridian. A terella floated on quickſilver will do the ſame, the magnetic axis conforming itſelf to the direction of the meridian.

It is not improbable, that in ſome future period it may be diſcovered, that moſt bodies are poſſeſſed of a polarity, and will aſſume directions relative to the various affinities of the elements of which they are compounded.

The directive power of a touched needle is of the greateſt importance to mankind, as it enables the mariner to traverſe the ocean, and thus unite the arts, manufactures, and knowledge of diſtant countries, together. The ſurveyor, the miner, and the aſtronomer, derive many advantages from this wonderful property.

The mariner's compaſs conſiſts of three parts, the box, the card or fly, and the needle.

The card is a circle of ſtiff paper repreſenting the horizon, with the points of the compaſs marked on it; the magnetical needle is fixed to the under ſide of this card; the center of the needle is perforated, and a cap, with a conical agate at it's top, is fixed in this perforation; this cap is hung on a ſteel pin, which is fixed to the bottom of the box, ſo that the card hanging on the pin turns freely round it's center; one of the points being from the property of the needle always directed towards the north pole. The box, which contains the card and needle, is a circular braſs box hung within a ſquare wooden one, by two concentric rings called jimbals, ſo fixed by croſs centers to the two boxes, that the inner one ſhall retain an horizontal poſition in all motions of the ſhip. The top of the inner

box

box has a cover of glafs to prevent the card from being difturbed by the wind.*

It has been already obferved, that the ancients do not feem to have been acquainted with the directive power of the magnet. The only thing that feems capable of being miftaken for fome fuch knowledge, is what Jamblichus tells us in his life of Pythagoras, *That Pythagoras took from Abaris, the Hyperborean, his golden dart, without which it was impoffible for him to find his road.* But the authority of the writer, as well as the obfcurity of the paffage, prevents any conclufion being drawn from it.

Paul the Venetian is faid to have introduced the ufe of the compafs in 1260, but this is faid not to have been his own invention, but borrowed from the Chinefe. P. Gaubil fays, the directive power of the needle was known to the Chinefe as early as the year A. D. 223, under the Dynafty of Haz. But the Abbi Renaudot, in his Differtation on the Stone, when the Mahomedans went firft to China, has adduced ftrong reafons to

* Before the compafs was invented, the navigating of fhips was a tedious and precarious operation, and feldom performed out of fight of land; but this inftrument enables the mariner to travel over the feas almoft in as direct and true a tract, as the land carrier directs his carriage in a well beaten road.

to prove, that the Chineſe knew nothing of the mariner's compaſs, till it was introduced there by the Europeans. Vertomanus affirms, that A. D. 1500 he ſaw an Eaſt Indian pilot direct his courſe by a compaſs, framed and faſtened like thoſe uſed in Europe; but this muſt be received with ſome caution, as Mr. Barlow, in 1597, ſays that in a perſonal conference with two Eaſt Indians he was told by them, that inſtead of our compaſs they made uſe of a magnetical needle of ſix inches or longer, ſet upon a pin in a diſh of white China earth filled with water; that in the bottom of the diſh they had two croſs lines, to mark the four principal winds, and that the reſt of the diviſions were left to the ſkill of the pilot. But to return to Europe, Mr. Perrault, in his parallel between the ancients and the moderns, has cited ſome verſes of Guyot de Provins, who wrote in 1180, which ſhew diſtinctly that the mariner's compaſs was known in the South of France at that time.

"There is," ſays he,

"A ſtar that never moves,
"And an art that ne'er deceives,
"By virtue of the compaſs,
"An ugly black ſtone
"Which always attracts iron."

Though by moſt writers the invention of the compaſs is aſcribed to Flavio Goin of Analſi in Campanee, who lived about the year 1300. He is ſaid to be the firſt that applied it to navigation in the Mediterranean.

Mr. de Lalande informs us, that in "Le tréſor de Brunet," a manuſcript in the French king's library, there is a paſſage which proves that the compaſs was made uſe of about the year 1260.

VI. The Needle of the Mariner's Compass does not point exactly to the North, but is observed to change it's Azimuth, pointing sometimes towards the East, and sometimes to the West of the Meridian.

Fig. 109, N S repreſents the true meridian line; and E W, the eaſt and weſt line which is perpendicular to it; now the magnetic needle A B does not direct itſelf ſo as to coincide with the meridian line N S, but ſeparates itſelf ſo as to form an angle N C B, at preſent of about 22 degrees.

This deviation from the meridian is called the variation of the needle, and is different at different parts of the world, being weſt at ſome places, eaſt at others, and in parts where the variation

variation is of the ſame name, it's quantity is very different.

Though the directive power of the compaſs was applied to the purpoſes of navigation in the fourteenth and fifteenth century, it does not appear, that there were any apprehenſions during that time of it's pointing otherways than due north and ſouth.

The variation of the compaſs is ſaid to have been firſt diſcovered by Columbus, in his voyage, the latter end of the fifteenth century, for the diſcovery of that part of the world which is now called the Weſt Indies. But the firſt perſon who diſcovered that it was real, and was the ſame to all needles in the ſame place, is generally allowed to be Sebaſtion Cabot. This was about the year 1497.

After the variation was diſcovered by Cabot, it was thought, for a long time, to be invariably the ſame, at the ſame places, in all ages; but Mr. Gellibrand, about the year 1625, diſcovered that it was different at different times, in the ſame place.

From ſucceſſive obſervations made afterwards, it appears, that this deviation was not a conſtant quantity, but that it gradually diminiſhed, and at laſt about 1660 it was found that the needle pointed due north at London, and has ever ſince been

been increaſing to the weſtward of the north. So that in any one place the variations have a kind of libratory motion, traverſing through the north to unknown limits eaſtward and weſtward.

Dr. Halley in the laſt century publiſhed a theory of the variation of the compaſs. In this work, he ſuppoſes that there are four magnetic poles in the earth ; two of which are fixed, and two moveable, by which he explains the different variation of the compaſs at different times in the ſame place. But it is impoſſible to apply exact calculations to ſo complicated an hypotheſis.

Mr. Euler has ſhewn, that two magnetic poles placed on the ſurface of the earth will ſufficiently account for the ſingular figure aſſumed by the lines which paſs through all the points of equal variation in the chart of Dr. Halley.

Mr. Euler firſt examines the caſe wherein the two magnetic poles are directly oppoſite ; ſecondly, he places them in two oppoſite meridians, but at unequal diſtances from the poles of the world ; thirdly, he places them in the ſame meridian ; finally, he conſiders them ſituated on two different meridians. Theſe four caſes may become equally important ; becauſe, if it is determined that there are only two magnetic poles,

poles, and that theſe poles change their ſituation, it may hereafter be diſcovered, that they paſs through all the different poſitions.

Mr. Euler, after having examined the different caſes, finds that they alſo expreſs the earth's magnetiſm, as repreſented in the chart publiſhed by Meſſrs. Mountaire and Dodſon in 1744, particularly throughout Europe and North America, if the following principles are eſtabliſhed.

Between the arctic pole and the magnetic pole 14° 53′. Between the antarctic and the other magnetic pole 29° 23′, 53° 18′ the angle at the north pole formed by the meridian's paſſing through the two magnetic poles, 250° the longitude of the meridian, which paſſes over the northern magnetic meridian.

I ſhall now give a ſhort deſcription of a *variation compaſs*, an inſtrument which is uſed to obſerve with accuracy, the deviation of the needle from the meridian. To this end it ſhould poſſeſs the following properties.

1. That it may be eaſily and accurately placed in the meridian.

2. It ſhould indicate ſmall variations of the needle.

3. That the nonius, which marks the ſmall variation of the needle, may be moved without diſturbing it.

4. That

4. That the needle may be eafily taken off and inverted, to difcover whether the line marked on the needle coincides with the direction of magnetifm in the needle.

Fig. 110 reprefents a variation compafs, which it is prefumed will anfwer the foregoing purpofes. It has a glafs cover, which is made to flide on or to be taken off occafionally, two graduated arches are fixed at each end of the box with a moveable nonius to each arch, the noniufes are both moved by means of the milled nut A, without difturbing the fituation of the needle.

The inftrument is placed in the meridian by a telefcope, whofe line of collimation is parallel to the zero line of the inftrument. The telefcope is to be placed in two forks, in the manner advifed by Mr. Magellan in his Collection de differens Traités fur des Inftrumens D'Aftronomie, &c. p. 227, where the reader will find fome obfervations on the adjuftments, which are too long to be introduced in this effay. When the inftrument is placed in the meridian, the method of obferving is to move the northern nonius till the middle divifion coincides with the line on that end of the needle; and the nonius will then fhew the angle that end of the needle makes with the meridian. If the line on the fouthern end of the needle coincides with the

middle

middle diviſion of it's nonius, the foregoing obſervation is ſufficient; if not, the ſouthern nonius muſt be moved till it coincides with this end of the needle, and the mean between the two numbers thus found will be the true angle.

The needle is ſo conſtructed, that it may be readily taken off the cap and inverted, in order to obſerve with the under face of the needle uppermoſt, to diſcover whether the line on the needle is parallel to the direction of the magnetiſm in the needle, and hence diſcover whether this line gives the true angle which the direction of magnetiſm makes with the meridian. Having made the obſervation as before with both ends of the needle, invert and obſerve what is now ſhewn by the inverted ends of the needle, and if the line is parallel to the direction of the magnetiſm in the needle, the mean of the obſervation with the inverted ends will agree with the foregoing; on the other hand, if it is not parallel to the direction of magnetiſm, but makes it appear too much when the needle is upright, it will appear as much leſs when inverted, ſo that the mean of the foregoing means is the true angle which the needle makes with the zero line of the compaſs.

About the year 1722 and 1723, Mr. George Graham made a great number of obſervations on the diurnal variations of the magnetic needle. In the year 1750, Mr. Wargentin took notice of the regular diurnal variation of the needle; and also of it's being disturbed at the time of an aurora borealis. About the latter end of the year 1756, Mr. Canton began to make observations on the variation, and in 1759 communicated the following valuable experiments to the Royal Society.

