An essay on electricity : in which the theory and practice of that useful science are illustrated by a variety of experiments, arranged in a methodical manner : to which is added an essay on magnetism

PLATE I.

Fig. 1.

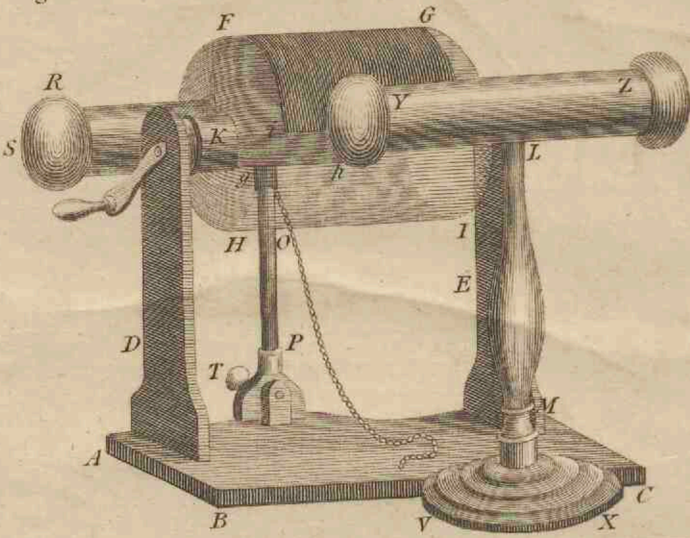
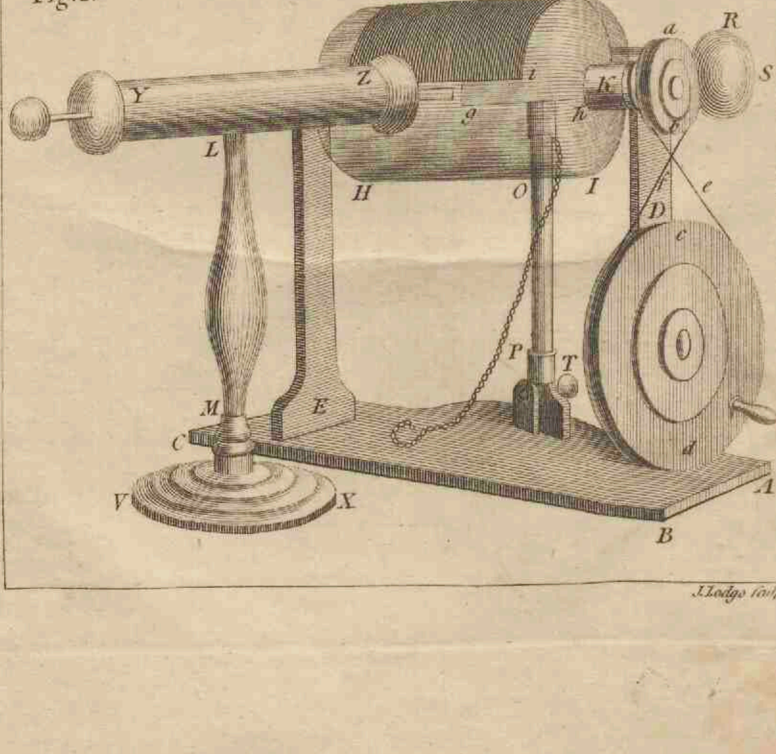


Fig. 2.



J. Lodge sculp.

AN ESSAY ON ELECTRICITY;

IN WHICH THE

THEORY AND PRACTICE

OF THAT USEFUL

SCIENCE,

Are illustrated by

A VARIETY of EXPERIMENTS,

Arranged in a Methodical Manner.

TO WHICH IS ADDED,

An ESSAY on MAGNETISM.

By GEORGE ADAMS,
Mathematical Instrument-Maker to His MAJESTY.

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M.DCC.LXXXIV.

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; its utility to man, will not be inferior to its dignity as a ſcience.

I have not attempted to trace Electricity from its first rude beginnings, or to follow the mind of man in its 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. Priestly. 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 is 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 its 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

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 wrote 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'Academie de Berlin for 1780, at a time when I could not procure them elſewhere.

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

I beg leave to avail myſelf of this opportunity to acquaint the public, that I am now engaged in a work deſcribing the mechanical parts of Mathematical and Philoſophical Learning, and explain-ing 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 its 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 its patronage, and which I mean to publiſh with all convenient ſpeed.

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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 phœnomena of nature, ſhould have remained ſo long in obſcurity; for, comparatively ſpeaking, its 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*; nevertheleſs their knowledge was circumſcribed, becauſe the mode of acquiring it was limited. Very little progreſs, therefore, was made in this branch of natural hiſtory, till the happy period arrived, when the philoſopher was emancipated from the chains of hypothetic reaſoning, and the uncertainties of vain conjecture.

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

Electricity has been dignified in a peculiar manner, by engaging the attention of the philoſophic hiſtorian; who has delineated, in a very pleaſing manner, the gradual progreſs of its diſcoveries. He has deſcribed the different theories that have been invented to account for its various phœnomena; has communicated to the public many valuable experiments of his own; and pointed out the extenſive field which remains to be inveſtigated.

Since the publication of Dr. Prieſtley's Hiſtory, the electrical apparatus has been conſiderably augmented, and many new experiments have been made. To deſcribe the one, and to arrange the other, under ſuch heads as will point out the connexion between the experiments and the received theory of electricity, was one of the principal views I had in compoſing this eſſay. I alſo wiſhed to put into the hands

hands of my cuſtomers a tract, which might enable them to uſe, with eaſe and ſatisfaction, the electrical machines and apparatus which I recommend.

As electricity is in its infancy, when conſidered as a ſcience, its definitions and axioms cannot be ſtated with geometric accuracy. I ſhall, therefore, endeavour to avoid, as much as poſſible, the uſe of poſitive expreſſion; I wiſh to invite the reader to examine the experiments himſelf, to compare them one with another, and then draw his own concluſions.

Experiment I.

Rub a dry glaſs tube with a piece of dry ſilk, preſent light bodies, as feathers, pith balls, &c. to it, they will be firſt attracted, and then repelled.

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 preceeding 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 body becomes poſſeſſed of more or leſs than its natural ſhare, 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, pencils of light will dart from them ſpontaneouſly, in a beautiful manner, and a ſnapping noiſe will be heard on the approach of any conductor.

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 IV.

Support a dry glafs rod on filk lines, or by glafs, bring an excited electric near it, and no attraction or repulfion will take place; becaufe the electricity cannot be tranfmitted through it.

Thofe metallic bodies which poffefs the power of tranfmitting electricity, are called conductors. Thofe fubftances, which are impervious to electricity, are called non-conductors.

A body which communicates with nothing but electrics, is faid to be infulated.

The moft important and fingular effects of electricity would have remained in obfcurity, if this power in fome bodies, to refift the paffage of electricity through their fubftances and over their pores, had not been difcovered. Inftances of the truth of this affertion will occur in almoft every page of this effay.

We learn, from the 3d and 4th experiments, that the electric powers may be communicated to infulated conducting fubftances by excited electrics; that thefe will then attract and repel light bodies, &c. fimilar to the electric itfelf; 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 fame circumftances, only lofes its electricity partially.

EXPERIMENT V.

Electrify, with excited glafs or fealing wax, two infulated cork balls, fufpended by lines about 6 inches long, and the balls will feparate from and repel each other.

EXPERIMENT VI.

Electrify one ball with glafs, the other with fealing wax, and they will be mutually attracted.

Thefe two oppofite and remarkably diftinct effects in the attractive and repulfive powers of electricity, were difcovered at an early period of the hiftory of this fcience

The electric power produced by the excitation of glafs is called pofitive electricity, and the power produced by the excitation of fealing wax is called negative electricity. This difference was at firft thought to depend on the electric, and that the two kinds of 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.

The difcovery of thefe diftinguifhing characteriftics in electric fubftances, engaged philofophers losophers in an experimental enquiry into the electric properties of most bodies, to ascertain whether they possessed the positive or negative powers. By this means the catalogue of electric bodies, which originally was very small, is now rendered exceedingly extensive, as will be seen by the following tables, which are taken from Dr. Priestley's History and Mr. Cavallo's Compleat Treatise of Electricity.

CATALOGUE of conducting substances.

1. Stony substances.

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

Lime-stone and lime just burnt are equally imperfect conductors.

Marbles conduct considerably better than free-stone, and there is found very little difference 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 its substance; though it will pass over about three quarters of an inch of its 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 plaiſter of Paris conduct 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 its 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 ſalts in general conduct better than any neutrals.

Vitriol of copper and of iron conduct very well, though they will not tranſmit a ſhock.

Vitriolated tartar gives a ſmall ſhock.

Salt-petre does not conduct ſo well as ſal-ammoniac. If the electric exploſion paſſes over its ſurface, it diſperſes into a great number

ber 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 its 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 fparks at a confiderable diftance from the prime conductor, like fome of the inferior pieces of charcoal.

Another piece of pyrites, which has been part of a regular fphere, confifting of a fhining metallic matter, will not conduct near fo well, though much better than any other ftony fubftance. It is a medium betwixt a ftone and an ore.

Black-lead in a pencil conducts a fhock feemingly like metal or charcoal. A fmall lump of it takes as full and ftrong a fpark from the prime conductor as a brafs knob.

4. Metals

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 power.

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.

Even 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.

The

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, ſaphires, 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.

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

was a non-conductor. 2d. That thefe circumftances are the degrees of heat to which this body is fubjected. He endeavours to fhew, that the principal changes which take place in any fubftance from an increafe of heat are an augmentation in the fize of its pores, and an increafe of velocity in the igneous particles contained in, and acting on, that body. He then proves, that the laft circumftance does not occafion the alteration in the electric properties; and infers, agreeable to the fyftem of Mr. Euler, that the principal difference between conductors and non-conductors of electricity confifts in the fize of the pores of the conftituent parts of the body.

In another interefting paper, which is publifhed in the Memoirs of the Academy of Berlin for 1779, Mr. Achard has fhewn the analogy between the production and effects of electricity and heat; and alfo, between that property in bodies by which they conduct the electrical fluid, and that which renders them fufceptible of heat. He gives an account of a new inftrument, adapted to afcertain the quantity of the electrical fluid which is conducted by bodies of different natures, placed in the fame circumftances.

By means of this inftrument it is poffible to afcertain, with great accuracy, the quantity of electricity a body lofes in a given time, by touching

Electrics.

All glass,
All Precious
Stones,
Amber,
Sulphur,
All resinous
substances,
feathers Wool &
Wax,
Silk and Cotton
Paper, Loaf sugar
Air when dry,
oils &
metalic oxides,
ashes,
most hard
stones.

Conductors

All Metals.
As follows;
Gold, silver,
Copper, Platina
Brass, Iron,
Tin, Mercury
Lead, semimetals,
metallic ores,
Charcoal
Fluids of an
animal body
Water, especially,
salt water &
other fluids
except oil.
Ice, snow,
saline substances
Earthy substances
smoke steam
& a vacuum —

touching another body that is not electrified. He has not yet favoured the public with an account of the experiments he has made with it ; only ſays, that he has conſtantly obſerved, that thoſe bodies which loſe and receive with difficulty their preſent degree of heat, receive alſo, and loſe with difficulty, their electricity. A deſcription of the inſtrument will be given in this eſſay.

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, hand, paper, baked wood.
	Negative	Other finer furs.

* 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.

White

White silk	Positive	Black silk, metals, black cloth.
	Negative	Paper, hand, hairs, weasel's skin.
Black silk	Positive	Sealing wax.
	Negative	Hare's, weazel's, and ferret's skins, loadstone, brass, silver, iron, 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.

friction. If one piece of glaſs be thicker than the other, the former becomes poſitive, the latter negative. 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 balance 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. Tranſ. 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

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.

CHAP.

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 its 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 to tranſmit it in full and continued ſtreams to the prime conductor.

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 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; that of the machine reprefented in fig. 1, is put in motion by a fimple winch, which is lefs complicated than the other, and is not liable to be out of order. Many practical electricians, however, prefer a machine which is moved by a multiplying wheel. They think that it fatigues the operator lefs than that which is moved by a fimple winch; and further, that a moderate increafe of velocity in the cylinder augments the momentum of the electric fluid, and produces a greater quantity of it in the fame time, which prevents its being abforbed by the cufhion.

As the two machines, which are reprefented in fig. 1 and 2, plate I, are nearly fimilar, the fame letters of reference are ufed in defcribing them.

Fig. 1 and 2. A B C reprefents the bottom board of the machine, the two perpendicular fupports D, E, which fuftain or carry the glafs cylinder F G H I, are firmly fixed to the board A B C; the axis by which the cylinder is moved is fixed into two caps, which are made fometimes of brafs, and fometimes of wood; one is cemented on each end of the cylinder. K, fig. 1 and 2, reprefents one of thefe caps. The axis of the cap K paffes through the fupport D; on the extremity of this axis a fimple winch is fitted, as in fig. 1, or a pulley, as in fig. 2. The axis of the other cap runs in a

fmall

ſmall hole which is fitted into the top of the ſupport E. 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; g h i a piece of ſilk that comes from the under edge of the cuſhion and paſſes over the cylinder till it almoſt touches the collecting points of the conductor. Near the top of the glaſs pillar O P is an arm of wood, to ſupport a conductor connected with the cuſhion, which is called a negative conductor. In both figures this is ſuppoſed to be fixed cloſe to the cuſhion, and to lye 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, and V X a wooden foot or baſe for the glaſs pillar. In fig. 1, this conductor is placed in a direction parallel to the glaſs cylinder; in fig. 2 it ſtands at right angles to the cylinder; it may be placed in either poſition occaſionally, as is moſt convenient to the operator.

If the negative conductor is required to be placed at right angles to the cylinder, and parallel to the conductor Y Z, fig. 2, it muſt be fixed on an inſulating ſtand, and be connected with the cuſhion by a wire, which paſſes under the cylinder.

Experiment VII.

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 negative conductor will be electrified negatively.