The observations were made by him for 603 days; on 574, out of these, the diurnal variation was regular. The absolute variation of the needle westward was increasing, from about eight or nine o'clock in the morning, till about one or two in the afternoon, when the needle became stationary for some time; after that the variation westward was decreasing, and the needle came back again to it's former situation in the night, or by the next morning.

THE DIURNAL VARIATION IS IRREGULAR WHEN THE NEEDLE MOVES SLOWLY EASTWARD, IN THE LATTER PART OF THE MORNING, OR WESTWARD IN THE LATTER PART OF THE AFTERNOON; ALSO WHEN IT MOVES MUCH EITHER WAY AFTER NIGHT, OR SUDDENLY BOTH WAYS IN A SHORT TIME.

These irregularities seldom happen more than once

once or twice in a month, and are always accompanied with an aurora borealis.

The attractive power of a magnet will decreafe while it is heating, and increafe while it is cooling; the greater the force of the fame magnet, the more it will loofe in a given degree of heat.

EXPERIMENT XXIV. — About E N E from a compafs, a little more than three inches in diameter, Mr. Canton placed a fmall magnet two inches long, half an inch broad, and three-twentieths of an inch thick, parallel to the magnetic meridian; and at fuch a diftance, that the power of the fouth end of the magnet was but juft fufficient to keep the north end of the needle to the N E point, or to 45 degrees.

The magnet being covered by a brafs weight of fixteen ounces, about two ounces of boiling water was poured into it, by which means the magnet was gradually heating for feven or eight minutes; and during that time, the needle moved about three quarters of a degree weftward, and became ftationary at 44° $\frac{1}{4}$; in nine minutes more, it came back a quarter of a degree, or to 44° $\frac{1}{2}$; but was fome hours before it gained it's former fituation, and ftood at 45°.

EXPERIMENT XXV.—On each fide of the compafs, and parallel to the magnetic meridian, he placed a ftrong magnet, of the fize above-mentioned; fo that the fouth ends of both the magnets acted equally on the north end of the needle, and kept it in the magnetic meridian; but if either of the magnets was removed, the needle was attracted by the other, fo as to ftand at 45 degrees. The magnets were both covered with brafs weights of fixteen ounces each. Into the eaftern weight about two ounces of boiling water was poured; and the needle in one minute moved half a degree, and continued moving weftward for about feven minutes, when it arrived at 2°¾. It was then ftationary for fome time; but, in twenty four minutes from the beginning, it came back to 2°½, and in fifty minutes to 2°¼. He then filled the weftern weight with boiling water, and in one minute the needle came back to 1°¼; in fix minutes more it ftood half a degree eaftward; and after that, in about forty minutes, it returned to the magnetic north, or it's firft fituation.

It is evident, that the magnetic parts of the earth in the north on the eaft fide, and the magnetic parts of the earth in the north on the weft fide of the magnetic meridian, equally attract the north end of the needle. If then the eaftern magnetic

magnetic parts are heated faſter by the ſun in the morning, than the weſtern, the needle will move weſtward, and the abſolute variation will increaſe; when the attracting parts of the earth on each ſide of the magnetic meridian have their heat increaſing equally, the needle will be ſtationary, and the abſolute variation will then be greateſt; but, when the weſtern magnetic parts are either heating faſter, or cooling ſlower than the eaſtern, the needle will move eaſtward, or the abſolute variation will decreaſe; and when the eaſtern and weſtern magnetic parts are cooling equally faſt, the needle will again be ſtationary, and the abſolute variation will then be leaſt. This may be ſtill further illuſtrated, by placing the compaſs and two magnets, as in the laſt experiment, behind a ſcreen near the middle of the day in ſummer; then, if the ſcreen be ſo moved, that the ſun may ſhine only on the eaſtern magnet, the needle will ſenſibly vary in it's direction, and move towards the weſt; and if the eaſtern magnet be ſhaded, while the ſun ſhines on the weſtern, the needle will move the contrary way. By this theory, the diurnal variation in the ſummer ought to exceed that in the winter; and we accordingly find by obſervation, that the diurnal variation in the months of June and July is almoſt double that of December and January.

The irregular diurnal variation muſt ariſe from ſome other cauſe than that of heat communicated by the ſun: and here we muſt have recourſe to ſubterranean heat, which is generated without any regularity as to time, and which will, when it happens in the north, affect the attractive power of the magnetic parts of the earth on the north end of the needle. The Reverend Dr. Hales has a good obſervation on this head, in the Appendix to the ſecond volume of his Statical Eſſays, which I ſhall here tranſcribe. "That the warmth of the earth, at "ſome depth under ground, has an influence "in promoting a thaw, as well as the change of "the weather from a freezing to a thawing ſtate, "is manifeſt from this obſervation; viz. Nov. "27, 1731, a little ſnow having fallen in the "night, it was, by eleven the next morning, "moſtly melted away on the ſurface of the earth, "except in ſeveral places in Buſhy-Park, were "there were drains dug, and covered with earth, "where the ſnow continued to lie, whether "thoſe drains were full of water, or dry; as "alſo where elm-pipes lay under ground; "a plain proof that theſe drains intercepted "the

"the warmth of the earth from aſcending from
"greater depths below them; for the ſnow
"lay where the drain had more than four
"feet depth of earth over it. It continued
"alſo to lie on thatch, tiles, and the tops of
"walls."

That the air neareſt the earth will be moſt warmed by the heat of it, is obvious; and this has frequently been taken notice of in the morning, before day, by means of thermometers at different diſtances from the ground, by the Reverend Dr. Miles, at Tooting, in Surrey; and is mentioned in p. 526, of the 48th volume of the Philoſophical Tranſactions.

The aurora borealis, which happens at the time the needle is diſturbed by the heat of the earth, is ſuppoſed to be the electricity of the heated air above it; and this will appear chiefly in the northern regions, as the alteration in the heat of thoſe parts will be greateſt. This hypotheſis will not ſeem improbable, if it be conſidered, that electricity is now known to be the cauſe of thunder and lightning; that it has been extracted from the air at the time of an aurora borealis; that the inhabitants of the northern countries obſerve the aurora to be remarkably ſtrong, when a ſudden thaw happens after ſevere cold weather; and that the curious in theſe matters

matters are now acquainted with a ſubſtance, that will, without friction, both emit and abſorb the electrical fluid, only by the increaſe or diminution of it's heat: for if the Tourmalin be placed on a plane piece of heated glaſs, or metal, ſo that each ſide of it, by being perpendicular to the ſurface of the heating body, may be equally heated, it will, while heating, have the electricity of one of it's ſides poſitive, and that of the other negative; this will likewiſe be the caſe when it is taken out of boiling water, and ſuffered to cool; but the ſide that was poſitive while it was heating, will be negative while it is cooling, and the ſide that was negative, will be poſitive.

IF A NEEDLE, WHICH IS ACCURATELY BALLANCED AND SUSPENDED SO AS TO TURN FREELY IN A VERTICAL PLANE, BE RENDERED MAGNETICAL, THE NORTH POLE WILL BE DEPRESSED, AND THE SOUTH POLE ELEVATED ABOVE THE HORIZON. THIS PROPERTY IS CALLED THE DIP OF THE NEEDLE.

Fig. 111, HO repreſents an horizontal line placed in the magnetic meridian *d e*, a line at right angles to it, *b a* the ſituation a needle would take at London with reſpect to the horizon, making

making with the horizontal line an angle of 72 with the vertical line.

This property was difcovered by Robert Norman, about the year 1576. We fhall give the account of the difcovery in his own words.

"Having, fays he, made many and divers compaffes, and ufing always to finifh and end them before I touched the needle, I found continually that after I had touched the yrons with the ftone, that prefently the north point thereof would bend or decline downwards under the horizon in fome quantity; infomuch, that to the flie of the compafs, which before was made equal, I was ftill conftrained to put fome fmall piece of wax in the fouth part thereof, to counterpoife this declining, and to make it equal again.

"Which effect having many times paffed my hands without any great regard thereunto, as ignorant of any fuch property in the ftone, and not before having heard nor read of any fuch matter; it chanced at length that there came to my hands an inftrument to be made, with a needle of fix inches long, which needle after I had polifhed, cut off at juft length, and made to ftand level upon the pin, fo that nothing refted but only the touching of it with the ftone: when I had touched the fame, prefently the north

north part thereof declined down in ſuch ſort, that being conſtrained to cut away ſome of that part to make it equal again, in the end I cut it too ſhort, and ſo ſpoiled the needle wherein I had taken ſo much pains.

" Hereby being ſtroken into ſome cholar, I applied myſelf to ſeek further into this effect, and making certain learned and expert men (my friends) acquainted in this matter, they adviſed me to frame ſome inſtrument, to make ſome exact trial, how much the needle touched with the ſtone would decline, or what greateſt angle it would make with the plane of the horizon." Thus far Mr. Norman.

The dipping needle, repreſented fig. 112, was conſtructed by Dr. Lorimer, and is deſcribed in the Philoſophical Tranſactions, vol. lxv. part 1, page 81. It appears to me better calculated for the ſea ſervice than any other I have ſeen; it is leſs liable to be affected by the motion of the ſhip, than thoſe which are ſuſpended by gimbols fixed to the upper part of the inſtrument, beſides other advantages which are derived from the double motion of the needle. The needle *a b* plays vertically upon it's own axis, which has two conical points, which are inverted into the oppoſite ſides of the upright parallellogram *c d*; into this parallellogram, and at right angles to

6 it,

it, a ſlender braſs circle *f g h* is fixed; this circle is ſilvered and graduated to every half degree upon which the needle ſhews the dip: this, for the ſake of diſtinction, is called the circle of the magnetic inclination. The braſs parallellogram, and conſequently the circle of inclination alſo, turns horizontally upon two other points, the one above and the other below, in correſponding ſockets in the parallellogram; theſe points are fixed in a vertical circle *l i*, which is of ſuch a diameter as to allow the circle of inclination and parallellogram to move within it. This ſecond circle may be called a general meridian; it is not graduated, but has a ſmall braſs weight fixed to the lower part of it, to keep it upright, and the circle itſelf is ſcrewed at right angles, into another circle of equal external diameter, which is ſilvered and graduated on the upper ſide to every half degree. It repreſents the horizon, as it ſwings freely upon gimbols, and is always nearly parallel to it.

The uſe of this inſtrument is very plain, as the inclination or dip is at any time apparent from inſpection, and alſo the variation, if the frame is turned round till the great vertical lines meet exactly in the plane of the true meridian: for the circle of inclination being always in the needle's vertical plane, the edge of it will evidently point out upon the horizon the variation E or W. But at ſea, when there is not too much motion, you turn the frame round, till the vertical circle is in the plane of the ſun's rays; that is, till the ſhadow of one ſide of it juſt covers the other, and the edge of the circle will then give the magnetic amplitude, if the ſun is riſing or ſetting, but the azimuth at all times of the day; and the true amplitude or azimuth being found in the uſual way, the difference is the variation. If the motion is conſiderable, obſerve the extremes of vibration, and take the mean for your magnetic amplitude or azimuth. This inſtrument has a conſtant power in itſelf, not only of ſetting itſelf in the proper poſition, but alſo of keeping itſelf ſo; or of reſtoring itſelf to the ſame ſituation, if at any time it has loſt it; and it is curious to ſee how, by it's double motion, it counteracts, as it were, the rolling motion of the veſſel. The degrees ſhewn by each end of the needle ſhould be attended to, and the medium taken for the true dip or variation: alſo apply a good artificial magnet in ſuch manner as to turn the parallelogram and circle of inclination half way round horizontally, ſo that the end of the axis of the needle, which before pointed to weſt, ſhall now point to the eaſt; and obſerve where the needle ſtands, and if it differs from the preceding obſervation,

ſervation, take the mean, which will be found as near the truth as it is poſſible for any inſtrument to give.

DESCRIPTION OF A TERELLA AND OF THE MAGNETISM OF THE EARTH.

If a touched needle is placed near a magnet, it's direction to the magnetic needle is ſuſpended, and it aſſumes a direction relative to it's ſituation and diſtance from the poles of the magnet.

EXPERIMENT XXVI.—Place a ſmall needle on the pointed end of the braſs ſtands, and then bring it near the magnet, and the needle will direct itſelf differently, according to the diſtance from the poles of a magnet; or,

Move the ſmall dipping needle over a magnet, and by it's varied ſituations it will illuſtrate the foregoing obſervation; or,

Theſe relative ſituations and tendencies may be pleaſingly obſerved, by placing ſeveral touched needles round a magnet at the ſame time.

Fig. 113, A B repreſents a magnet, B the north pole, A the ſouth; *ba*, *ba*, *ba*, &c. ſeveral ſmall magnetic needles placed round the ſouth pole of the magnet; *ab*, *ab*, *ab*, ſimilar needles placed round the north end; *a* the north pole of these needles, *b* the south pole, *c* the center on which they turn. From this experiment may be derived others, accurately investigating the nature of the magnetic curves.

Now, if the earth is a great magnet, or if a large magnet is placed within it, we see from the foregoing experiment, that magnetic needles placed on it's surface would have different directions in different places, which is conformable to experience; and the apparent irregularities in the variation of the needle must be occasioned by the situation of the magnetic poles of the earth.

If the magnetic poles agreed with those of the earth, there would be no variation, and the magnetic needle would point to the true north and south. If the axis of the magnetic poles passed through the center of the earth, it would be easy to assign the quantity of the variation at every place; but as this is not the case, to account regularly for the variation, it would be necessary to know the exact situation of the magnetic poles of the earth, their number, force, and distance from the real poles, whether they shift their place, and if they move, the quantity of motion every year.

Dr. Haller supposed the earth to be an hollow sphere,

ſphere, with an internal nucleus in the cavity; he looked upon each part (the external and internal) to be a ſeparate magnet endowed with two poles, and whoſe magnetical axes were not coincident. A compaſs needle on the ſurface of the globe would be acted upon in the ſame manner as it would be by a magnet with four poles, and thus explains the variation. But as the variation changes in proceſs of time, he ſuppoſed that the poles do not keep the ſame poſition with reſpect to the ſurface of the earth and one another, and accounted for this motion, by ſuppoſing that the diurnal motion of the earth was impreſſed from without, and that the velocity of the internal part was leſs than the external. Therefore the nucleus would ſeem to turn ſlowly towards the weſt, and it's poles deſcribe ſmaller circles round the poles of the earth. And as the relative poſition of the four magnetical poles to each other, and to the poles of the earth, is changed, ſo muſt the direction of the needle be varied.

Mr. Euler, who has conſidered the ſubject in every point of view, and treated it with greater perſpicuity than any other writer, ſees no reaſon for adopting ſo laborious and complicated an hypotheſis. He thinks that every thing may be accounted for by two magnetic poles which are not directly oppoſite to each other, or whoſe magnetic

magnetic axis does not paſs through the axis of the earth, whereby he avoids many difficulties with which the other theory is incumbered.

In order to inveſtigate the phænomena of the variation and the dip of the needle, Gilbert, who ſuppoſed the earth to be a magnet, ground a loadſtone into a round figure, like a globe, which he called a terella or little earth, as it exhibited in ſome degree the ſame phænomena which take place on the different parts of the ſurface of the earth. But little progreſs, however, was made with this inſtrument, as it did not ſufficiently correſpond with the nature of the earth's magnetiſm. It has ſince received ſeveral improvements from Mr. Magellan, but ſtill remained very defective. The following improvement by Dr. Lorimer will, I hope, prove of eſſential ſervice, in diſcovering the laws by which the myſterious properties of the magnet are directed.

This terella conſiſts of a twelve inch terreſtrial globe, ſo contrived that the two hemiſpheres may be ſeparated or united at pleaſure. Two ſtrong artificial magnets are placed within the globe, in correſponding ſockets at the center of each hemiſphere, but ſo fitted, that while they act as one magnet, their extremities or ends may be placed in various poſitions, and moveable to any latitude within 30 degrees of the pole, and are

are likewiſe moveable round the axis to any degree of latitude at pleaſure.

Mr. Savery has adduced ſeveral inſtances to ſhew the force and action of the earth's magnetiſm; among others, that it will ſupport ſmall pieces of iron. He hung up a bar of iron, about five feet long, by a loop of ſmall cord, at the upper end, and then carefully wiped the lower end, and the point of a nail, that there might be no duſt or moiſture to prevent a good contact; then holding the nail under the bar, with it's point upward, he kept it cloſe to the bar, holding only one finger under it's head for the ſpace of thirty or more ſeconds, then withdrawing his finger gently downwards that the nail might not vibrate; if it fell off, he wiped the point as before; and tried ſome other part of the plane at the bottom of the bar. If the ends are ſimilar, and the bar has no permanent virtue, it is indifferent which end is downwards; if it has an imperfect degree of polarity, one end will anſwer better than the other.

EXPERIMENT XXVII.—The upper end A of a long iron rod, which has no fixed polarity, will attract the north end of a magnetic needle; the under end B repels the north end of the needle; invert the iron bar, and the end B, which is now

now the upper one, will attract the north pole of the needle that it repelled before; the cafe is the fame, if the bar is placed horizontally in the magnetic meridian, the end towards the fouth will be a north pole.

Iron bars of windows, which have remained long in a vertical pofition, acquire a fixed polarity. Mr. Lewenhoek mentions an iron crofs, which had acquired a very ftrong polarity. Mr. Canton propofed to make artificial magnets without the affiftance of natural ones; but in this he was miftaken, for his poker and tongs were natural magnets, and had their verticity fixed by being heated and cooled in a vertical pofition; and an iron or fteel bar, though without a verticity, while it remains in that pofition, exerts a polarity, and is able to communicate a fixed verticity to the fmall bar, and is therefore for the time a natural magnet. And further, every iron bar, from the largeft fize to a fixpenny nail, will exert this power when treated as above mentioned. But how this power is raifed fo foon to a degree greatly exceeding that which communicated it, we do not know; nor is it more eafy to account for the facility with which the magnetic power is withdrawn by a friction contrary to that which gave it.

THE

THE MAGNETIC MATTER MOVES IN A STREAM FROM ONE POLE TO THE OTHER, INTERNALLY, AND IS THEN CARRIED BACK IN CURVED LINES, EXTERNALLY, TILL IT ARRIVES AGAIN AT THE POLE, WHERE IT FIRST ENTERED, TO BE AGAIN ADMITTED.

EXPERIMENT XXVIII.—Put one of the glaſs panes over a magnetical bar, ſift ſteel filings on the glaſs, then ſtrike the glaſs gently, and the filings will diſpoſe themſelves in ſuch a manner as to repreſent, with great exactneſs, the courſe of the magnetic matter. The curves by which it returns back to the pole, where it firſt entered, are alſo accurately expreſſed by the arrangement of the filings. The largeſt curves riſe from one polar ſurface, and extend to the other; they are larger in proportion as they riſe nearer the axis or center of the polar ſurface; the curves, which ariſe from the ſides of a magnetical body, are interior to thoſe which ariſe from the polar ſurfaces, and are ſmaller and ſmaller in proportion to their diſtance from the ends. That the magnetic matter does move back, in a direction contrary to that with which it paſſes through the magnetical body, is confirmed by it's action on a ſmall compaſs needle, when preſented to it at different places. See fig. 103.

The greater the diſtance is between the poles of a magnet, the larger are the curves which ariſe from the polar ſurface.

THE IMMEDIATE CAUSE WHY TWO OR MORE MAGNETICAL BODIES ATTRACT EACH OTHER, IS THE PASSAGE OF ONE AND THE SAME MAGNETICAL STREAM THROUGH THEM.