The principal parts of an electrical machine are, 1ſt. The electric, as the glaſs cylinder.

2d. Thoſe mechanical contrivances by which the cylinder is put in motion.

3d. The cuſhion and its appendages.

4th. The two prime conductors.

Before the electrical machine is put in motion, examine thoſe parts of it which are liable to be injured by friction, or by dirt or grit between the rubbing ſurfaces, particularly the axes which work in the wooden ſupports

D and

D and E, likewiſe the axes of the large wheel c d, fig. 2. When the cuſhion is taken off, the cylinder ſhould move exceedingly free. If, on turning it round, any grating or diſagreeable noiſe is heard, diſcover the place from whence it ariſes, wipe it clean, and then rub over it a ſmall quantity of tallow. Examine, in the ſame manner, the axis of the large wheel c d, fig. 2. Put a drop of oil occaſionally to the axis of the cylinder; examine the ſcrews that belong to the frame or cylinder, and if they are looſe tighten them.

Wipe the glaſs cylinder carefully, to free it from that moiſture which glaſs attracts from the air; be particularly attentive to leave none on the ends of the cylinder, becauſe any damp that remains on theſe will convey the electricity from the cylinder to the ſupports, &c.

Take care that no duſt, looſe threads, or any filaments adhere to the cylinder, its 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; theſe pillars muſt be rubbed more lightly than the cylinder, becauſe they are varniſhed.

A heated iron is ſometimes placed on the foot of the conductor, to evaporate the moiſture which would injure the experiments.

In order to find out an effectual mode of exciting powerfully an electrical machine, it is neceſſary to frame an idea of the mechaniſm by which the cylinder extracts the electric fluid from the cuſhion, and thoſe bodies which are connected with it; I have, therefore, ſubjoined thoſe conjectures on which I have worked, and by which I have been able to excite, in the moſt powerful manner, thoſe machines which have paſſed through my hands.

It appears to me, that the reſiſtance of the air is leſſened, or a kind of vacuum is produced, where the cuſhion is in cloſe contact with the cylinder. The electric matter, agreeable to the law obſerved by all other elaſtic fluids, is preſſed towards that part where it finds leaſt reſiſtance; the ſame inſtant, therefore, that the cylinder is ſeparated from the cuſhion, the fire iſſues forth in abundance. 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

C 3 any

any amalgama 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 amalgama 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 amalgama was spread over the whole of the flap; the cushion was then put in its place, and the loose flap of leather doubled down, or rather turned in, more or less, till by successive experiments the situation was discovered which produced the greatest effect; for, by this means, the quantity of amalgama acting against the cylinder was lessened. I was naturally led to contract the breadth of the cushion, and place it in such manner that it might be easily raised or lowered.

The advantages gained by this method were confiderably improved by a very ingenious Gentleman. He glued a bit of leather on a large piece of cork, and placed his amalgama on the leather; with this he rubbed that zone of the glafs cylinder which bears againft the cufhion. By this excellent contrivance, the line of contact between the cylinder and cufhion is rendered very perfect, the fmaller pores of the glafs are filled with the amalgama, and the fuperfluous parts of it are depofited on the cufhion.

Beccaria fuggefts, that the amalgama thus depofited on the furface of the glafs forms a continued feries of conducting particles, which carry the fire to the prime conductor, and, under certain circumftances, back again to the cufhion.

Another ingenious electrician afcertains the line of contact, formed between the cylinder and cufhion, by placing a line of whiting, which had been previoufly diffolved in fpirits of wine, on the cylinder: on turning the cylinder this whiting is depofited on the cufhion, and marks the places which bear againft the cylinder; the amalgama is to be placed only on thofe parts which are marked by the whiting.

Either of thefe modes will fucceed. If the firft is ufed, no amalgama is to be placed on the

the cuſhion; that which is rubbed into the cylinder, and depoſited by it on the cuſhion in its revolutions, will produce an aſtoniſhing quantity of fire. In either method, 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 amalgama ſtick to it, they muſt be wiped off carefully.

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.

A very ſmall quantity of tallow placed over the amalgama, is obſerved to give more force to the electric powers of the cylinder.

EXPERIMENT VIII.

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. 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; for the air not only reſiſts the emiſſion of the fluid, but alſo diſſipates what is collected by means of the conducting ſubſtances, which are continually floating in it.

Theſe ends are effectually anſwered by letting a non-conducting ſubſtance proceed from the line of contact to the collecting points of the prime conductor, and placing theſe points within its atmoſphere. When no amalgama is put on the cuſhion, a plain piece of black ſilk, or one ſlightly impregnated with bees-wax, fixed to the under edge of the cuſhion, and proceeding from thence to the collecting points of the conductor, will anſwer exceeding well. If the amalgama is placed on the cuſhion, a piece of oil'd-ſilk ſeems to anſwer the beſt.

I was informed, by an ingenious friend, that he had for many years uſed a piece of black ſilk, which was impregnated from one end to the other with amalgama, in which a ſmall quantity of bees-wax had been mixed; this he rubbed into the ſilk with a piece of ſponge. If the force of the machine diminiſhed while it was in uſe, he refreſhed it by holding an amalgamated ſponge againſt the cylinder when it was revolving.

It is often very advantageous to dry the oil'd or black ſilk before the machine is uſed.

The

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 amalgama are much in requeſt at preſent. One is made of quickſilver five parts, zink one part, 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.

The following experiment ſeems to illuſtrate and confirm the foregoing conjectures on the mechaniſm by which the fluid is extracted from the cuſhion, and the bodies connected with it.

Experiment IX.

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.

Every electrical machine ought to be furniſhed with an inſulated cuſhion and two prime conductors, one for poſitive, the other for negative electricity; as, by theſe, either electricity

city is produced at pleaſure, a greater number of experiments may be performed, and the properties of the electric fluid more eaſily explained.

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 other bodies. If they are connected together, the electricity of the one will deſtroy that of the other; for, though it 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 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

each other, and may be diftiuguifhed by oppofite effects.

Experiment XI.

If the cufhion and the conductor are both infulated, it is obferved, that the lefs electric fluid is obtained, the more perfect the infulation is made.

The moifture which is at all times floating in the air, together with the fmall points, from which it is impoffible totally to free the cufhion, do not permit it to be perfectly infulated, fo as to afford no fupply of electric matter to the cufhion.

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

From this experiment it is inferred, that the electric powers do not exift in the electrics themfelves, 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 againft the cufhion, but is collected by that operation from it, and from thofe bodies which are connected with it.

As Dr. Franklin feems to have fuggefted this idea firft, that the electric fluid is collected

from

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 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 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

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

A deſcription of ſome parts of the electrical 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 its ends. To diſcharge a leaden bottle with it, hold the ſemicircular part in the hand, place one ball of the diſcharging rod on the coating of the phial,

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. When the univerſal diſcharger is made on a large ſcale, it is ſuperior to any apparatus hitherto contrived to enable a perſon to electrify himſelf. AB, fig. 3, pl. II, is the wooden baſe of this inſtrument; 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 fitted a double joint, or one which has both a vertical and horizontal motion; on the top of each joint is a ſpring tube, which

which receive 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 GH is removed. The preſs conſiſts of two boards, which are brought cloſe to each other by means of the ſcrews a a.

Fig. 5, Plate II, is Mr. Kinnerſly'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 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.

Mr. Achard, who has conſidered the ſubject with attention, ſays, that an electrometer ought to have the following properties:

1. That it ſhould be ſimple in its conſtruction, and not compoſed of many parts.

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

3. That it ſhould indicate ſmall as well as large degrees of electricity.

4. Not be adjuſted to any fixed meaſure.

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

6. That the obſerver be enabled to read off the diviſions at a diſtance, which will prevent his weakening the influence of the electric powers.

This gentleman has publiſhed a very ingenious paper on the nature and properties of electrometers,

ters, which I meant to have introduced in this place if I had not been informed that he had made ſtill further improvements on the ſubject which he deſigned to communicate to the public.

Plate II, Fig. 6, repreſents the quadrant electrometer, the moſt uſeful inſtrument of the kind yet diſcovered, as well for meaſuring the degree of electricity of any body, as to aſcertain the quantity of a charge before an exploſion; and to diſcover the exact time the electricity of a jar changes, when, without making an exploſion, it is diſcharged 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 ſemicircle, ſo as always to keep near its ſurface; the extremity of the ſtem 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 ſtem, and moves along the graduated arch of the ſemicircle, ſo 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 inftrument, which will be defcribed hereafter.

Plate II, Fig. 9, is an electrometer which was contrived many years fince by Mr. Townfend, to afcertain the real force of the electric explofion. a b is a fmall ivory plate, c a loofe cone of ivory to be placed on the plate ab, efg a circle which turns freely on two centers, an arm, d, of wood proceeds from this circle and lyes on the cone of ivory. The difcharge is made to pafs under the cone which throws up the arm d, the elevation of which is marked by the index h; a piece of filk ftring is fixed at one end to the bottom board at i, and paffes over the wheel, a weight k is tied to the other end to regulate the friction of the circle efg.

Fig. 8 is an infulating ftool; the feet are of glafs. When it is ufed, the infulation will be rendered more perfect by placing a fheet of paper well dried under the feet of the ftool.

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 its strong attractive and repulsive powers. The phœnomena 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, we are sorry to own, they still remain involved in deep obscurity, and we are still totally ignorant of that mechanism by which light bodies, when electrified, approach or recede from each other.

To enter into a discussion of the difficulties which perplex this subject, would lead me too 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 its transmission through them, with the greatest velocity; and this in proportion to the gravity of the body, its 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 substances that are brought within the influence of electrified bodies, become possessed of a contrary electricity; or, electrified substances, 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

which are immerged in an electric atmosphere, always become possessed of a contrary electricity to that of the body in whose atmosphere they are immerged.

Experiment XIII.

Fix the end A of the wire AB, 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 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 XIV.

Fix the end C of the wire CD, 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 atmosphere, 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 XV.

Present a fine thread towards an electrified conductor; when it is at a proper distance it will fly towards and stick to 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

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 XVI.

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 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 thoſe which are faſtened to the wire z e, and will point towards each

other

other as so many radii of a circle. The electric fluid passes from the threads of the wire into those of the hoop, and thus occasions the seeming attraction between them.

Place the hoop b c d on an insulating stand, and when it is saturated with the electric matter, the threads which are tied to it will be repelled by those 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 XVII.

Suspend the small metal plate F, fig. 13, to the conductor by the hook H; place the stand I directly under it, and the large plate G on the top of the stand; the upper part of the stand I is moveable, so that the distance of the two plates from each other may be occasionally varied. Lay small paper images, or any other light substances, on the under plate, then put the machine in action, and the light bodies will be attracted and repelled by each plate, and move from one plate to the other with considerable velocity.

The

The light bodies placed on the under plate become poſſeſſed of an electricity which is contrary to that of the upper plate, and are therefore attracted by it, and acquire the ſame electricity with it; they are then repelled, and part with this electricity to the ſtand, and are again in a proper ſtate to be attracted by the upper plate. That theſe 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 diſturbed, will be evident from the following experiment.

Experiment XVIII.

Remove the under plate and ſtand, hold in its ſtead, by one corner, a pane of glaſs, which has previouſly been made very clean and dry; now, as glaſs does not tranſmit electricity, no contrariety in the electric ſtates of the conductor and the light ſubſtances can be occaſioned, and therefore no attraction or repulſion is obſerved.

If a finger is preſented to the under ſide of the glaſs plate, the light bodies will be attracted and repelled; the cauſe of this will be ſeen when the nature of the Leyden phial is explained.

Mr.

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 balance againſt its " 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."

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* Philoſophical Eſſays. Preface, page 25.

EXPERIMENT XIX.

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 XX.

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 XXI.

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

when the conductor is electrified, appear like a kind of electrical rope-dancer.-----See fig. 15.

Experiment XXII.

Cut a piece of leaf brafs, with an obtufe angle at one end, and a very acute one at the other, prefent the large end towards an electrified conductor, and when the leaf brafs is within its atmofphere let it go, it will then fix itfelf to the conductor by the apex of its obtufe angle, and, from its continual wavering motion, will appear to be animated.

The next experiment requires confiderable attention to make it fucceed; as a fmall difference in the apparatus, or in the force of the machine, &c. will make it fail; when it anfwers, it generally affords pleafure to, and excites admiration in the fpectators.

Experiment XXIII.

Fix the ring N O P, fig. 16, to the end of the conductor, place the plate G, fig. 13, on its ftand I under it, and at a little diftance from it, put a very light hollow glafs ball upon the plate but within the ring, turn the cylinder, and the little ball will defcribe an orbit about the ring, and turn at the fame time about its own

own axis; the poles of its rotation are nearly at right angles to the plane of its orbit.

EXPERIMENT XXIV.

Fig. 17 reprefents a fmall fet 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

knob a, ſhould communicate with the conductor.

Fig. 19 repreſents another kind. In this the clapper is ſuſpended from the fly b c d, the axis of the fly reſts in a ſmall hole on the top of the glaſs pillar e f, the upper part of the axis moves freely 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 its 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 XXV.

Take 10 or 12 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 XXVI.

Bring a downy feather or lock of cotton near the end of an excited tube, or the knob of a

charged

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 its electricity. The ſame ſide of the feather is always 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 phœnomena are occaſioned by the ſtate of the electric fluid, in thoſe ſubſtances which are influenced by the machine.

EXPERIMENT XXVII.

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, till the contrariety between them is destroyed.

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

Experiment XXVIII.

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

Experiment XXIX.

Bodies electrified with contrary powers attract each other strongly, although an electric plate is interposed between them.

CHAP. IV.

Attraction and Repulsion considered, relative to the two ſtates of Electricity.

THE experiments deſcribed in this chapter are ſimple, eaſily performed, and certain in their reſults; and, though they may at firſt ſight appear to be trifling, yet, on an attentive examination, they will be found of conſiderable importance, as they afford a clue to inveſtigate and explain a variety of electric phœnomena, and exhibit, in a ſtrong point of view, ſome of the contrary effects of negative and poſitive electricity.