EXPERIMENT XXIX. — Let two magnets be placed at ſome diſtance from each other, the ſouth pole of one oppoſed to the north pole of the other, lay a pane of glaſs over them, and ſprinkle it with ſteel filings, then ſtrike the pane gently with a key, and the filings will arrange themſelves in the direction of the magnetic virtue. The filings which lay between the two polar ſurfaces, and near the common axis, are diſpoſed in ſtrait lines going from the north pole of one, to the ſouth pole of the other: the pores being now in the ſame direction, ſo that the fluid which paſſes through A B, fig. 104, finds the pores at the pole *a* open to receive them, it will therefore paſs through this, and coming out at *b* will turn towards A, to continue it's ſtream through the magnet, and thus form one atmoſphere or vortex, which preſſed, on all ſides, by the elaſtic force of the other, carries the magnets towards

towards each other. At different diſtances from the axis the filings deſcribe regular curve lines, which run from one pole to the other, and diverge from each other in moving from the ſouth pole, till they come half way; they then converge more and more, till they arrive at the north pole. If the oppoſed poles are diſtant from each other, ſome arches will paſs from one pole to the other of the ſame magnet; fewer will be formed in this manner if they are brought nearer together, and more will proceed from one magnet to the other; the ſtream of the magnetic matter will ſeem more concentrated and abundant.

EXPERIMENT XXX.—While the magnets remain in the foregoing poſition, place a ſmall untouched bar or needle in the ſtream of the magnetic virtue; this will paſs through it, and give it a polarity in the direction of the ſtream.

EXPERIMENT XXXI.—On the ſame principle, a large key, or other untouched piece of iron, will attract and ſupport a ſmall piece of iron, while it is within the ſphere of action of the pole of a magnet, but will let them fall when it is out of the magnetic ſtream.

EXPERIMENT XXXII.—A ball of ſoft iron, in contact with a magnet, will attract a ſecond ball, and that a third, till the ſtream becomes too weak to ſupport a greater weight.

EXPERIMENT XXXIII.—Place two magnets parallel to the horizon with two poles of the ſame name oppoſed to each other, and their diſtance in proportion to the ſtrength of the magnets; ſuſpend a needle nicely ballanced on a thread between them, and either pole will attract the needle notwithſtanding their mutual repulſion.

EXPERIMENT XXXIV.—Put into motion one of the ſmall whirligigs with an iron axis, and then take it up by a magnet; it will preſerve it's rotatory motion much longer than if it were left to whirl on the table; a ſecond and a third whirligig may be ſuſpended one under another, according to the ſtrength of the magnet, and yet continue in motion.

EXPERIMENT XXXV.—Place a magnet upon each of the braſs ſtands, with their poles of contrary names oppoſed to each other, and a pleaſing chain of iron balls may be ſuſpended between them. Preſent either pole of another magnet towards them, and they will fall down.

EXPERIMENT XXXVI.—Place two bars in a line with the north end of one to the ſouth end of the other, and about one third the length of the bar diſtance from each other, to which diſtance the power ſeems to be ſeparated in moſt bars; place the glaſs panes on theſe bars, and then ſift the filings over them, and they will range themſelves between the bars, in the ſame manner they are ranged about the middle of each bar; ſhewing that when the powers are ſeparated to this diſtance, they act much in the ſame manner as when they are ſeparated in the ſame bar.

MAGNETIC REPULSION ARISES FROM THE ACCUMULATION OF THE MAGNETIC FLUID, AND THE RESISTANCE FORMED TO IT'S ENTRANCE IN THE MAGNET.

EXPERIMENT XXXVII.—If the two poles of the ſame name of two magnets are brought near to each other, and placed under a pane of glaſs, on which iron filings have been ſtrewed, the filings will be diſpoſed into curves, which ſeem to turn back from each other towards the oppoſite pole. The fluid, which proceeds from B, fig. 103, meeting with reſiſtance from the pores at D, is forced

forced to turn back, and circulate round it's own magnet, and thus form two atmofpheres, which act againft each other, in proportion to the force and quantity of the ftream which paffes through the magnets.

EXPERIMENT XXXVIII.—Take a fteel needle, with a very fine point, and rub it from the eye to the point five or fix times with the north pole of a magnetic bar; the eye will be the north, and the point the fouth pole of the needle.

The attraction and repulfion of magnets is not hindered or increafed by the interpofition of any body whatever.

EXPERIMENT XXXIX.—Dip one point of the needle in fteel filings, and it will take up a confiderable quantity. Take the magnetic bar in one hand, and the needle with the filings in the other, hold them parallel to the horizon, with the point of the needle near the fouth pole of the magnet, and the fteel filings will fall from the point of the needle; as foon as the filings drop off from the point, withdraw it from the fphere of action of the magnet, and the point will be fo far deprived of it's attractive quality, that it will not again attract the fteel filings. If the needle is not taken away, but continues for a few minutes about half an inch from the bar, the polarity of the needle will be changed.*

EXPERIMENT XL.—Place two magnets close to each other, with the north and south poles conjoined together, in this situation the magnetic power is so far counteracted or condensed, as to have very little effect on iron, hardly sustaining the smallest piece; separate the magnets half an inch, and they will support a piece of iron; close them, and they will let it drop.

EXPERIMENT XLI.—Suspend two sewing needles from the pole of a magnet, and the needles will diverge; the repulsion will be augmented by the addition of another magnet; it is also increased by applying a bar of iron to the opposite pole of the magnet, and diminished by applying it to the same.

EXPERIMENT XLII.—Bring a bar of iron towards the extremity of the needles, and their repulsion will be augmented.

EXPERIMENT XLIII.—Suspend by a thread the light cylindrical bar G D, fig. 114, which has a round head at each end, and place it at a little

* Farther Proofs, &c. by Mr Lyon, p. 60.

little diſtance from the magnet M, then bring an iron wire EE, near the lower head D, and the cylinder will be repelled, but will be attracted by the ſame wire if it is brought near the upper head.

EXPERIMENT XLIV.—Hang a number of balls to each other, by applying the firſt to the north pole of a magnet, preſent the ſouth pole of another magnet to one of the middle balls, and all thoſe below it will thereby be deprived of the magnetic ſtream, and fall aſunder; the ball to which the magnet was applied will be attracted by it, and all the others will remain ſuſpended. If the north end of the magnet be preſented, then the ball, to which it is applied, will alſo drop.

A ſingular fact is related by ſome ancient writers on magnetiſm: That if two loadſtones, a ſtronger and a weaker, have their repellent poles brought together, the weaker will have it's power confuſed, and will not come to itſelf for ſome days; the polarity of the part, in contact, becomes inverted by the ſtronger power; but as that power reaches but a little way beyond the polar ſurface, the unaltered power, in the remaining part of the ſtone, is able, by it's contrary force, to reſtore the confuſed part of the ſtone in a few days.

It

It does not appear that there is any certain law of attraction peculiar to magnetifm; for in different pairs of magnets, the force will vary at different diftances. The magnetic attraction is not to be computed from the center of the magnets, but from the center of the pole.*

Though many experiments have been made to difcover, whether the force by which two magnets are repelled or attracted, acts only to a certain diftance; whether the degrees of it's action within, and at this diftance, is uniform or variable, and in what proportion, to the diftances it increafes or diminifhes; yet we can only infer from them, that the magnetic power extends further at fome times, than it does at others, and that the fphere of it's action is variable.

The fmaller the loadftone or the magnet is, the greater is it's force, *cæteris paribus*, in proportion to it's fize. When the axis of a magnet is fhort, and of courfe it's poles very near, their action on each other weakens the magnetic force. A variety of other caufes will alfo occafion great irregularity in the attraction of magnetifm. If one end of a magnet is dipped in fteel filings, we fhall find that they are very

* The magnetic effects of the contrary pole muft be alfo confidered in eftimating the forces of magnetic attraction and repulfion.

ſeldom diſtributed with uniformity, but diſpoſed in little tufts, ſome places more thick than others. The force of magnetic attraction between the ſame magnets, and at the ſame diſtance, may be varied by turning the magnets on their axis, and making different parts of the polar ſurfaces regard each other. If a ſtrong magnet be applied to a weaker, a kind of repulſion ſeems to take place even between two poles of the ſame name, but it's force is overpowered by the attraction of the ſtronger.

EXPERIMENT XLV.—If a touched needle is placed near a magnet, it's direction to the magnetic meridian is ſuſpended, and it aſſumes a direction relative to it's ſituation and diſtance from the poles of the magnet. Place a ſmall needle on the pointed end of one of the braſs ſtands, and then bring it near the magnet, the needle will direct itſelf differently, according to it's diſtance from the poles of the magnet. Theſe relative ſituations and tendencies are more pleaſingly obſerved by placing ſeveral touched needles round the bar at the ſame time. The motion of the ſmall dipping needle further illuſtrates this propoſition. From the three laſt experiments various others of conſiderable importance may be derived for accurately inveſtigating the curves, according to which the magnets act, and illuſtrating further ſome of the intricate branches of magnetiſm.

The northern magnetiſm is deſtroyed by the communication of the ſouthern, and *vice verſa.* Hence it is clear, that the two magnetic powers counteract each other, and that if both be communicated to the ſame arm of a magnet, the magnetiſm acquired by the arm will be that of the ſtrongeſt, and as the difference between the two powers.

Two ſtrait magnets will not be weakened, if they are laid parallel to one another, with poles of the oppoſite denomination correſponding to each other, the ends being connected together by pieces of iron, which will keep up and facilitate the circulation of the magnetic fluid through them; but they ſhould never be ſuffered to touch each other, except when they lie in the ſame direction, and with poles of contrary names.

A ſingle ſtrait magnet ſhould be always kept with it's ſouth pole towards the north, or downwards, in the northern magnetic hemiſphere, and *vice verſa* in the ſouthern hemiſphere. Iron ſhould never be lifted but by the ſouth pole of a ſtrait magnet in this hemiſphere of the world.

Every kind of violent percuſſion weakens the power of a magnet; a ſtrong magnet has been entirely deprived of it's virtue by receiving ſeveral ſmart ſtrokes of a hammer; indeed, whatever deranges, or diſturbs the internal pores of a magnet, will injure it's magnetic force, as the bending of touched iron, wires, &c.

EXPERIMENT XLVI.—Fill a ſmall dry glaſs tube with iron filings, preſs them in rather cloſe, and then touch the tube as if it was a ſteel bar, and the tube will attract a light needle, &c. ſhake the tube ſo that the ſituation of the filings may be diſturbed, and the magnetic virtue will vaniſh.