Theſe experiments may all be made with a ſmall and portable apparatus; conſiſting generally of two braſs tubes, as A and B, fig. 22, each of theſe is ſupported on a glaſs pillar G, which ſcrews into a wooden foot H, a pair of ſmall pith balls ſuſpended on linen threads, as I, K, fit upon each tube by means of a ſmall braſs ring; theſe tubes, with a piece of ſealing wax or a glaſs tube, are ſufficient to illuſtrate the greater part of the experiments in this chapter, as well as ſome of the principal phœnomena in electricity.

The apparatus will be rendered more complete by the addition of two more braſs tubes with their ſtands, a ſmall Leyden phial, and a piece of varniſhed ſilk.

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

Experiment XXX.

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.

Experiment XXXI.

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.

Experiment XXXII.

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 XXXIII.

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 XXXIV.

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 XXXV.

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 XXXVI.

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.

Experiment XXXVII.

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 fartheſt from the conductor; ſo that one end will

will be electrified negatively, the other end positively, as will be seen by the balls.

EXPERIMENT XXXVIII.

Apply a stick of excited wax to the tube D, fig. 23, as at A, while it remains there the balls open with negative electricity; raise the wax, as at B, and the balls will close; raise it still higher, and they will open with positive electricity.

EXPERIMENT XXXIX.

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 balance the loss sustained, the tube, thread, and balls must be in a negative state. *

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

Experiment XL.

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

Experiment XLI.

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 XLII.

Excited glaſs held at about one inch diſtance from the end B, of a ſolid cylinder of glaſs B, D, fig. 28, Pl. III, which is ſix feet long, and about

* Ibid, p. 8.

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, 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. *

It

* Ibid, p. 18.

It is not improbable that the attractive and repulsive motions of electrified bodies, are owing to the alternate condensation and delatation of the electric fluid on the surface of these bodies, 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 ; this 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 XLIII.

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

earth in a hot day, or at any time near a body ſtrongly heated.

It appears, from ſeveral experiments of Becaria, that if the air is thoroughly exhauſted from a glaſs receiver, the attraction and repulſion of electrified bodies within the receiver, grow languid, and ſoon ceaſe altogether.

Experiments on the attraction and repulſion of excited ſilk ribbons.

Experiment XLIV.

Put a black and a 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 repel each other.

Experiment XLV.

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.

Ex-

Experiment XLVI.

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

Experiment XLVII.

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 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 XLVIII.

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-

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 XLIX.

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 L.

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 LI.

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 LII.

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

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 were preſented to each other they were 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 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

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.

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 powerfull, 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 ſhow, 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 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 momentum or effort of the electric fluid ſeems to be produced by the incumbent preſſure of the atmoſphere on the electric matter, and the preſſure of one part of this matter upon another; which muſt be very great, if the parts of it are in contact, or act immediately one on the other throughout the wide immenſity of ſpace.

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 zig-zag direction; and this, probably, becauſe the more fluid

fluid electric matter has to paſs with great rapidity through the denſer and leſs fluid atmoſphere, which reciprocally act upon each other.

It will be ſeen, by a great variety of experiments, that the electric fluid is diſſipated, unleſs it is reſiſted by the preſſure of the atmoſphere, which keeps the fire together in a body, and by concentrating it increaſes its ſplendor. The ſpark which explodes in the air is vivid, like lightening; but, if the ſame is tried in an exhauſted receiver, inſtead of a ſpark and exploſion, we have only a ſilent, faint, diluted ſtream.

Beccaria ſays, that the air reſiſts the electric ſpark in proportion to its denſity, and the thickneſs of the ſtratum it oppoſes to the ſpark, or the length of the paſſage they open for themſelves through its ſubſtance. He alſo ſhews, 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 ſubſide.

The electric ſpark appears of a different colour according to its 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 its 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 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.

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The two foregoing experiments are ſo analagous to the famous experiment of Mr. Hauxſbee, 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. Hauxſbee 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 thineſt, 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 lye 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 me by Mr. Haas, the inventor of an improved air pump, which far

exceeds

exceeds thoſe that have been hitherto made uſe of.

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 its 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 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 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, in other words, the power of a point to prevent an exploſion, depends on its having a perfect uninterrupted metallic communication with the earth; though this is not quite ſufficient, as may be ſeen by Ex. LXIII, where the fluid is concentrated and collected by the non-conducting ſubſtance, which ſurrounds the point.

Experiment LXIV.

Let any perſon ſtand on the inſulating ſtool, and connect himſelf by a 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,

ceſſary, 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 compleat.

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, fig. 33, then pour a ſmall quantity of ſpirit of wine into it, and fix it by its 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

floor holds the ladle, and the insulated person takes the spark.

Experiment LXVI.

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 LXVII.

Insulate a small crucible, containing three or four lighted coals, throw a spoonful of water on the coals, and in a short space of time, an electrometer, which communicates with the coals by means of a wire, will diverge with negative electricity.

From

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

A ſpecies of air which is inflammable is frequently generated in coal mines: the air alſo emitted by ſtirring the mud of ſome ſtanding waters, has been found to be inflammable. Putreſcent animal matter alſo emits this fluid. It may be obtained by diſtillation from wax, pitch, amber, coals, and other phlogiſtic ſubſtances. The following is the moſt convenient method of procuring it: put ſome ſmall nails or iron filings into the bottle r, fig. 37, 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 s 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:

ration: in a little time the mixture will effervefce, and emit a fluid which will pafs through the bent tube, go into the bottle K, and at laft fill it totally, expelling the water; the bottle is then to be removed, and corked as expeditioufly as poffible.

Fig. 39 reprefents a brafs piftol for inflammable air; a b is a chamber of brafs, to the mouth a c of which a cork is fitted, a perforated piece of brafs fcrews on to the bottom of this chamber, (this piece is reprefented by itfelf in fig. 40) a glafs tube is cemented into the perforation of this piece, and a brafs wire is alfo cemented into the glafs tube; one end of this wire is furnifhed with a ball, the other extremity is bent, fo as to come within about a tenth of an inch of the brafs piece. Fig. 41 is a brafs cap, which fcrews on the piftol, to preferve the glafs tube from any accident. The air with which the piftol is to be charged fhould be kept in a corked bottle: take out the cork, and apply in the fame inftant the mouth of the piftol to the opening of the bottle, and the common and inflammable air will mix together, becaufe the former being lighter than the latter will naturally defcend; keep the piftol in this fituation about 15 feconds, then remove it, and cork both the bottle and piftol with the utmoft expedition.

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

Experiment LXVIII.

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 its ends, firſt with ſealing wax, then with ſilk, and afterwards with ſeal-

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ing 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 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 fixed.

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 LXIX.

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 LXX.

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 LXXI.

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.

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EXPERIMENT LXXII.

A lucid cone appears on the collector of a negative conductor, and a lucid ſtar on a point placed at the oppoſite end of the conductor.

The ſuſceptibility of points to receive or part with the electric matter, and the different appearance of the light on the point, in various experiments, has led many electricians to conclude, that theſe appearances determined, in a deciſive manner, the direction of the electric fluid. They ſuppoſe, that the appearance of the globular light or ſtar is an indication that the electric fluid is entering by that point; and that the fluid proceeds from the point on which the lucid cone or bruſh is ſeen. This opinion is confirmed, by obſerving that theſe appearances are conformable to the laws obſerved by other fluids, which diverge from the reſiſtance they meet with from the air; as is the caſe when the electric fluid iſſues from a point placed at the end of a poſitive conductor. To this it has been objected, that the rays may be conſidered as converging from ſo many points in the ſurrounding air towards the metallic point. But it is difficult to ſay, why a viſible ray ſhould be ſuppoſed to break out from one point of the atmoſphere rather than another, as it is known to reſiſt the paſſage of the fluid, and ſeems to reſiſt it equally; and therefore, when it proceeds from the air to a point, it percolates ſlowly, inviſibly, and equally on all ſides, till it comes ſo near as to force its way through the intermediate ſpace, and ſettle on the point, where it will appear as a luminous globule.

Experiment LXXIII.

Bring an excited glaſs tube near a point that is fixed at the end of a poſitively electrified conductor, and the luminous bruſh will be turned out of its direction by the action of the excited tube; if the tube is held directly oppoſite to the point, the bruſh will vaniſh.

Experiment LXXIV.

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 69, 70, 71, 72, 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 LXXV.

Put a wire, which has a ball at one end, into the hole at the end of a poſitive conductor, place

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 LXXVI.

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 its center with great rapidity. 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 retrograde 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 LXXVII.

Electrify the two insulated wires MN, oP, 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 MN, oP.

EXPERIMENT LXXVIII.

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

EXPERIMENT LXXIX.

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.

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

of a candle, and occaſion an undulation in 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 its action on our bodies, an effect which is productive of great advantages in medical electricity.

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 phœnomena 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 accomodates itſelf ſo eaſily and ſatiſfactorily to a variety of appearances, as to make us almoſt loſe ſight of the objections againſt it.

EXPERIMENT LXXX.

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,

charged, or modify the electric fluid in a peculiar manner. To discharge the jar, or restore it to its natural state, bring one end of a 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 LXXXI.

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, which, 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 is ſmall, the powers of nature operate in a gentle manner to reſtore 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.

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

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 its 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. 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-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.

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.

Dr. Franklin's Theory of the Leyden Bottle.

Glafs is fuppofed to contain at all times, on its two furfaces, a large quantity of the electric fluid; which is fo difpofed, that if you increafe the quantity on one fide, the other muft throw off an equal proportion; or, when one fide is pofitive, the other muft be negative; now, as no more of the electric fluid can be forced on one fide 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 increafed or leffened on the whole, though a change may be made in its place and fituation; i. e. we may throw an additional quantity on one of its fides, if, at the fame time, an equal quantity can efcape from the other, and not otherwife. That this change is effected by lining parts of its two furfaces with a non-electric; through the mediation of which, we are enabled to convey the electric fire to every phyfical point of the furface we propofe to charge, where it exerts its activity in repelling the electric particles naturally belonging to the other fide; all of which have an opportunity of efcaping by the lining in contact with this furface,

which,

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 its 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 its ſtate effected, without the equal and contemporary 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 its ſuper-abundance 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 on the other) that its 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 its original ſtate of equality on the two ſides of the glaſs.

Ex-

Experiments on charging and discharging the Leyden Phial, intended to elucidate and confirm Dr. Franklin's Theory.

EXPERIMENT LXXXII.

Screw a Leyden phial, whose coating is free from points, upon an insulated stand, and place it so that its 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.

EXPERIMENT LXXXIII.

Place the same insulated phial so that its 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,

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 LXXXIV.

Screw the phial a, fig. 42, on the inſulated pillar d, and bring its knob in contact with the conductor; hold another bottle c, of the ſame ſize with a, ſo that its 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 its 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 LXXXV.

Place the knob of an inſulated bottle in contact with a poſitive conductor, and connect the outer

outer coating with the cuſhion, or a negative conductor, turn the cylinder, and the bottle will be charged with its own electricity; the fluid from the exterior coating being tranſferred to the interior one.

Experiment LXXXVI.

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 LXXXVII.

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 LXXXVIII.

Fix a quadrant electrometer to the ball of a Leyden bottle, and charge it negatively; when

when it has received a full charge the index will ſtand at 90 degrees; then place the bottle with its electrometer at the poſitive conductor, turn the cylinder, the electrometer will deſcend, and the bottle will be diſcharged by the contrary electricity.

Experiment LXXXIX.

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 XC.

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 the 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.

Ex-

Experiment XCI.

T V, fig. 46, reprefents a bottle, whofe exterior coating is formed of fmall pieces of tin-foil, placed at a little diftance from each other. Charge this bottle in the ufual manner, and ftrong fparks of electricity will pafs from one fpot of tin-foil to the other, in a variety of directions; the feparation of the tin-foil making the paffage of the fluid from the outfide to the table vifible. Difcharge this bottle, by bringing a pointed wire gradually near the knob, and the uncoated part of the glafs between the fpots will be pleafingly illuminated, and the noife will refemble that of fmall fired crackers. If the jar is difcharged fuddenly, the whole outfide furface appears illuminated. To produce thefe appearances the glafs muft be very dry.

Experiment XCII.

String a parcel of fhot on a filk ftring, leaving a fmall fpace between each of them; fufpend this from the conductor, fo that it may reach the bottom of a coated phial, which is placed on an infulated ftand; connect another ftring of fhot to the bottom of the jar and let it communicate with the table, turn the machine, and

a

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 XCIII.

Hold a phial in the hand which has no coating on the outſide, and preſent its 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, beautiful ramifications will proceed from that knob of the diſcharger which is on the outſide all over the jar.

Experiment XCIV.

Let a chain be ſuſpended from the conductor and paſs into an uncoated bottle, ſo 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 inſide of the jar, and thus charge it by degrees.

Experiment XCV.

Fig. 47 repreſents two Leyden phials, placed one over the other. Various experiments may be made with this double bottle, which are

 very

very pleaſing, and elucidate clearly the received theory.

Bring the outſide 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 diſcharging rod upon the coating of B, and with the other touch the knob of the jar A, which will cauſe an exploſion. Now place one ball of the diſcharger on the knob of A, and bring the other ball to its coating and you have a ſecond diſcharge. Again, apply one ball of the diſcharger 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 diſcharge from the coating of A to its 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 its 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 ſub-

ſtances

ſtances 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 contrary State of the two oppoſite Sides of a charged Leyden Bottle, ſhewn by their reſpective attractive and repulſive Powers.

Experiment XCVI.

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 XCVII.

Electrify two pair of the pith balls which are fixed to the braſs tubes, as in fig. 22, Pl. 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 XCVIII.

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 XCIX.

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.

Ex-

Experiment C.

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 CI.

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 CII.

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 repell 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 its 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 brisk motion, and may thus be driven about on the surface of the glass, like a feather in the air by an excited tube. The ball being deprived of its electricity by the pin, it instantly flies to that part of the glass which attracts it most forcibly.

To excite the pane of glass; 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 Appearances of the Electric Light.

In chapter 6 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, or globule, fhews the point is receiving the electric matter, whilft the luminous brufh, or cone, indicates that it is proceeding from the point. We fhall now examine the ftates of the different fides of the Leyden bottle by thefe appearances. For this, and many other purpofes, the apparatus which is reprefented in fig. 49 will be found very convenient; I have endeavoured to combine the parts of it in fuch manner as will 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 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 ab, cd, 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

either the ball E, the knobs e or f, the cap C, or the ſocket g, on the top of the pillar; the balls may be unſcrewed from theſe wires, which will then exhibit a blunt point. M is a wooden table, to be ſcrewed on the glaſs pillar occaſionally.

Experiment CIII.

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 CIV.

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.

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 CV.

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 CVI.

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 CVII.

Fig. 53 is an electric jar, B B the tin-foil coating, C a stand which supports the jar, D a socket

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 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 illumined 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 CVIII.

Take a Leyden phial, the neck of which ſhould not be very broad, ſet the coating on the

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 CIX.

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

Experiment CX.

An analysis of the Leyden phial, by means of the Leyden vacuum E, fig. 49.——Screw this

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 charging 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 CXI.

Fig. 61 repreſents the luminous conductor on the inſulating ſtand. Set 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

This tube, when mounted on its 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 CXII.

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

atmo-

atmoſphere, ſince it would increaſe the intenſity of the electric atmoſphere.

Experiment CXIII.

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 CXIV.

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.

Experiment CXV.

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 former; now compleat the circuit, by bringing a diſcharging rod

from

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 CXVI.

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 CXVII.

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

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 CXVIII.

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.

EXPERIMENT CXIX.

If a cylindrical plate of 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 CXX.

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 CXXI.

Let a coated phial be ſet on an inſulating ſtand, and let its 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. *

Experiment CXXII.

* 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

* Encyclopædia Brittanica, Vol. IV, p. 2698.

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 CXXIII.

Let the same phial, with the pith balls affixed to its 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 CXXIV.

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.

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 tinfoil, 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 compleated. 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 as to augment its 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

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 CXXV.

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 CXXVI.

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 its 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 CXXVII.

The diſcharge of a battery through a ſmall ſteel needle will, if the charge is ſufficient, communicate magnetiſm to the needle.

Experiment CXXVIII.

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 CXXIX.

Difcharge a battery through a flender piece of wire, ex. gr. one 50th of an inch in diameter, the wire will be broken to pieces, or melted, fo as to fall on the table in glowing balls.

When a wire is melted in this manner, the fparks fly frequently to a confiderable diftance, being fcattered by the explofion in all directions.

If the force of the battery is very great, the wire will be entirely difperfed by the force of the explofion. Small particles of fuch fubftances as cannot be eafily 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 difcharge of fufficient ftrength is paffed 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 refiftance in proportion as the paffage through which it is to pafs is longer. Dr. Prieftley could melt nine inches of fmall iron wire at the diftance of 15 feet, but at twenty feet diftance he could only make 6 inches of it red hot.

Ex-

EXPERIMENT CXXX.

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 its paſſage, or from a want of ductility in the metal, which is therefore leſs capable of expanſion.

EXPERIMENT CXXXI.

Diſcharge a battery through a chain which is laid on paper, and black marks will be left on the paper in thoſe places where the rings of the chain touch each other; the rings will be more or leſs melted at thoſe places.

Experiment CXXXII.

Take two pieces of window glaſs, of about 3 by 2 inches, place a ſlip of braſs or gold leaf between them, leaving the metallic leaf out beyond the glaſs at each end; then place the two pieces of glaſs in the preſs of the univerſal diſcharger, bring the points of the wires ET, EF, fig. 33, to touch the ends of the leaves, and paſs a diſcharge through them, which will force part of the metal into the glaſs, and ſtain it with a colour which differs from the metal that is made uſe of. The metallic leaf ſhould be made narroweſt in the middle, becauſe the force of the electric fire is in proportion to its denſity, which is increaſed when the ſame quantity of fire is compelled to paſs through fewer conducting particles.

The exploſion in melting the ſtripes of leaf-gold, &c. renders them non-conducting, and leſs capable after each diſcharge to tranſmit another. Some particles of the metal are driven into the glaſs, which is really melted; thoſe parts of the metal which lye contiguous to the glaſs are the moſt perfectly fuſed. The pieces of glaſs which cover the ſlip of metal are generally broken to pieces by the diſcharger.

Ex-

Experiment CXXXIII.

Place a thick piece of glaſs on the ivory plate of the univerſal diſcharger, fig. 3, Pl. II, and a thick piece of ivory on the glaſs, on which a weight from one to ſeven pounds is to be placed; bring the points of the wires EF ET againſt the edge of the glaſs, and paſs the diſcharge 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 glaſs will be broken, and ſome part of it ſhivered to an impalpable powder. When the piece of glaſs is ſtrong enough to reſiſt the ſhock, the glaſs is often marked by the exploſion with the moſt lively and beautiful colours. I have been informed by Mr. Morgan, that if the glaſs is cemented down the effect is the ſame as when it is preſſed by the weights; and this mode is in various experiments more convenient.

Experiment CXXXIV.

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 CXXXV.

Fig. 66, a, repreſents an inſulated rod, nearly touching a charged jar d, 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 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 lightening. Dr. Prieſtley

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 CXXXVI.

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 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.

I have been informed by a gentleman, that it was his cuſtom to make a variety of circuits for the difcharge of a large jar or battery; and, that having a fufficient number of thefe, he could introduce himfelf into one of them, and take his part of the fhock without inconvenience, it even was not difagreeable; and he could by this means leffen the fenfation almoft to nothing.

Experiment CXXXVII.

Mr. Henly made a double circuit, the firft by an iron bar, one inch and a half in diameter, and half an inch thick; the fecond, by four feet and a half of fmall chain. On difcharging a jar, containing five hundred fquare inches of coated furface, the electricity paffed in both circuits, fparks being vifible on the fmall chain in many places. On making the difcharge of three jars, containing together fixteen fquare feet of coated furface, through three different chains at the fame time, fig. 67, bright fparks were vifible in them all. The chains were of iron and brafs, of very different lengths; the fhorteft ten or twelve inches, the longeft many feet in length. When thofe jars were difcharged through the iron bar before-mentioned, together with a fmall chain, three-quarters of a yard in length, the whole chain was illumined, and covered throughout with

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 fir-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 CXXXVIII.

Paſs the ſhock through this ſmall thread of quickſilver, which will be inſtantly diſploded, and will break or ſplit the tube in a curious manner. *

Experiment CXXXIX.

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

* Nicholſon's Introduction to Philoſophy, p. 413.

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 explode in every direction the parts of the reſiſting ſubſtances through which it paſſes.

Experiment CXL.

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

A diſcharge ſent through a green leaf tears the ſurface in various directions, leaving an image in miniature of ſome of the effects of lightening. 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 its 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 CXLI.

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 CXLII.

If a long narrow trough of water is made part of the circuit in the diſcharge of a battery,

 and

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 CXLIII.

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

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 inſtantaniety 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 ſurprizing 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 its motion appears ſlow, and not eaſily reconcilable with this immeaſurable velocity; and it is alſo certain, that this fluid is reſiſted in its 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 118, 119, 120 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 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 extream rapidity with which the fire passes, did not prevent our perceiving the successive commotions received by the persons who form

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 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 *d* 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 *d*, and then through him to the outſide, without acting on *f*, *g*, *h*, which would be out of its 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 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 its 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 its own deficiency.

It appears alſo, from other experiments, that one ſide of a charged electric may contain

more

more of one power than is ſufficient to balance 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 which obtained on the ſide of the jar, which was touched the laſt before the diſcharge.

It may not be improper to introduce here an hypotheſis which has been offered to the public inſtead of the received theory.

HYPOTHESIS.

1. The two electric powers exiſt together in all bodies.

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

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

4. The powers cannot be ſeparated in electric ſubſtances.

5. The two electricities attract each other ſtrongly through the ſubſtance of electrics.

Electric ſubſtances are impervious to the two electricities.

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

CHAP.

CHAP. IX.

On the Influence of pointed Conductors for Buildings.

THE importance of electricity, as well as its 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, the surprizing phœnomena of thunder and lightening 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 lightening 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 lightening; 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 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.

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 electric fluid, and its 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 its electricity eaſier, and from a greater diſtance, when a pointed conducting ſub-

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 its electric ſituation.

Fig. 68 repreſents the gable end of a houſe, fixed vertically on the horizontal board FG; 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 its 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 CXLIV.

Place a jar with its 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

* See Volta's Paper, Phil. Tran. vol. 72.

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 connexion, 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, will throw out the little piece of wood to a considerable distance by the lateral force of the explosion. See fig. 68.

Unscrew the ball, and let the point which is underneath be presented to the conductor, and then you will not be able to charge the jar; for the sharp point gradually draws the fire from the conductor, and conveys it to the coating on the outside of the jar.

The prime conductor is supposed to represent a thunder cloud discharging its 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 strike from one part to another, and thus endanger the whole building.

Ex-

Experiment CXLV.

Mr. Henly affixed to the top of a glaſs ſtand 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 ſharp point; (ſee fig. 69) round the middle of this wire hung a chain, 12 inches long; he connected the chain with the coating of a charged bottle, and brought the 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 CXLVI.

The ſame gentleman connected a jar, containing 509 ſquare inches of coated ſurface, with the prime conductor. (See fig. 68) If the

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 CXLVII.

He afterwards made a double circuit to the thunder houſe; the firſt by a knob, the ſecond by a ſharp pointed wire, at an inch and a quarter diſtance from each other, but exactly the ſame height. The charge being the ſame, the knob was firſt brought under the prime conductor, which was half an inch above it, and followed by the point at an inch and a quarter diſtance, yet no exploſion fell upon the ball, as the point drew off the charge ſilently, and the piece in the thunder houſe remained unmoved.

Experiment CXLVIII.

He inſulated a large jar, and connected, by chains, with the external coating, on one ſide, a knob,

knob, on the other a ſharp pointed wire, both being inſulated, and ſtanding five inches from each other, (ſee fig. 70) and placed an inſulated copper ball, eight inches in diameter, ſo as to ſtand exactly at half an inch diſtance both from the knob and the point; the jar was then charged, and the diſcharge made by the diſcharging 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 diſcharged by a loud and full exploſion, and the chain was very luminous.

Experiment CXLIX.

Mr. Henly ſuſpended by a ſilk ſtring from one end of a wooden bar, which turned freely in a 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; (ſee fig. 71) he gave a ſtrong ſpark from the knob of a charged phial to the bladder, he then preſented towards it a braſs ball, two inches diameter, and obſerved that the bladder would come towards it at the diſtance of three inches, and when it got within an inch, would throw off its electricity in a full ſpark. He then gave it another ſpark, and preſented a pointed wire towards

wards the bladder, which never approached to the point, nor ever gave any ſpark, the electricity being carried off.

Experiment CL.

Take two or three fine locks of cotton, faſten one of them to the conductor by a fine thread, another lock to that, and a third to the ſecond, put the machine in action, and the locks of cotton will expand their filaments, and will extend themſelves towards the table. Preſent a ſharp point under the loweſt and it will ſhrink up towards the ſecond, and this towards the firſt, and altogether towards the prime conductor, where they will continue as long as the point remains under them.

Experiment CLI.

Faſten a number of fine threads or hair to the end of the prime conductor; when the cylinder is turned, theſe will diverge like rays proceeding from a center: continue turning the cylinder, and preſent a point towards one ſide of the conductor, and the threads on one ſide will hang down, and loſe their divergence, but thoſe on the other ſide will ſtill continue to diverge; which ſhews, that the power of points to draw off electricity does not extend round the electrified body when means are used to keep up the supply of electricity.

Fig. 72 represents an oval board, three feet long and two feet broad, coated on both sides with tin-foil, and suspended by silk lines from the double hook, this turns on an axis, which is fastened to one arm of a nice balance, and counter-poised 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 CLII.

Connect the pendulous board with the prime conductor by a small wire, a few turns of the machine will electrify the apparatus. When this experiment was made, the board was attracted by the table at 15 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 the 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 descend 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 Mr. Henly, which is the 148th 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

The other part of the circuit confifted of a brafs rod alfo; 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 thofe prongs were fo conftructed, that either of them could be made longer or fhorter, juft as the experiment required. On the end of one of the prongs was fixed a ball of brafs, three quarters of an inch in diameter, and on the other a fharp fteel point or needle. The fhoulder of this fork fcrewed into a fmall plate of iron, that was fixed on the infide of a wooden veffel, which contained the greateft part of a cylindrical glafs jar, twelve inches three quarters high, and about four inches in diameter. This glafs was rather thick than otherwife, and the coating of it (which was tin-foil) meafured nearly 144 fquare inches on each furface. Befides this coating, part of the infide of the wooden veffel was coated alfo with tin-foil, for the purpofe of making a fecure communication between the iron plate and the outward coating of the jar. Within the jar itfelf was fitted a cylinder of wood, that was covered with tin-foil alfo, to make a communication between the infide coating of the glafs and a brafs rod, that was fixed upright in the center of the wooden cylinder. This upright rod having a ball of brafs at the end, three quarters

ters of an inch in diameter, was bent towards the firft part of the circuit; fo 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 diftances, as occafion required; and thus anfwered the purpofe of an electrometer.

Mr. Wilfon began the experiments where the electrometer was ftruck at the greateft diftance, and then adjufted the diftances of the ball accordingly; fo that if the point was ftruck when they were adjufted, the moving of the ball the thirty-fecond part of an inch would occafion the ball to be ftruck in preference to the point, and *vice verfa*. Afterwards he leffened the ftriking diftance of the electrometer, in every experiment, till he attained the leaft diftance.

Upon reverfing part of the apparatus, and fixing the ball to the bottle, and the fork to the ftand, all thofe experiments were repeated again; the copper ball being put neareft to the glafs, in the place of the forked part, and the forked part in the place of the copper ball. This fet of experiments being compleated, he made others, where the ball only was oppofed; and after them, where the point only was oppofed to the copper ball.