EXPERIMENT XLVII.—But though a violent percuſſion will deſtroy a fixed magnetiſm, yet it will give polarity to an iron bar which had none before; for a few ſmart ſtrokes of an hammer, on an iron bar, will give it a polarity, and by hitting firſt one end of the bar, and then the other, while it is held in a vertical ſituation, the poles may be changed. Twiſt a long piece of iron wire backwards and forwards ſeveral times, then break it off at the twiſted part, and the broken end will be magnetical.

EXPERIMENT XLVIII.—If a magnet be cut through the axis, the ſegments, which were joined

joined before, will avoid and fly from each other.

EXPERIMENT XLIX.—If a magnet is divided by a ſection perpendicular to the axis, the parts which were joined before will have acquired contrary poles, one north, the other ſouth, thus generating a new magnet at every ſection.

From theſe, and ſimilar experiments, Mr. Eeles infers, that magnetiſm conſiſts of two different diſtinct powers, which in their natural ſtate are conjoined, and exert but little ſenſible action, and ſtrongly attract each other at all times; but when they are ſeparated by force, they act like thoſe of electricity; for if magnetiſm is excited in two different pieces of ſteel by the ſouth pole of a magnet, the ends repel each other; but if one piece be excited by the north pole, and another by the ſouth, they will attract each other. He further ſuppoſes, that a magnet attracts, and is attracted, not entirely according to it's own ſtrength, but according to the quantity of iron to be attracted; and that magnetiſm is a quality inherent in all iron, and of which it cannot be diveſted; for fire, which will deſtroy a fixed magnetiſm, does not deprive it of it's natural quantity; on the contrary, it will give it a polarity, or fixed magnetiſm, ac-

cording

cording to the manner of heating or cooling of the iron.

The powers of magnetiſm, like thoſe of electricity, are excited and ſeparated by friction. This effect is wonderful in both, but more ſo in magnetiſm, where two powers, naturally attracting each other, remain ſeparated in the ſame ſteel bar for many years, and yet they may be reduced to their natural ſtate by the friction of two other magnets, acting in a contrary order to that by which the poles were originally ſeparated.

Magnetiſm and electricity act ſtrongeſt at corners, edges, and points.

Magnetiſm may be communicated to a ſmall ſteel needle, by paſſing the diſcharge of a large battery through it.

The diſcharge of a battery through a ſmall magnetic needle will ſometimes deſtroy the magnetiſm, and at other times invert the poles of the magnet, which has alſo been frequently effected by lightning.*

EXPERIMENT I.—Place a magnet M, fig. 115, at a given diſtance from the needle A B, fig. 115, that it makes the needle deviate from the meridian N C to C B, forming an angle N C B

* See Eſſay on Electricity, p. 150.

C B of 40 degrees. Now apply a bar of iron I to the magnet M, ſo that it may be perpendicular to it, but only covering half the breadth of the magnet, and the needle will go back to 30 degrees.

EXPERIMENT LI.—Place on the other ſide a bar Y, exactly ſimilar to the bar I, and ſituated in the ſame manner; the needle will be very little affected, nay, by altering a little the ſituation of the bar, the needle will not be at all affected by it.

Remove the bar Y from the magnet by a parallel motion, and the needle will approach ſtill nearer the meridian, or, in other words, the action of the magnet will be weaker.

EXPERIMENT LII.—Place a magnet M, fig. 116, at ſome diſtance from the needle A B, and parallel to the magnetic meridian N S, the needle will deviate from it's ſituation; now approach ſlowly towards the needle with a bar of iron, moving it in the equator of the needle, and the attraction of the needle to the magnet will be diminiſhed, till a ſmall part of *g* of the iron bar gets beyond the magnet; when it's action will be conſiderably increaſed, and the needle more ſtrongly attracted.

EXPERIMENT

EXPERIMENT LIII.—Place a magnet ſo that it may attract a needle by it's ſouth pole, place one end of a bar of iron on the north pole of the magnet, and it will immediately attract the needle with more force.

EXPERIMENT LIV.—Place a ſtrong magnet at ſome diſtance from a magnetic needle, ſo that it may either not act on the needle or elſe make it deviate only a certain quantity from the meridian; apply a bar of iron to the magnet, placing the bar between it and the needle, and the needle is immediately agitated.

EXPERIMENT LV.—Let the magnet be placed ſo near to the needle as to produce a ſenſible effect on it, then place the bar of iron on the pole of the magnet, deſcribe a circle with the bar of iron, and the action of the magnet appears to be weakened, and the needle returns to the ſituation it had before the magnet was placed near it.

EXPERIMENT LVI.—Place a bar of iron between a magnet and the needle, ſo that it may be perpendicular to the magnet; and the needle endeavours to recover it's true ſituation, and even returns to it, if the bar be thick enough, or if two or three more are interpofed.*

* Van Swinden, Memoire fur l'Electricité et le Magnetifme.

MAGNETICAL RECREATIONS.

BOX OF METALS.

THIS box contains five metallic tablets, of the ſame ſhape and ſize, that they may be placed indiſcriminately into ſimilar holes made in the bottom of a box. One of the tablets is gilt to repreſent gold, the ſecond is ſilvered to repreſent ſilver, the third is of copper, the fourth of tin, and the fifth of lead. A ſmall magnetic bar is incloſed in each of theſe pieces of metal, but is placed in a different ſituation in each piece. Another part of the apparatus is a ſmall magnetic perſpective, furniſhed at bottom with a magnetic needle, ſimilar to thoſe in ſmall compaſſes; a piece of paper is paſted at the bottom of the perſpective on the inſide, on which are marked the initials of the different metals; theſe initials are ſo placed as to correſpond with the magnets which are incloſed in the metals. If this perſpective be placed over any of the tablets, ſo that the north and ſouth line is perpendicular to the front of the box, the needle will point to the initial letter of the metal over which it is placed.

placed. Prefent the box to any one to difpofe of the tablets as he pleafes, then to fhut the box, and to return it you; when by means of the perfpective you will be enabled to tell him how he has placed them.

COMMUNICATIVE MIRROR.

This apparatus confifts of the perfpective and ftand reprefented NOLMK, fig. 118, four tablets as R, and a fmall box AB with a drawer to hold one of the tablets.

A fmall circular card with a touched needle, and on which are placed four pictures at right angles to each other, plays on a pivot in the foot MK of the perfpective. Over part of this card is a hole, the center of which coincides with the center of the tube LN. An inclined mirror is fixed in the perfpective NO, fo as to be directly over the above-mentioned hole. There are alfo four tablets, on each of which a fmall picture is pafted fimilar to thofe on the card, and a magnetic bar inclofed in each. If one of thefe is placed in the drawer of the box AB, and the perfpective over that, as in fig. 118, and the fore part is then preffed down to difengage a fpring which is within the foot, then will the card place itfelf fo as to correfpond with the

 tablet

tablet in the drawer, and a ſimilar figure will be ſeen by looking in at the eye end of the perſpective. Conſequently, if you preſent the four tablets to any perſon, deſiring him to place any one of them in the drawer and conceal the others, then ſhut the drawer and return it; now place the perſpective in a box, and preſſing the part T as above-mentioned, and you may ſhew him the figure on the tablet he placed in the drawer, in the eye end of the perſpective.

Theſe, and many other recreations of this kind will be found in " Hooper's Rational Recreations," the greater part of which I have executed with improvements.

OF THE ACTION OF THE MAGNETIC ATMOSPHERE.

The pole of a magnet produces, on the part of a bar to which it is applied, the pole of a contrary name: therefore, if two bars fully touched have the poles of the ſame name joined together, they tend to produce on each other a force of a contrary name to that with which they are endowed; and this effect will diminiſh the polar force of each bar; conſequently the magnetic force of each longitudinal element of an artificial magnet diminiſhes as it's bulk is increaſed, and the total force of two magnets fully touched, and of of the ſame length but unequal in bulk, will be in a leſs ratio than that of their maſs.

If the magnet does not touch the bar, but is held at ſome diſtance from it, the phænomena will be the ſame; but the bar will acquire leſs magnetiſm than when it was in contact with the magnet.

Each point of a magnet may be looked on as the pole of a ſmaller magnet, tending to produce on the points of the magnet a force contrary to it's own. The effect of this tendency will be greater, in proportion to the force of the point, and it's nearneſs to thoſe points on which it acts; and the force of a magnet will depend on the reciprocal action of theſe points on each other.

The action of a magnetic point is increaſed according as the intenſity of the other points on it increaſes, as their number is greater, and their diſtance from it is leſs. The more the magnetic points are (from the figure of the magnet) brought together, and the ſtronger their action on each other in order to deſtroy their reciprocal forces, the weaker is the force of each point.

Hence in two bars of the ſame weight and length the broadeſt will be the moſt powerful, becauſe it's longitudinal fibres are more inſulated.

If a bar is divided into two parts, each will receive

receive a greater degree of magnetiſm than when they were united.

From the ſame analogy we may infer, that the exterior points and edges of a magnet will have more power than the interior ones of the ſame bar, as they are alſo more inſulated.

A bar is ſaid to be ſaturated with magnetiſm, if when ſuſpended freely in an horizontal poſition it continues to make the ſame number of oſcillations in the ſame time, though continued to be rubbed with a magnet. As each point of a magnet tends to deſtroy the magnetiſm of the neighbouring parts, the bar appears to be in a forced or unnatural ſtate, and the magnetic fluid endeavours to ſpread itſelf over the bar in an uniform manner, and conſequently to weaken and deſtroy it's powers. The greater part of what has been ſaid on the action of the particles of magnetiſm on each other will be found equally applicable to electricity.

FINIS.

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A magnetical apparatus, from 2l. 12s. 6d. to	10	10	0
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PLATE I.

Fig. 1.