 Having

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

TABLE I.

EXPERIMENTS made at Dr. HIGGINS'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 conſtituted 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.*	*Ball 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

		Apparatus reversed.
Electrometer —	21	23
Ball — —	24	25
Point — —	64	30

"Ever

" Ever ſince the diſcovery of the identity of electricity and lightening, 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 its paſſage, it will always chooſe to run along a metaline 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 its deſtination. When a quantity of electricity is 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

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, when lightening ſtrikes a tree, a houſe, or a thunder-rod, it is not becauſe theſe objects are high, or in the neighbourhood of the cloud, but becauſe they communicate with ſome place below the ſurface of the ground, againſt which the impetus of the lightening is directed, and at that place the lightening 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 by means of the inequality and moiſture of its ſurface, 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 lightening 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: 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 its way. We are therefore ſure, that in whatever place the outer zone

of

of positively electrified earth is thinnest, there the lightening will strike, whether a conductor happens to be present or not. If there is a conductor, either with a knob or sharp pointed, the lightening 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 its 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 lightening 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 there the positively electrified zone is thinner than where the conductor was.

"To suppose that a pointed conductor will exhaust a thunder cloud of its 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 effecting this, there is an impossibility, because they have the same kind of electricity with the clouds themselves.

"Besides,

"Besides, Becaria has obſerved, that during the progreſs and increaſe of the ſtorm, though the lightening 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 lightening 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 lightening 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 its power of *drawing off* the electric matter, was neither able to prevent the flaſh, nor to turn it forty-ſix feet out of its way. The matter of fact is, the lightening 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,

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 its point; for the former was the way in which the lightening actually paſſed.

"The ziz-zag kind of lightening is the moſt dangerous, becauſe it muſt overcome a very violent reſiſtance of the atmoſphere, and where-ever 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 which 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 lightening is that which aſſumes the form of balls. Theſe are produced by an exceeding great power of electricity, gradually accumulated till the reſiſtance of the atmoſphere is no longer able to confine it. In general, the lightening breaks out from the electrified cloud by means of the approach of ſome conducting ſubſtance; but the fire-balls ſeem to be formed not becauſe there is any ſubſtance at hand to attract the electric matter from the cloud, but becauſe the electricity is accumulated in ſuch a quantity that the cloud can no longer contain it. Hence,

ſuch

ſuch balls fly off ſlowly, and have no particular deſtination; their appearance indicates a prodigious commotion and accumulation of electricity in the atmoſphere, without a proportionable diſpoſition in the earth to receive it. This diſpoſition is however altered by a thouſand circumſtances, and the place which firſt becomes moſt capable of admitting electricity will firſt receive a fire-ball. Hence this kind of lightening has been known to move ſlowly backwards and forwards in the air for a conſiderable time, and then ſuddenly fall in one or more houſes, according to their being more or leſs affected with an electricity oppoſite to that of the ball at the time. It will alſo run along the ground, break into ſeveral parts, and produce ſeveral exploſions at the ſame time.

" It is very difficult to imitate this kind of lightening 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 batttery 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.

i.e. it would have been at a loſs for a conductor; The negative ſide of the battery was the place of its deſtination, but to that it could not eaſily have got, becauſe of the great quantity of atmoſphere which lay in its 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 lightening, 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 other 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.

escaped.* The reason of this is, that in thunder-storms there is a zone of earth considerably under the surface, which the lightening desires to strike, (if we may use the expression) because it has an electricity opposite to the lightening itself. Those objects, therefore, which form the most perfect conductors between the electrified clouds and that zone of earth will be struck by lightening, 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 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 its 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

* 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.

upon its 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 lightening 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 its 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 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 lightening 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

the materials of it cannot readily conduct the electric fluid."*

* See Encyclopædia Britannica, Art. Lightening, 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 lightening, 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. 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 phœnomena 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 its preſſure, but alſo by its 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 cieling, 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. Theſe boards may be conſidered

as

as the coatings to the plate of air which is between them.

EXPERIMENT CLII.

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 its 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 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 phœnomena of lightening.

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 the 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

tural to think that it would run over its ſurface very eaſily. But inſtead of this, ſo great is its 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 its progreſſive motion violently forces the vitreous particles aſunder in all directions.

Experiment CLIII.

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 its contents on one of the hemiſpheres, in a ſtrong flaſh, attended with a ſmart exploſion; vivid corruſcations 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 lightening, it is Nature invested with her own attire.

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 CLIV.

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 show any signs of attraction.

Experiment CLV.

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 CLVI.

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.

CHAP. XI.

Of the Electrophorous.

FIG. 73 reprefents an electrophorous. This inftrument was invented by Mr. Volta, of Coma in Italy.* It confifts of two plates of a circular form, the under plate is of brafs covered over with a ftratum of an electrical fubftance, generally of fome negative electric, as wax, fulphur, &c, the upper plate is of brafs, with a glafs handle fcrewed on the center of its upper furface.

Refinous electrics generally fucceed better for an electrophorous than thofe made only of glafs, not only as they are lefs affected by the humidity of the air, but as they feem to have the power of retaining longer the electricity which is communicated to them.

To ufe this apparatus, firft excite the under plate c, by rubbing its coated fide with a piece of clean dry flannel, or hare-fkin; when this plate is well excited, it is to be laid on the table with the electric uppermoft. Secondly, place

* Mr. Wilck, in Auguft, 1762, contrived a refinous apparatus, to which he gave the name of a perpetual electrophorous. See Scripta Academiæ Suec. 1762.

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 CLVII.

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 electrophorous; from whence he infers, that

it

it is not neceſſary that the inferior metallic plate ſhould touch exactly in all its ſurface the electric coating.

Experiment CLVIII.

He inſulated, in a 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 ſometime 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, retains all its properties.

Experiment CLIX.

Having excited the upper ſurface of an electrophorous of wax, he placed the upper plate on it, and after ſome time lifted it off by its 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;

repulsion; which proves, that the electrophorous cannot render the upper plate electric, unless it is touched by a body which is capable of giving or taking electricity from it.

Experiment CLX.

Place the upper plate on an excited electrophorous, bring 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 electrophorous only renders the upper plate electric when it has received or lost a quantity of electricity.

Experiment CLXI.

Place one of the small brass conductors with its pith balls on the upper plate, and then put them both on the electrophorous, 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 electrophorous by its glass handle the balls diverge with great force, forming a very large angle; on

taking

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 its natural ſhare to the under one; it alſo ſhews, that the former, as ſoon as it is laid on the electrophorous, 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 electrophorous.

Experiment CLXII.

Inſulate an electrophorous, and ſuſpend a pith ball by a linen thread, in ſuch 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 electrophorous, 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 electrophorous.

EXPERIMENT CLXIII.

Electrify the under ſide of the electrophorous, 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 CLXIV.

Inſulate an electrophorous 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 electrophorous acquires all the properties which are given to it by exciting the upper ſurface.

EXPERIMENT CLXV.

Connect the upper plate by a chain with the prime conductor, and electrify it, then take a ſpark from the chain, and the electrophorous will acquire as before the ſame powers which it gains when the upper ſurface is rubbed.

Experiment CLXVI.

The ſame effect is produced by placing a Leyden phial on the upper plate of an unexcited electrophorous, then charging and diſcharging it on the plate.

From the three laſt experiments we learn, that the electrophorous may be put in action by communication as well as by friction.

Experiment CLXVII.

Mr. Achard placed the upper plate on an excited electrophorous, and a cube of metal, furniſhed with a glaſs handle, on this plate; on taking the cube by its 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 CLXVIII.

By examining the electrophorous with ſmall pith balls we find,

1. That as ſoon as the upper plate is placed on an electrophorous of wax it acquires a weak poſitive electricity; and the contrary, if placed on an electrophorous of glaſs.

2. That

2. That when the upper plate is touched by the finger it loſes all its electricity.

3. When the upper plate is touched by the finger and removed from the electrophorous, it acquires a ſtrong negative electricity, if the electrophorous is of glaſs; and a poſitive electricity if it is of wax.

The electrophorous 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 cauſe that the electricity of the electrophorous continues ſo long.

Inſulated and excited glaſs induces the negative electricity on bodies brought within the ſphere of its action, while negative electrics, in ſimilar circumſtances, produce the poſitive electricity. Therefore the ſurface of the electrophorous ought to communicate immediately a poſitive electricity if it is of wax, the negative if it is made of glaſs, which is perfectly conformable to experiments. But when the upper plate is touched by the finger, the upper ſurface of the electrophorous ceaſes to be inſulated, and gives the negative electricity to the upper plate, if it is of glaſs, and the contrary if of wax, agreeable to the different experiments which are deſcribed in Chap. IV.

Electric bodies do not put the fluid in that degree of motion which is neceſſary to produce the ſpark, or exhibit the phœnomena of attraction and repulſion, while they are in contact with conducting ſubſtances, which is the reaſon why the upper plate exhibits no ſigns of electricity while it remains in contact with the under one, though they become ſenſible the inſtant it is removed from it.

As the theory of this inſtrument has been 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 electrophorous) 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 its 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 its 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

with any of its 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 CLXIX.

Place a piece of metal on an excited electrophorous, 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 electrophorous, and then remove it by means of ſome electric, and afterwards ſift upon the electrophorous ſome finely powdered reſin, which will form on its 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 CLXX.

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 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 CLXXI.

Suspend a small cylinder of gilt paper by tinfoil, 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, and does not give the least sign of electricity when taken out.

Experiment CLXXII.

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 its density is diminished, in proportion as it spreads itself

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 phœnomena of atmoſpheric electricity, as why the vapour of electrified water gives ſuch ſmall ſigns of electricity, and why the electricity of a cloud is increaſed by being compreſſed or condenſed.

Experiment CLXXIII.

Excite a ſlip of white flannel or a ſilk ribbon, and take as many ſparks from it as it will give, then double or roll it up, and the contracted flannel will be ſtrongly electrical, give ſparks, and throw out bruſhes 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 conſtructed for making obſervations on atmoſpherical electricity, will ſeldom affect the moſt ſenſible electrometer when the ſky is free from electrical clouds; but by means

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of the apparatus now to be deſcribed it will appear, that theſe conductors are always electrical, and conſequently the air which ſurrounds them muſt be at all times electrified. This method not only determines the exiſtence, but alſo the quality of the electricity, whether poſitive or negative, and that, even when the conductor will not attract the fineſt thread; but if a very ſmall attraction is viſible in the conductor, then the apparatus will give long ſparks.

The electrophorous 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 electrophorous, and becomes unfit for our purpoſe.

The apparatus adapted for this purpoſe conſiſts of the upper plate of an electrophorous, 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

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 electrophorous, 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 its 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 electrophorous 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 electrophorous; 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 electrophorous are, 1. That the varnish is always thinner than the common resinous stratum of an electrophorous; 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 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 its 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 pafs from one furface to the other, fhould meet with fome refiftance or oppofition in one of the furfaces, as will be evident in the fecond part.

It is immaterial whether the non-conducting or femi-conducting ftratum be laid upon one or the other of thofe planes; all that is neceffary is, that they fhould coincide together, which renders it proper to ufe two planes that have been ground together, and one of them varnifhed. A fingle metal plate, covered with filk, with three filk ftrings faftened to it by way of handle, may be conveniently ufed for ordinary experiments.

To ufe the apparatus, the upper metal plate muft 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 electrophorous, and that only.

The apparatus being left in that fituation a certain time, will acquire a fufficient quantity of electricity, though but very flowly.

Remove the communicating wire from the metal plate, and, by means of its infulated handle, feparate it from the under one; it will now attract a thread, electrify an electrometer, and, if it is ftrong, will give fparks, &c. though

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 phœnomena 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 electrophorous, 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 electrophorous, according

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to this method, will raiſe its 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; its principal uſe being to collect and render ſenſible that ſmall quantity of electricity which would otherwiſe remain imperceptible and unobſerved.

Hitherto we have adapted our condenſer to the detecting weak atmoſpherical electricity, as brought down by the conductor; but this, though the principal, is not the only uſe to which it may be applied. It will likewiſe diſcover artificial electricity, when it is ſo weak as not to be diſcoverable by any other means.

A Leyden phial charged, and then diſcharged by touching its coated ſides with the diſcharging rod or the hand, appears to be quite deprived of its electricity; yet, if you touch the knob of it with the metal plate of the condenſer, (ſituated upon an imperfect conducting plane) and immediately take up the plate, it will

will be found to give very conſpicuous ſigns of electricity. But, if juſt ſufficient 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 ſtrong ſpark, and if touched again, a ſecond ſcarce ſmaller than the former; and thus, ſpark after ſpark may be obtained for a long time.

This method of producing ſparks, by means of a phial which is not charged ſo high as to give ſparks of itſelf, is very convenient for various 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 its 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)

tion) 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 its 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. 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 be eaſily 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 a ſtill better method may be 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 rubbed 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 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

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 phœnomena of attraction and repulsion, and especially the degree of elevation of an electrometer, correspond.

That the *intensity* of electricity must be inversely proportional to the *capacity* of the body electrified will be clearly exemplified by the following experiment.

Experiment CLXXIV.

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, its intensity would be diminished to one degree; and on the contrary, if the electricity of the long conductor was con-

contracted into the 60th part of that capacity; its 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 its 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 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 its 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 there-

therefore no advantage has hitherto been deduced from it. The following experiment will ſhew this increaſed capacity in the ſimpleſt manner.

EXPERIMENT CLXXV.

Take the metal plate of an electrophorous; hold it by its handle in the air, and electrify it ſo high 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 plane 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 its former ſtation, namely, to 60°; excepting the loſs that the air, &c. may have occaſioned during the experiment.

The reaſon of this phœnomenon 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 its intenſity, 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 CLXXVI.

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

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 CLXXVII.

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 its 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 CLXXVIII.

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, but poſſeſſed of contrary electricities, as may be aſcertained by electrometers.

If the inferior plane is inſulated firſt, and then the electrified plate is brought over it, then the latter will cauſe an endeavour in the former to acquire a contrary electricity, which the inſulation prevents from taking place; hence the

the intenſity of the electricity of the plate is not diminiſhed, at leaſt, the electrometer will ſhew a very little, and almoſt imperceptible depreſſion, which ſmall depreſſion is owing to the imperfection of the inſulation of the inferior plane, and to the ſmall rarefaction and condenſation of the electric fluid which may take place in different parts of the ſaid inferior plane. But if, in this ſituation, the inferior plane be touched ſo as to cut off the inſulation for a moment, then it will acquire the contrary electricity, and the intenſity in the metal plate will be diminiſhed.

If the inferior plate, inſtead of being inſulated, were itſelf a non-conducting ſubſtance, then the ſame phœnomena would happen, viz. the intenſity of the electrified metal plate laid upon it would not be diminiſhed. This, however, is not always the caſe, for if the ſaid inferior non-conducting plane is very thin, and is laid upon a conductor, then the intenſity of the electrified metal plate will be diminiſhed, and its capacity will be increaſed by being laid upon the thin inſulating ſtratum; as in that caſe, the conducting ſubſtance, which ſtands under the non-conducting ſtratum, acquiring an electricity contrary to that of the metal plate, will diminiſh its intenſity, &c. and then the inſulating ſtratum will only diminiſh the mutual action of the two atmoſpheres more or leſs, according as it keeps them at greater or ſmaller diſtances from each other.

The intenſity or electric action of the metal plate, which diminiſhes gradually as it is brought nearer and nearer to a conducting plane not inſulated, becomes almoſt nothing when the plate is nearly in contact with the plane, the compenſation or natural balance being nearly perfect. Hence, if the inferior plane only oppoſes a ſmall reſiſtance to the paſſage of the electricity, (whether ſuch reſiſtance is occaſioned by a thin electric ſtratum, or by the plane's imperfect conducting nature, as is the caſe with dry wood, marble, &c) that reſiſtance, joined to the interval, however ſmall, that is between the two plates, cannot be overcome by the weak intenſity of the electricity of the metal plate, which on that account will not dart any ſpark to the inferior plane, (except its electricity were very powerful, or its edges not well rounded) and will rather retain its electricity; ſo that being removed from the inferior plane, its electrometer will nearly recover its 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,

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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 edgwise, for then its 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 balanced 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, its electricity is not dissipated. This apparent paradox is clearly explained by the theory of electric atmospheres.

'Tis still more like a paradox, that neither touching the metal plate with a finger or piece of metal will deprive it of all its 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 phœnomenon could not be explained on the supposition, that the finger or metals 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 its 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 its capacity ſo far diminiſhed as to render the intenſity of its 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 its 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 applications from it ; nevertheleſs, it will be uſeful to exemplify it by an experiment.

Experiment CLXXIX.

Suppoſe a Leyden phial or a conductor, ſo weakly electrified that its intenſity is on half a degree,

degree, or even leſs : if the metal plate of the condenſer, when ſtanding upon its 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 its electricity, proportional to the plate's capacity, viz. ſo much as ſhould make the intenſity 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 ſtood inſulated in the air ; or, which is the ſame 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, its capacity being leſſened ſo as to remain equal to the 100th part of what it was before, the intenſity of its electricity muſt become 50°, ſince the intenſity of the electricity in the phial or conductor was half a degree.

If a ſmall quantity of electricity, applied to the metal plate of the condenſer, 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

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 its plane, the electricity in it appears much condenſed and vigorous; ſo, when the ſame plate contains a ſmall quantity of electricity, ſuch as cannot give a ſpark or affect an electrometer, that electricity may be rendered very conſpicuous by communicating it to another ſmall plate or condenſer.

Mr. Cavallo firſt thought of this improvement, by reaſoning on Mr. Volta's experiments. He made a ſmall metal plate not exceeding the ſize of a ſhilling. This ſecond condenſer is of great

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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 my condenfer acquired fo fmall a quantity of electricity, that being afterwards taken from the inferior plane, and prefented to an extreamly 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 its 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 by both condenfers, and then communicated to an electrometer, it will hardly affect that inftrument, and yet is fufficient to afford conviction that the metal can be electrified by the friction of a perfon's hand.

Before the difcovery of the condenfer and Mr. Cavallo's very fenfible electrometer, we

were

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. XII.

Of Atmoſpherical Electricity.

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 their relation to the other phœnomena of the weather. His apparatus was admirably well adapted for this purpoſe, and ſuperior to any thing that we are at preſent acquainted with, for intimating eaſily and at all times the electricity of the air. It not being at firſt ſuſpected, that electricity was ſo intimately blended with every operation of nature, as it is now known to be. The labourers in this part are of courſe very few, the principal are P. Beccaria, Mr. Ronayne, and Mr. Cavallo.

I have extracted and methodized the reſults of the obſervations made by P. Beccaria, introducing occaſionally thoſe made by others, that the reader might be in poſſeſſion of the moſt material facts, and excited to inveſtigate and purſue with attention this delicate and important ſubject; for, indeed, little certainty can be expected from any ſyſtem of meteorology where the action of the principal agent is not particularly conſidered and attended to.

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The apparatus used by P. Beccaria, for investigating the electricity of the atmosphere, 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 raised over the chimney, the other end was fastened to the top of a cherry-tree. The extremities of the wire 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.

The electricity, in serene weather, generally makes each of the balls diverge about 6 lines; when it is very strong, they will diverge 15 or 20 degrees from the metal plate; when weak, the divergence is very small.

In serene weather, the wire, after being 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

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 100th 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 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 obſerved between the finger and the plate of braſs to which they are affixed.*

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* In making obſervations on the electricity of the atmoſphere in clear weather, it is eſſential to repeat them very frequently; i. e. to obſerve the velocity with which the electricity riſes after it has been annihilated; which P. Beccaria generally eſtimated by the number of ſeconds elapſed before the balls began to manifeſt their electricity.

The electricity, when the weather clears up, is always poſitive. When the weather is clearing up, and becomes dry quickly, the electricity riſes to a great degree of intenſity, and affords frequent opportunities for repeating the obſervations. It ſometimes happens, that the electricity, cauſed by the clearing up of the weather, continues in its ſtate of intenſity for a long while; and alſo, after being interrupted, it begins afreſh. Theſe accidents ſeem to be owing to the electricity being brought over by the wind from great diſtances.

P. Beccaria ſays, that whenever he obſerved 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 ceaſed, and the balls diverged with poſitive electricity, he always wrote down *certain tendency to clear weather.*

Prior Ceca ſays, that a ſtrong poſitive electricity 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 foretells 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, 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

tricity 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 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 its 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.

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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 proportional to the dryneſs of the air, and the ſmallneſs of its difference from that of the preceding day. If this ſtate of dryneſs does not obtain, no diſcernable 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 than 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 begun 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 its 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 its intenſity in proportion to the

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 wind, 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 its intensity is not so constant, it begins with greater rapidity, and ends sooner.

If, under the above circumstances respectively, the general dryness of the air happens to be less, the electricity that arises 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 its 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 CLXXX.

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 preserve the insulation of the glass with warm cloths. The electric signs that will arise in two threads suspended to such bottle will exactly represent 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

less

leſs rare, as the difference between the heat of the air in the room, and that of the water in the bottle, is leſs or greater, and the inſulation of the bottle is more or leſs exact.

In a thunder-ſtorm Mr. Ronayne obſerved, that the flaſhes would cauſe ſudden changes. Sometimes the electricity would be extended, ſometimes diminiſhed; at other times increaſed, and ſometimes even changed to the contrary again, though none was perceived before; it would come on ſuddenly with a flaſh of lightening. A large thunder-cloud, when it darkens the hemiſphere, does not produce ſo much electricity as a branch of it, or even as a common ſhower; that a ſtorm does not go in a regular current of the wind, but obliquely and zig-zag; viz. it rains in that region from whence the ſtorm 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 ſchool-boy's kite with this

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 the 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 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 overhead. 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 of the ſtring of the kite which comes within the room, C the ſilk lace, DE 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 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 its 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

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 its 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 a pith ball 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

When the electricity of the atmoſpere 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. 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 its 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

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 AG, which is thruſt into a piece of cork, faſtened to the end A of the tube. The end G of the wire AG 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 CB; which part of the tube is covered with a ſilk lace, in order to adapt it better to the hooks. The part FL 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 CB. 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 AG. 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

to clean it often, particularly when a ſhower of rain is approaching.

Deſcription of a ſmall portable Atmoſpherical Electrometer, 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 its 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 G being alſo covered with ſealing-wax, projects a ſmall way within the tube C D M N; into this ſmaller tube a wire is cemented, which, with its under extremity, touches the flat piece of ivory H, faſtened 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 ſcrews into the braſs cap E F, which cap is open at the bottom, and ſerves to defend the waxed part of the inſtrument from the rain, &c.

TM and KN are two narrow ſlips of tin-foil, ſtuck to the inſide of the glaſs CDMN, and communicating with the braſs bottom AB. They ſerve to convey that electricity which, when the corks touch the glaſs, is communicated to it, and, being accumulated, might diſturb the free motion of the corks.

To uſe this inſtrument for artificial electricity, electrify the braſs cap by an electrified ſubſtance, and the divergence, or convergence of the balls of the electrometer, at the approach of an excited electric, will ſhew the quality of the electricity. The beſt manner to electrify this inſtrument is, to bring excited wax ſo near the cap that one or both of the corks may touch the ſide of the bottle CDMN, after which they will ſoon collapſe and appear unelectrified. If now the wax is removed, they will again diverge, and remain electrified poſitively.

When this electrometer is to be uſed to try the electricity of the fogs, air, clouds, &c. the obſerver is to do nothing more than to unſcrew it from its caſe, and hold it by the bottom AB to preſent it to the air a little above his head, ſo that he may conveniently ſee the corks P, which will immediately diverge if there is any electricity; i. e. whether poſitive or negative may be aſcertained, by bringing an

excited

excited piece of ſealing-wax or other electric towards the braſs cap E F.

General Laws deduced from the Experiments performed with the Electrical Kites.

1. The air appears to be electrified at all times. Its electricity is conſtantly poſitive, and much ſtronger in froſty than in warm weather; but it is by no means leſs in the night than in the day time.

2. The preſence of the clouds generally leſſens the electricity of the kite: ſometimes it has no effect upon it, and it very ſeldom increaſes it.

3. When it rains the electricity of the kite is generally negative, and ſeldom poſitive.

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 effect of it in his legs; it

appears more like the difcharge of an electric jar, than the fpark taken from the prime conductor of an electrical machine.

6. The electricity of the kite is in general ftronger or weaker, according as the ftring is longer or fhorter, but it does not keep any exact proportion to it. For inftance; the electricity brought down by a ftring of a hundred yards may raife the index of the electrometer to 20°, when with double that length of ftring the index of the electrometer will not go higher than 25°.

7. When the weather is damp, and the electricity is pretty ftrong, the index of the electrometer, after taking a fpark from the ftring, or prefenting the knob of a coated phial to it, rifes furprizingly quick to its ufual place, but in dry and warm weather it rifes exceedingly flow.

It appears, from the obfervations which have been made on the electricity of the atmofphere, that Nature makes great ufe of this fluid in promoting vegetation.

1. In the fpring, 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 increafe till that part of the autumn in which the laft fruits are gathered.

2. It

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 Imperfection 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 phœnomena, it is rather surprizing 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 its 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 phœnomena, 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 phœnomena. If electricity is not the sole cause of several meteorological appearances, it is undoubtedly concerned

cerned more or lefs in their formation; fo that by neglecting to obferve it, as well as the barometer, &c. we lofe the fruits of other, even very exact, meteorological obfervations.

The influence of electricity on vegetation is proved by a fet of obfervations made by different philofophers; but it evidently appears, that the botanic meteorological obfervations alone will never be fo ufeful as might be expected, till we unite thofe made by an inftrument which will indicate the electric ftate of the atmofphere, to thofe made with other inftruments. It is owing to this caufe, perhaps, that it is impoffible to draw any conclufion from the botanical meteorological obfervations of Meffrs. Gautier and Duhamel, which were continued from 1751 to 1769.

Mr. Achard has had an opportunity of making only a few obfervations, but they were fufficient to convince him of the intimate connection that fubfifts between the formation of the moft part of meteors, and atmofpherical electricity.

To difcover if the atmofphere was electrical, he made ufe of a pair of light pith balls which were attached to a refinous rod. This electrometer, from its fimplicity, is almoft preferable to any other for merely difcovering that electricity exifts in the atmofphere.

During the month of July, 1778, Mr. Achard obſerved daily the electricity of the atmoſphere in the morning, at noon, and in the evening, with a pair of ſmall pith balls, which were placed above the roof of the houſe, above 40 feet high, and ſufficiently diſtant from buildings, trees, &c. During the whole time there was only 10 days which gave no ſigns of electricity; 17 days, including the foregoing 10, in which he could obſerve no electricity in the morning, though it became very ſenſible at noon, and was very much increaſed towards the ſetting of the ſun. Every other day he found the air electrical during the whole day, but always ſtrongeſt a little before ſun-ſet, a ſhort time after which it began again to diminiſh.

If in ſerene weather the ſky became ſuddenly cloudy, the electrometer indicated continual changes in the electricity of the atmoſphere; ſometimes increaſing, then diſappearing, then re-appearing; in which caſe, it had generally changed from poſitive to negative, or *vice verſa*. In windy weather he found it difficult to obſerve with the electrometer, on account of the continual motion of the balls. It ſeemed to vary conſiderably when the air was heavy, but not windy. When the weather was very calm, and the ſky without clouds, the electro-

meter

meter 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 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. Tranſ. for 1773, are obſervations on the electricity of fogs, which prove that they are generally electrical. Mr. Achard has made ſeveral obſervations, the reſults of which

which correſpond entirely with thoſe, for he conſtantly found that the air was more or leſs electrified by a fog. Twice he obſerved, that in the ſpace of a few minutes the fog ceaſed altogether, and fell in form of a fine rain; and though it was very thick, diſappeared in about ſeven minutes. It is alſo very probable that rain is occaſioned by electricity; and of this we ſhall be convinced, if we conſider the attractions and repulſions that the terreſtrial or atmoſpheric electricity muſt occaſion, as well between the ſurface of the globe and the vapours contained in the air, as between the particles of vapour which always neceſſarily tend to diſperſe or unite the aqueous particles which ſwim in the atmoſphere, and to bring them nearer, or carry them farther from, the earth.