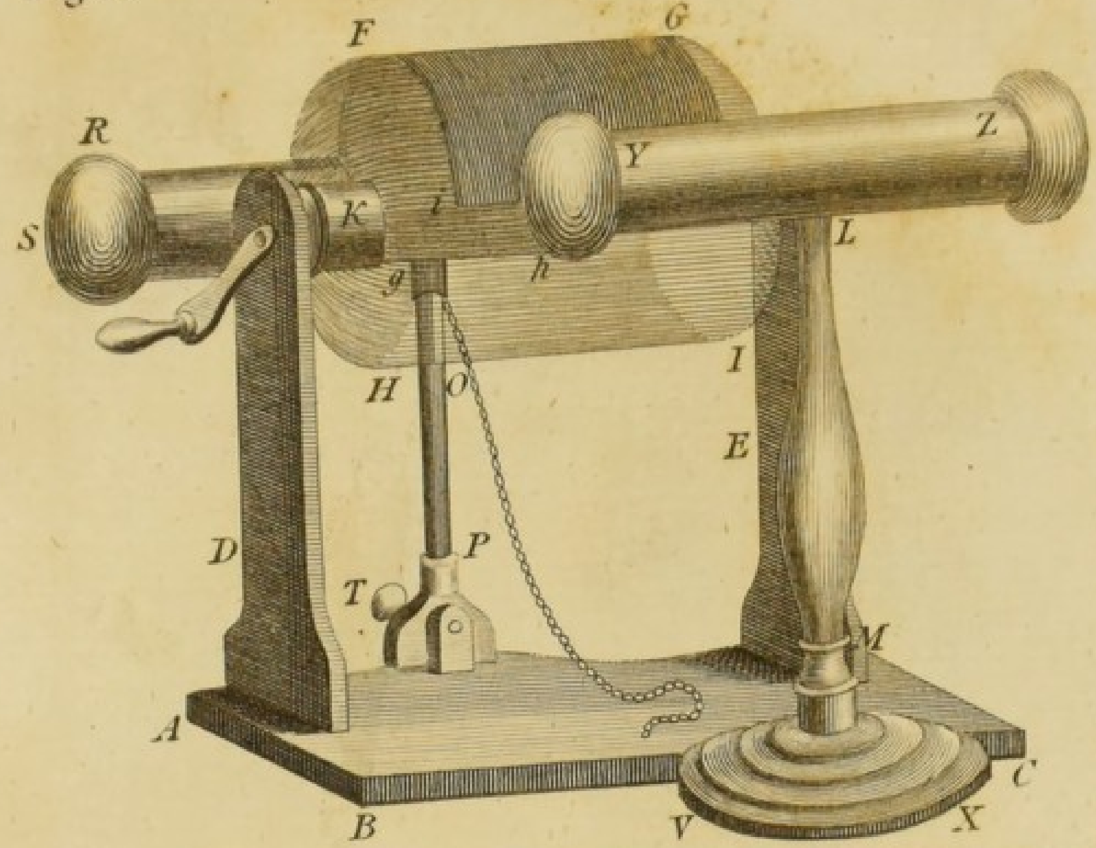

Fig. 2.

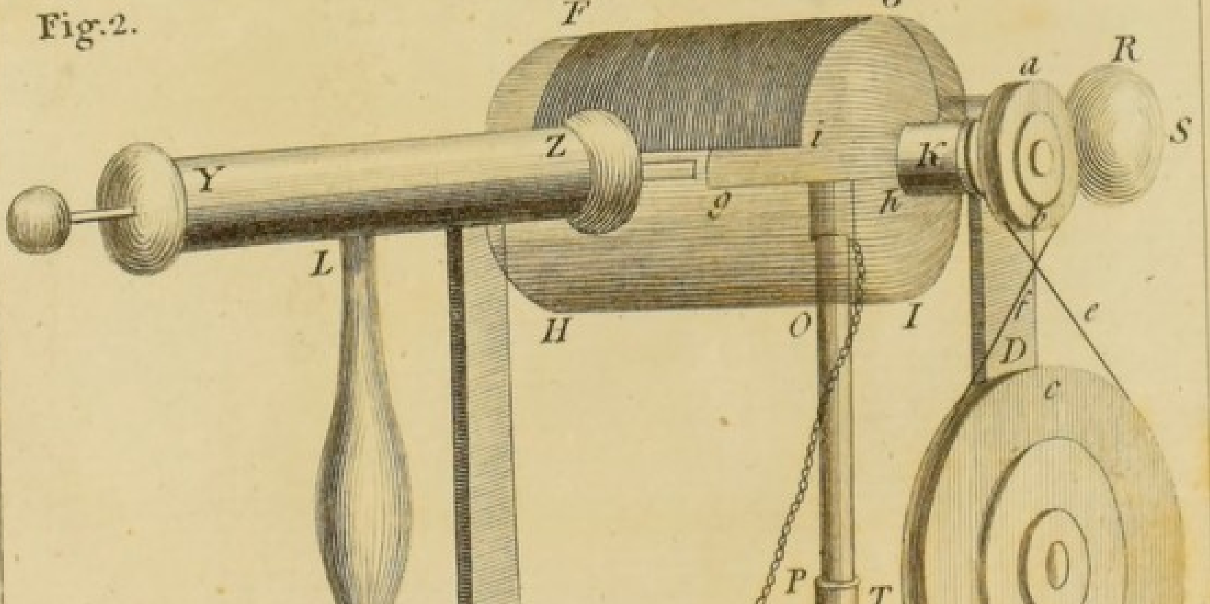

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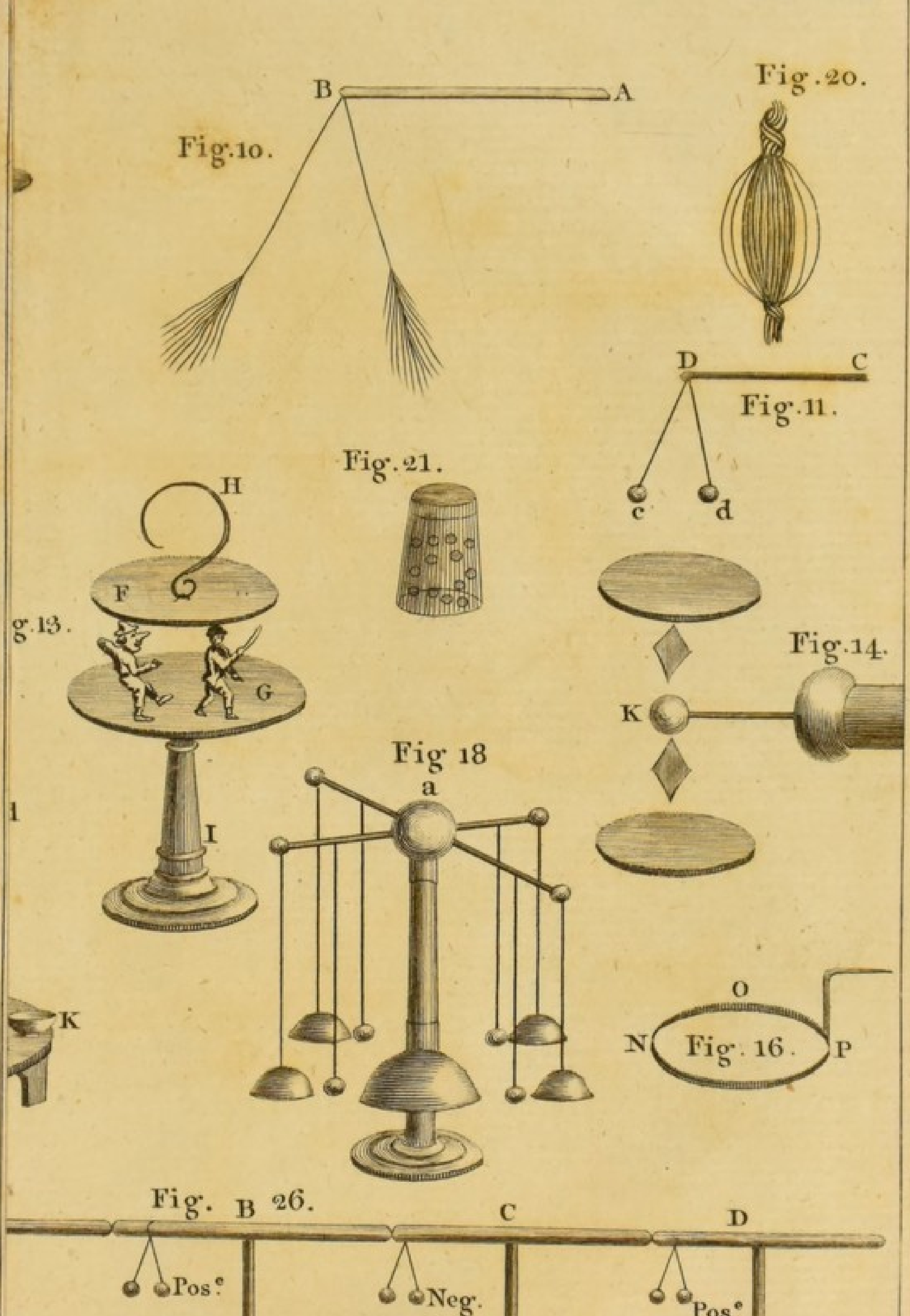
PLATE. II.



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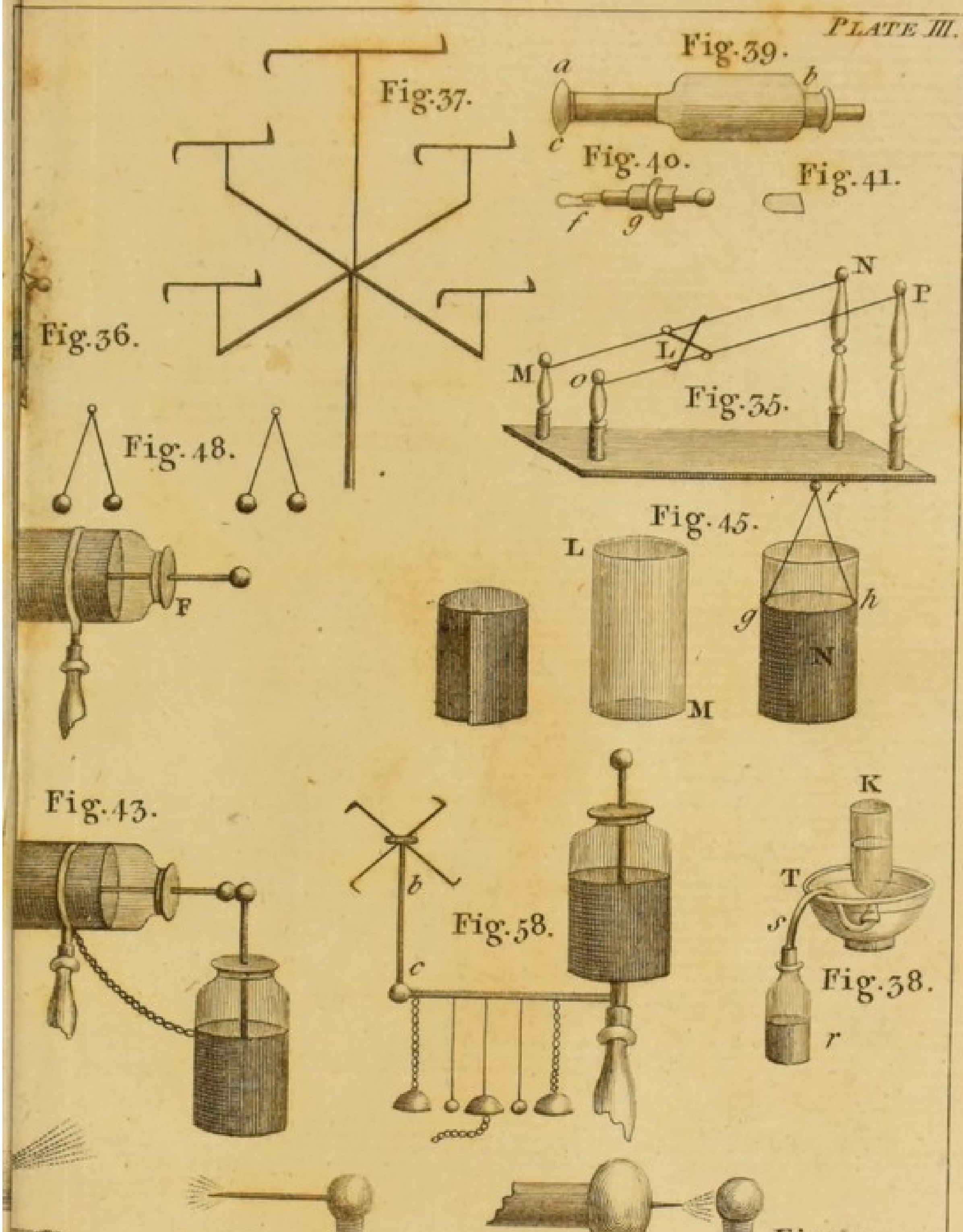

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PLATE IV.

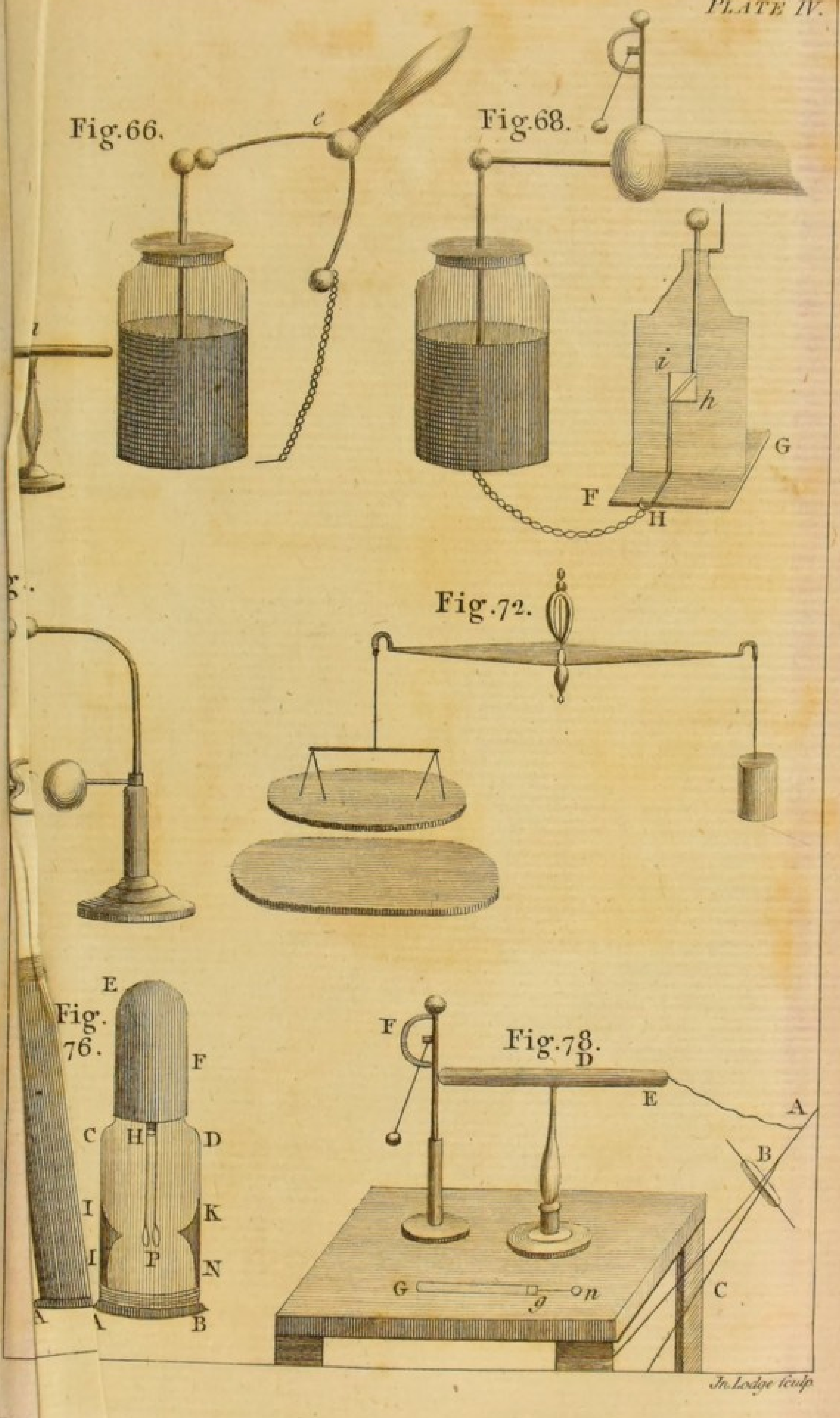

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PLATE V.

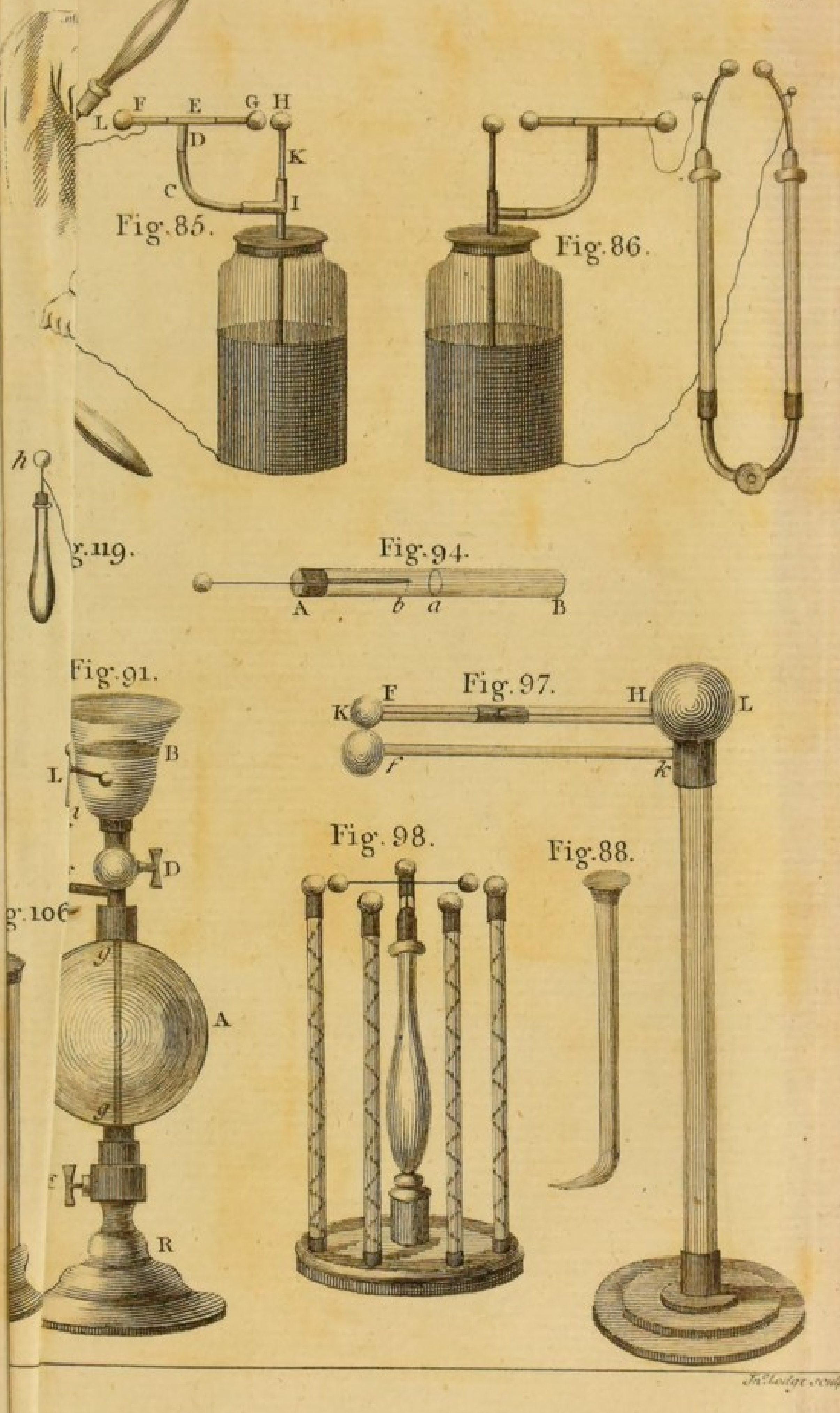

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Fig. 103.