Having proved the neceſſity of combining obſervations on the electricity of the atmoſphere with other meteorological obſervations, Mr. Achard proceeds to deſcribe the properties requiſite in a good atmoſpherical electrometer, the want of which accounts for the neglect and ſupineneſs of philoſophers on this ſubject.

Neceſſary

Necessary Requisites in an Atmospherical Electrometer.

1. It should be easy in its 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 are 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 its electricity by transmission. The cone must be high enough, and its inferior base must exceed far enough, in diameter, its superior extremity, to prevent the rain, even though it should fall in an oblique direction, from wetting, either in its 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. On the truncated part of the cone Mr. Achard fastens

a

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 its 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,

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 relation, 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 electrical, 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, if the lightening 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 form-

ing

ing its 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 lightening.

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 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 its electricity to the vapours which it contains. This is evident from the formation of lightening, which is not produced by the diſcharge of the electrical matter of the air, but by that of the vapours which float in that 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 theſe meteors, he has conſtructed a machine that is adapted to diſcover both its 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 its 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 ſmalleſt degrees of electricity. As this inſtrument is but little elevated, and has no pointed extremity, nity, 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 its electricity directly from the air, or by the intervention 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.

CHAP. XIII.

On the Diffusion and Subdivision 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 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 apertures. It does not make any liquor evaporate through the pores either of metal or of 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 is not ſenſibly accelerated, if the tube is not leſs than 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 its 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 its 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.

Experiment CLXXXI.

Fig. 77, repreſents a metal phial, to which a capillary tube is adapted, which will only permit

mit 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 CLXXXII.

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 CLXXXIII.

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 CLXXXIV.

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 CLXXXV.

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 CLXXXVI.

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 CLXXXVII.

Diſcharge a battery through a drop of water, previouſly placed on the knob of one of its bottles, the whole will be inſtantly exploded into vapour; the ſparks will be much longer than common, and more compact.

Beccaria obſerves, that by ſending a diſcharge to a greater or leſs diſtance, through one or more drops of quickſilver, the diſcharge diffuſes itſelf into drops, and drives them into vapour; part of it riſing into the air in the form of ſmoke, the other part remains on the glaſs.

Experiment CLXXXVIII.

A drop of water, hanging from the condenſing ball of an electrified conductor, will ſtretch towards water placed in a cup under it, lengthening and ſhortening itſelf according to the force of the electricity.

EXPERIMENT CLXXXIX.

Place a drop of water on the prime conductor, turn the machine, and long zig-zag ſparks may be taken from it; the drop will take a conical figure; the body that receives the ſpark will be wetted, and the ſparks will be conſiderably longer than can be obtained from the conductor without the water.*

EXPERIMENT CXC.

Stick a piece of ſealing-wax on the conductor, in ſuch 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

* Nicholſon's Introduction to Philoſophy.

when it is thus placed, it may be readily fired by a taper.*

EXPERIMENT CXCI.

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 CXCII.

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.

CHAP. XIV.

Of the Electric Light in Vacuo.

EXPERIMENT CXCIII.

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. The stream often divides 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.

From some experiments made several years since by Mr. Wilson, with an excellent air-pump of Mr. Smeaton, he observed, that very small differences of air occasioned very material differences in the luminous effects produced by the electric fluid; for when all the air was taken out

out of the receiver, which this pump at that time was capable of extracting, no electric light was viſible in the dark. Upon letting in a little air by a ſtop-cock, a faint electric light was viſible, and by letting in a little more air increaſed the light, which again decreaſed on letting in more air; till at laſt, on admitting great quantities, it intirely vaniſhed. By this experiment it appeared, that a certain limited quantity of air was neceſſary to occaſion the greateſt luminous effect.

EXPERIMENT CXCIV.

Fig. 82, repreſents an exhauſted receiver, ſtanding on the plate of an air pump, *a b* an electrified wire diſcharging a ſtream *b c* of the electric fluid on the plate of the air pump. If the ſtratum of air on the outſide of the receiver be leſſened by the application of the finger to the receiver, and by this means an opportunity be given to the fluid on the outſide to eſcape, the fluid within will be impelled to that part, as at *d e f*. It has been inferred from this experiment, that no repulſive power exiſts between the particles of the electric fluid; becauſe, if it was in itſelf really elaſtic, or endowed with a repulſive power of its own, it is not probable it could paſs in an uninterrupted

ſtream,

ſtream, as at *b c*, when the reſiſtance was taken off; it would then ſpread wider, and diſplay its 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 to any natural tendency of the electricity itſelf.

The following experiment of Beccaria conveys a clear idea of the reſiſtance the air makes to the paſſage of the electric fluid, and of the diminution of that reſiſtance in an exhauſted receiver.

Experiment CXCV.

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. On exhauſting the receiver the following changes took place: firſt, the rays of the bruſh became longer; ſecondly, the rays diverged leſs, were fewer in number, and the ſize of the remaining rays was increaſed; thirdly, they all united at laſt, 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 aſſiſtance of other

other electrics, we are able to communicate electricity on electrics, as well as non-electrics; for when this is removed, the fluid pervades the vacuum, and flies off to a considerable distance.

Experiment CXCVI.

To distinguish with great accuracy the changes in the form and length of the electric spark when it is passing through a receiver, the air of which is more or less rarefied; 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 single uniform ray, of a purple colour, passes from one ball to the other; but in proportion as the air is admitted, the ray acquires a quivering motion, which indicates that a resistance to its motion then begins, and this interruption is followed by a division of the ray or stream; the ray now acquires a more vivid light; and, lastly, it becomes the common spark, which is emitted with greater or less facility, in proportion to the power of the machine, and the resistance of the air.

Experiment CXCVII.

Present a thin exhausted flask, similar to that represented at E, fig. 49, but without any coating on the outside, 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 considerable time, flashing at intervals in a manner which very much resembles the Aurora Borealis. The light may be revived by passing the flask through the hand. The stroke of the fluid against the glass is very sensibly heard and felt in this experiment

The flexuous motions of the electric fluid in an exhausted receiver may, in some degree, be produced at pleasure. By wetting the outside of the receiver, the fire will follow the direction of the wetted line, as the resistance is now lessened on one side; and the fire can adhere and accumulate itself on the inside of the receiver, because, by means of the dampness, it can expel a portion from the outside.

This experiment may be exhibited very pleasingly, by making a toricellian 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

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 CXCVIII.

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. Upon making the diſcharge, the light is ſeen to return in a cloſe body.

Experiment CXCIX.

A very perfect vacuum for the paſſage of the electric fluid may be made by a double barometer, or long bent tube of glaſs filled with mercury and inverted, each leg ſtanding in a baſon of mercury; the bent part of the tube above the mercury forms a compleat vacuum. If a

bottle

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 CC.

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 from air, according to the ordinary mode of filling barometers; then place a fmall drop of æther on the quickfilver, and put the finger on the end of the glafs tube, invert the tube, and then infert the end *f* in a bafon of quickfilver, taking care not to remove the finger from the end of the tube, till the end is immerged half an inch under

under the ſilver. When the finger is removed, the quickſilver will deſcend, and the ether 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 an indebted for this valuable experiment to Mr. Morgan, of the Equitable Aſſurance Office.

See alſo Ex. 110, 111, 119, 120, of this Eſſay, for further obſervations on the appearance of the electric light in vacuo.

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;

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 its 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 one inſtance, among many, it has been ſhewn, that the rain which 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 its capacity, which is continually changing by heat or cold, muſt move and operate on it.

As heat, or fire in action is the firſt mover in the animal machine, and the chief active principle during its exiſtence, and as electricity exhibits ſo many phœnomena, 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

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 its 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 its 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 its 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 Mr. Walsh's experiments,

ments, that the will of the animal commands the electric powers of its organs. If these reflections are juſt, we may with ſome probability foretell, 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 its influence upon it. 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 of attempting to collect the electrical fire from hair alone, without the aſſiſtance of any other electrical apparatus. To this end, he deſired a young lady to ſtand on wax, and comb her ſiſter's hair, who was ſitting in a chair before her; ſoon after ſhe had begun to comb, the young lady on the wax was ſurprized to find her whole body electrified, and darting out ſparks of fire againſt every object that approached her. The hair was ſtrongly electrical, and affected an electrometer at a conſiderable diſtance. He charged a metallic conductor from

* Sir John Pringle's Diſcourſes, p. 84.

it, and in the ſpace of a few minutes collected a ſufficient quantity of fire, to kindle common ſpirits, and by means of a ſmall jar, gave many ſmart ſtrokes to all the company.

Mr. Cavallo obtained, by means of a ſmall condenſing plate, very ſenſible ſigns of electricity from various parts of his own body, and the head of almoſt any other perſon.

When the diſoveries in this ſcience, ſays Mr. Brydone, are further advanced, we may find, that what we call ſenſibility of nerves, and many other diſeaſes, which are known only by name, are owing to the bodies being poſſeſſed of too large or too ſmall a quantity of this ſubtle fluid, which is perhaps the vehicle of all our feelings. It is known, that in damp and hazy weather, when this fire is blunted and abſorbed by the humidity, its 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 its abſence: nor can this appear ſurprizing, if it is from the different ſtate

of

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 amongſt 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 too great a ſhare of electrical fire; and it is not improbable, that many of our invalids owe their feelings to the oppoſite cauſe.

EXPERIMENT CCI.

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 its death, make the diſcharge in the ſame manner, and the fluid will paſs viſibly over the body, and not through it; evincing,

cing, that the power or medium which tranſmitted the ſhock through the animal, is loſt with its life. This experiment is taken from Mr. Cavallo's treatiſe on medical electricity. Its 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 CCII.

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. Its 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 its 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, whoſe palſies did not ariſe from the ſpinal marrow. Is it not a convincing proof, that the vital fire is the cauſe of muſcular motion, and that this is the ſame with that which is collected by the electrical machine?

As the ſcience of medicine knows of no ſpecific, ſo we are not to ſuppoſe, that electricity will triumph over every diſorder to which it is applied. Its ſucceſs will be more or leſs extenſive, according to the diſpoſition of the ſubject, and the talents of thoſe who direct it; it cannot therefore appear ſurpriſing, that many diſorders have been refractory to its powers, and others have only yielded in a ſmall degree; or, that the progreſs of the cure has often been ſtopped by the impatience, or prejudice, of the diſeaſed: but, at the ſame time, it muſt be acknowledged, that even in its infancy, when it had to combat againſt fear, prejudice, and intereſt, its ſucceſs was truly great: we have ſurely then the higheſt reaſon to expect a conſiderable increaſe of ſucceſs, now that it is cultivated

tivated and promoted by professional men of the first merit.

Experiment CCIII.

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, of 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 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 heat; nay, even by plunging it in boiling water.

EXPERIMENT CCIV.

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.

A liſt of diſeaſes, in which it has been ſucceſsful, is given by ſome writers, but I refrain from following their example, becauſe I underſtand there is a rational ſyſtem formed on the experiments of the laſt four years; to comprehend which, a knowledge of diſeaſes, their cauſes and ſymptoms, is requiſite.

In this ſyſtem, it is ranked as an anti-ſpaſmodic, is conſidered as the moſt powerful external application to diſeaſes, and, from the various manners in which it is uſed, ſerves the purpoſes of a ſedative, a ſtimulant, and a deobſtruent. In medicine, it becomes then applicable to palſies, rheumatiſms, intermittents; to ſpaſm, obſtruction, and inflammation. In ſurgery it has conſiderable ſcope for action; where contractions and ſprains, tumors, 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 ap-

plication

plication 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 its operations rendered more rapid, sensible, and efficacious, by applying it in different manners and quantities to the human frame. The modes formerly used were the shock, the 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 its action in each case varied, by causing the fluid to pass through materials which resist its passage in different degrees; it may be applied to the naked integuments, or to the skin covered with different resisting substances; and its power may

be

be rarefied 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.

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 is uſual.

3. A Leyden bottle with an electrometer.

4. A pair of large directors 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 its 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 its 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.

Fig. 85 is the medical bottle, furniſhed with an electrometer, to limit the force of the ſhock, and enable the operator to give a ſucceſſive number of them of the ſame force. C is a bent piece of glaſs, on the upper part of which is cemented a braſs ſocket D, furniſhed with a ſpring tube E; the wire F moves in this tube, ſo that the ball G may be ſet at a convenient diſtance from the ball H. The end I of the bent piece of glaſs is alſo furniſhed with a ſpring tube, which ſlides upon the wire K, communicating with the inſide of the bottle.

To uſe this bottle, place the ball H in contact with the conductor, or connect them together 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

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 from the outſide to 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. The ſhock 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 to 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 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.

The handles of the directors ſhould be carefully dried, as alſo the bent piece of glaſs C, and thoſe parts of the bottle which are above the coating. It is likewiſe neceſſary to preſs the ends of the directors against the part, to convey the shock more readily.

Some gentlemen have thought the electric forceps a very convenient instrument to conduct the shock through any particular part of the body. Their use is evident from an inspection of fig. 86.

The following mode of extracting the condensed fluid from the inside of a charged Leyden jar has been found, in certain circumstances, peculiarly advantageous. Connect a director, by means of a wire, with the ball of a Leyden jar, charge the jar, either compleatly or partially, and then apply the ball or point of the conductor to the part intended to be electrified, and the fluid, which was condensed in the phial, will be thrown on the part in a dense slow stream, attended with a pungent sensation, which produces a considerable 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. It is obvious, that in this case the circuit between the inside and the outside of the jar is not compleated, 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 the

the conducting ſubſtances near it, to reſtore the equilibrium.