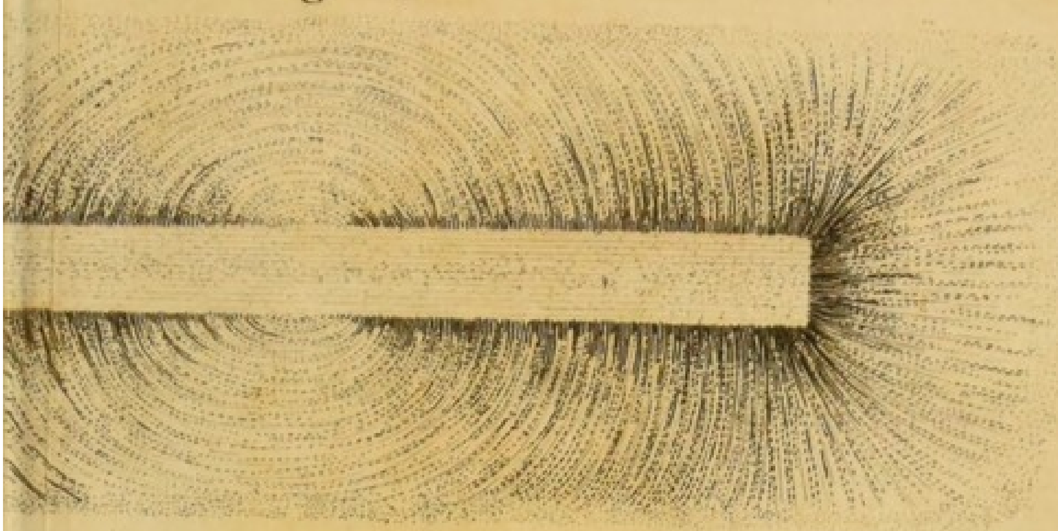

Fig. 104.

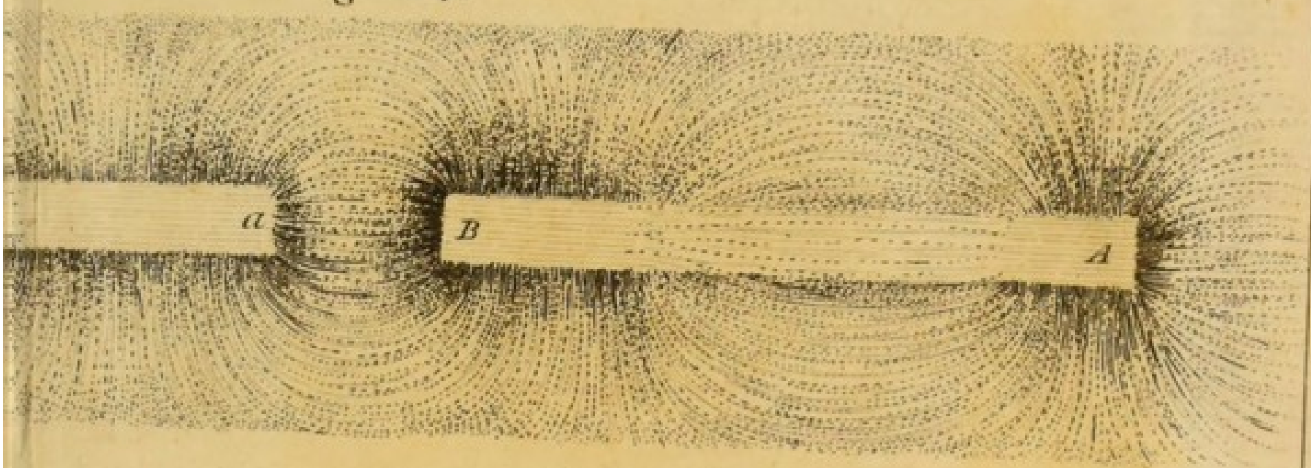

Fig. 105.

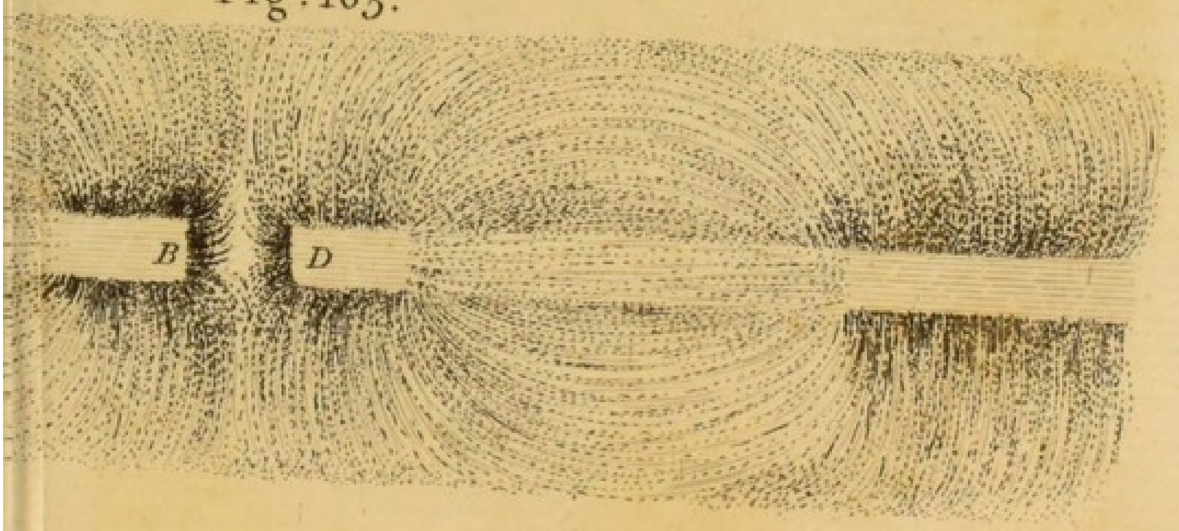

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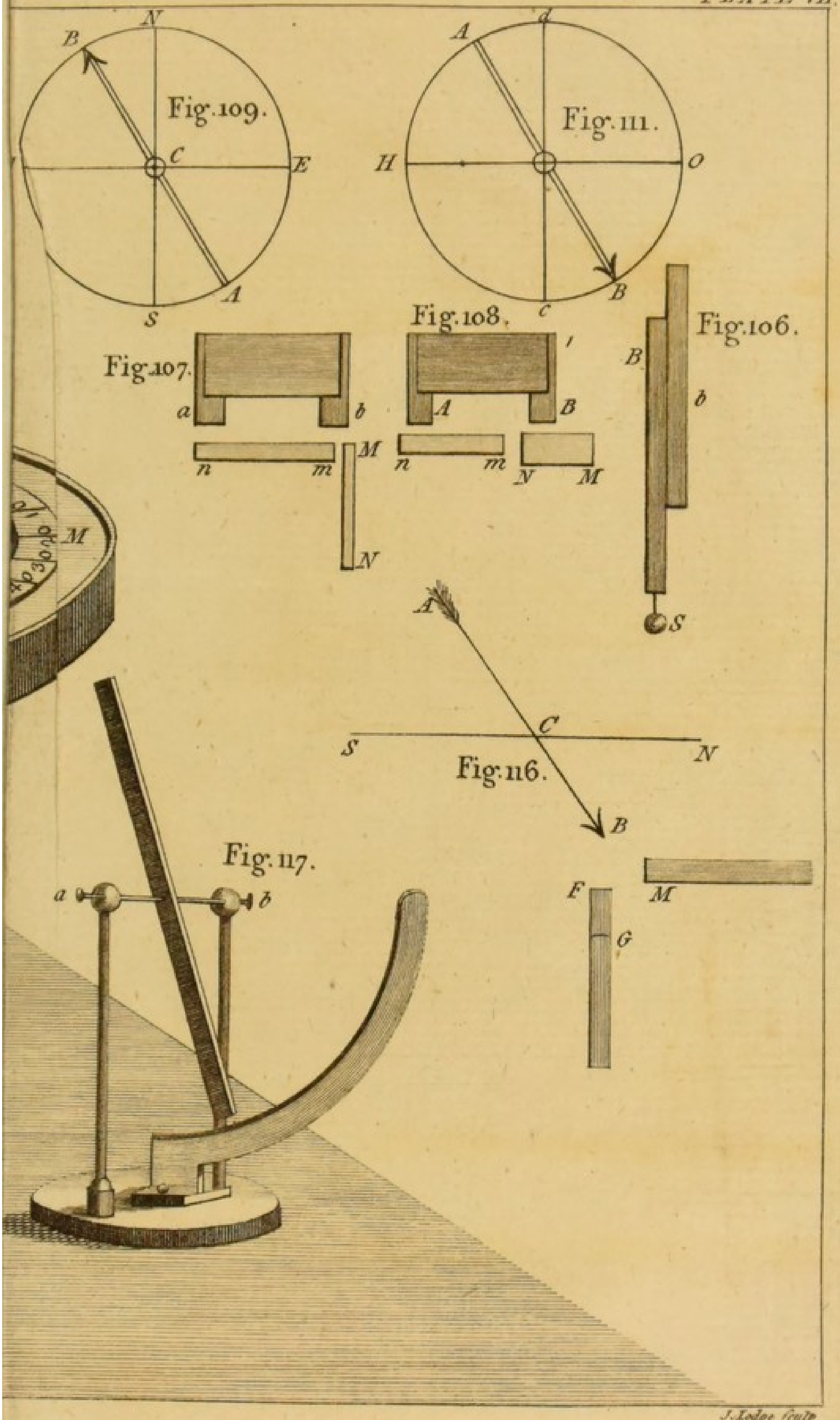
PLATE VII.



J. Lodge sculp