To paſs a ſtream of the electric fluid through any part of the human body, connect one director by a wire with the poſitive conductor, and another director with the negative conductor, or inſulated cuſhion, then place the end of the directors at the extremities of the part, and turn the cylinder, the fluid will paſs through the part from one director to the other.

To throw the fluid on any part of the body, connect the director with the poſitive conductor, turn the cylinder, and then preſent the braſs end of the director towards the patient, and the fluid will paſs between the ball and the patient. Or you may inſulate the patient, and then draw the communicated electricity from him by the directors. In this caſe, a wire ſhould paſs from the braſs part of the director to the ground, or to the hand of the operator. In either of theſe caſes, the quantity of the fluid and its mode of action may be varied, by making the fluid paſs through points or balls of metal or of wood, or by covering the ſkin with flannel; whenever the fleſh-bruſh is adviſed, it is highly probable that covering the affected part with flannel, and then rubbing it with the ball of a director, connected with the machine, would have a ſuperior effect.

The reſiſtance to the fluid's motion may be varied by increaſing the thickneſs of the covering, or the nature of the ſubſtance through which it is to paſs.

Some peculiar effects have taken place from the application of the interrupted ſpark; that is, a ſpark received from a ſecond conductor, placed within the ſtriking diſtance of the prime conductor. It is not improbable, that in this caſe the condenſation and expanſion of the ſpark may be more rapid than when it is received from the prime conductor alone. The director, when the interrupted ſpark is required, ſhould be connected with the ſecond conductor, and then uſed as in other caſes.

Fig. 87 repreſents an univerſal diſcharger upon a large ſcale, with a patient ſitting between the two pillars, one ball reſting at A, the other being placed at B. The convenience of this apparatus is obvious, from an inſpection of the figure; for as the joints have both an horizontal and vertical motion, and the wires paſs through two ſpring ſockets, they may therefore be placed in any direction, and the balls fixed in any required ſituation. Hence, by connecting one wire with a poſitive conductor, and the other with a negative one, or one with the bottom of a Leyden bottle, and the other with the electrometer; the ſhock or ſtream may be con-

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.

L and M, fig. 84, repreſent glaſs tubes, through which ſmall wires are made to paſs, to convey the fluid directly to the ear or throat.

Fig. 88 repreſents another glaſs tube, of a larger ſize, the end of which is capillary; a ſmall quantity of roſe-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 ſubdivided, gentle, and refreſhing ſtream of this fluid may be thrown on the patient.

It is in all caſes moſt adviſeable 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 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 is a pamphlet intitled, " Confiderations on the Efficacy of Electricity in removing Female Obftructions," by Mr. Birch; to whom I am indebted for a variety of important obfervations and practical remarks on the different branches of electricity; and if its merits were to be confined to this difeafe alone, (in which it may be reckoned a fpecific) it would be entitled to the attention of practitioners; but we have reafon to expect much more from it, fince the prejudices of the Faculty feem 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 lightening, 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 was occaſionally added 4800 yards of wire. The electric blaſt from this machine fired gunpowder 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, about an inch and a quarter long, and two tenths of an inch in diameter, when the cartridge was filled with common gunpowder unbruiſed; a wire, communicating with the earth, was then faſtened to the bottom of the braſs ſtem. 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, ſo that it frequently touched the tin-foil with which they were covered. In this ſituation, a ſmall, faint, luminous ſtream was frequently obſerved between the top of the cartridge and the metal. Sometimes this ſtream would ſet fire to the gunpowder the moment it was applied, at others, it would require half a minute or more before it took effect. This difference in time was ſuppoſed to be owing to ſome ſmall degree of moiſture in the powder, or the paper.

Gun-powder may alſo be fired by a ſtream from a large charged Leyden jar, in the following manner:

EXPERIMENT CCV.

Fix a ſmall cartridge on a metallic point, which is fitted to a wooden or glaſs handle; make a communication from the wire to the ground, then preſent the cartridge to the knob

of

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 compleating 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 CCVI.

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 CCVII.

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 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 CCVIII.

Fix the ladle I, fig. 33, into the hole at the end of the conductor, place a small piece of camphor in the ladle, set the camphor on fire, and then put the machine in action; the camphor will throw out a variety of small shoots, and have the appearance of an imperfect vegetation.

EXPERIMENT CCIX.

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 outer 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

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 A: *s* is a ſmall cock, to cut off, or open a communication with, the air in the ball, and the jet K. N is a ſmall pipe to hold a piece of wax taper, L a braſs pillar, on the top of which is a braſs ball; *a* is a pillar of glaſs, furniſhed at top with a ſocket; a wire *b* ſlides in this ſocket, a ball is ſcrewed on to the end of the wire. F is a cock, by which the ball A is filled with inflammable air, and which afterwards ſerves to confine the air and the water that falls from the baſon B into the ball A.

To uſe this inſtrument, after having filled the reſervoir A with pure inflammable air, and the baſon B with water, turn the cocks D and S, and the water which falls from the baſon B will force out ſome of the inflammable air, and cauſe it to paſs through the jet K into the air. If an electric ſpark is made to paſs from the braſs ball *m* to the braſs ball *n*, the inflammable jet, which paſſes through the pipe K, will be fired. To extinguiſh the lamp, ſhut firſt the cock S, and then the cock D.

To fill the reſervoir Aa with inflammable air, which is to be made in the uſual manner, and with the uſual apparatus, having previouſly

filled

filled A with water, place the foot R under water, on a board or ſtool in a large tub of water, that the bent glaſs tube, through which the inflammable air paſſes, may paſs commodiouſly 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 uſe. This inſtrument is convenient to preſerve a quantity of inflammable air ready for any occaſional experiment, as charging the inflammable air piſtol, &c. It is alſo convenient to light a candle for œconomical purpoſes, as the ſmalleſt ſpark from an electrophorous, or a ſmall bottle, is ſufficient to fire the air.

A ſmall battery of inflammable air piſtols is occaſionally made, that affords conſiderable amuſement; as either one piſtol, or the whole together, may be fired at the pleaſure of the operator.

The following experiment was made by Mr. Kinnerſly with his electrical thermometer, which is deſcribed in page 33 of this Eſſay.

Experiment CCX.

Having put ſome tinged water into the large tube, he placed the two wires within the tube in contact, and paſſed a large charge of electricity

tricity from above thirty ſquare feet of coated glaſs, which produced no rarefaction in the air, and ſhewed that the wires were not heated by the fire paſſing through them. When the wires were about two inches aſunder, 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, occaſioned a very conſiderable expanſion in the air; and the charge of a battery of thirty ſquare feet of coated glaſs, would raiſe the water in the ſmall tube quite to the top: upon the coaleſcing of the air, the column of water inſtantly ſubſided, till it was in equilibrio with the rarefied air; then gradually deſcending as the air cooled, ſettled where it ſtood before. By carefully obſerving at what height the deſcending water firſt ſtopped, the degree of rarefaction might be eaſily diſcovered.

Experiment CCXI.

Take a glaſs tube, about four inches long, one quarter of an inch in diameter, and open at both ends; moiſten the inſide of the tube with oil of tartar per deliquium, then fix two pieces of cork into the ends of the tube, and paſs a wire through each cork, ſo that the ends of the wires, which are within the tube, may be about three quarters of an inch aſunder. Connect one wire with the outſide coating of a large jar, and form a communication from the other to the ball of the jar, ſo as to paſs the diſcharge through the tube; repeat this ſeveral times, and the oil of tartar will very often give manifeſt ſigns of cryſtalization.*

Experiment CCXII.

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 CCXIII.

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.

* Cavallo on Medical Electricity, p. 117.

light. To illuminate this phoſphorous, 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 luminous, and remain ſo for a conſiderable time.

Experiment CCXIV.

Diſcharge a jar over a thin piece of wood, which is cut in the ſhape of a creſcent, and covered with this phoſphorus, and the creſcent will be luminous in the dark.

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 its 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 from ten minutes, a quarter, half, or three quarters of an hour, to one, two, or three hours, 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 CCXV.

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;

glaſs; the diſcharge was made by compleating the circuit 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 CCXVI.

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 diameter, which weighed eight ounces, and was carefully inſulated. The firſt conductor loſt fifteen degrees of its 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 its inſtantaneous contact with the ſame cylinder. After having filled this cylinder with lead, which produced an addition of five pounds to its weight, and conſequently to its maſs, I repeated the ſame experiments, and obtained from them the very ſame reſults.

This is followed by other experiments, which are a farther 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,

maſs, but different in extent of ſurface, when they are placed in ſimilar circumſtances, are charged with an unequal quantity of electrical matter, 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 ſubtilty, and, in moſt caſes, inviſibility of the electric fluid, render all reaſoning about its 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 is equal to one of thoſe ſpots, would without injury conduct a ſhock much greater than any battery hitherto conſtructed could give. It is moſt probable, therefore, that though violent flaſhes of electricity, which act alſo as fire, will enter into the ſubſtance of metals and conſume them, yet it immediately diſperſes itſelf over their ſurface, without entering their ſubſtance any more, till being forced to collect itſelf into a narrow compaſs, it again acts as fire.

In many caſes the electric fluid will be conducted very well by metals reduced to a mere ſurface. A piece of white paper will not conduct a ſhock, without being torn to pieces, as it is an electric ſubſtance; but a line drawn on it with a black lead pencil, will ſafely convey the charge of ſeveral jars. It is impoſſible we can think, that the fire here paſſes through the *ſubſtance* of the black lead ſtroke, it muſt run over its ſurface; and if we conſider ſome of the properties of metals we ſhall find, that there is great reaſon to ſuppoſe that their conducting power lies at their ſurface.

Fig. 92 repreſents a ſmall glaſs tube, ſtopped at one end with a piece of cork; *k* is a wire which paſſes through a piece of cork, fitted into the

the other end of the tube, the upper part of the wire is furniſhed with a braſs ball, the end of the wire within the tube is bent at right angles to the reſt of the wire.

EXPERIMENT CCXVII.

Take out the upper cork and wire, pour ſome ſallad oil into the 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

fimilar mode through them. The perforation may be made with water in the tube inftead of oil.

Mr. Lullen produced very confiderable effects by paffing the fhock through wires that were inferted in tubes filled with oil. The fpark appears larger in its 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 its charge. Struck with this phœnomenon, the Doctor proceeded to try the experiment on a jar which was not broke, and whose ſtrength he had previouſly aſcertained by repeated diſcharges: he took off a little of the outſide coating, and put on the glaſs a patch of cement, about an inch in diameter, then drawing the coating over it, he charged the jar, but before it had received half its 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 CCXVIII.

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 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 CCXIX.

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 CCXX.

Place a piece of ſmoaking wax-taper on the prime conductor, turn the cylinder, the volume

lume of ſmoak will become more contracted, and its 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 experiment, therefore, clearly evinces, that ſmoke is a conductor of electricity.

Experiment CCXXI.

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 CCXXII.

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,

balls, and a glaſs handle be fixed to the middle of the bent glaſs. This 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. 118, 119, 120, of this Eſſay. But I ſoon found, that the circuit of a diſcharging rod was not ſufficiently extenſive for the purpoſe.

Experiment CCXXIII.

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 balanced, 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 its 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 CCXXIV.

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 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

The arms F H f h, 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 A 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 I, (this ball is an exact counterbalance 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, counterbalances the ball I and the weight laid on it.

A, fig. 99, 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 90 degrees, or a quarter of a circle. The 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

* Philosophical Transactions, Vol. 82, p. 384.

grees 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 60 grains: that in very few inſtances it will ſtand 60 grains weight; and he thinks it hazardous to go more than 45 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, 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 weight on the internal ball, and ſeeing that they coincide with the diviſions on the arm FH, when the ſlide is removed to them.

Obſervations and Experiments made by Dr. Prieſtley on the Effects of Electricity on different elaſtic Fluids.

Experiment CCXXV.

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 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 manifeſtly ſo, and the red part did not readily mix with the liquor. If the tube was inclined when the ſparks were taken, the redneſs extended twice as far on the lower ſide as on the upper. In proportion as the liquor became red, it advanced nearer to the wire, ſo that the air in which the ſparks were taken was diminiſhed; the diameter amounted to about one fifth of the whole ſpace; after which, a continuance of the electrification produced no ſenſible effect.

To determine, whether the cauſe of the change of colour was in the air, or in the electric matter, Dr. Prieſtley expanded the air in the tube, by means of an air pump, till it expelled all the liquor, and admitted freſh blue liquor in its place; but after this, electricity produced no ſenſible effect on the air or on the liquor; ſo that it was clear, that the electric matter had decompoſed the air, and made it depoſit ſomething of an acid nature. The reſult was the ſame with wires of different metals. It was alſo the ſame when, by means of a bent tube, the ſpark was made to paſs from the liquor in one leg, to the liquor in the other. The air, thus diminiſhed, was in the higheſt 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.

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.

The electric ſpark, when taken in alkaline air, appears of a red colour; the electric exploſions, which paſs through this air, increaſe its 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, that 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 conceſſion 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 abſorbed by water. In the courſe of this proceſs, the air was carefully transferred three times from one veſſel to another; and the laſt veſſel, in which the exploſions were made in it, was, to all appearance, as black as the firſt; ſo that the air ſeems to be all convertible into this black ſubſtance.

Thinking this diminution of the vitriolic acid air might ariſe from its abſorption by the cement, with which the glaſs tubes employed in the laſt experiment were cloſed, he repeated it with the air from quickſilver, in a glaſs ſyphon confined by quickſilver, and the reſult was the ſame.

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

He took the ſimple electric ſpark from a conductor of a moderate ſize, for the ſpace of five minutes without interruption, in a quantity of vitriolic acid air, without producing any change in the inſide of the glaſs; when immediately after, making in it only two exploſions of a common jar, each of which might be produced in leſs than a quarter of a minute with the ſame machine in the ſame ſtate, the whole of the inſide of the tube was compleatly covered with the black matter. Now had the electric matter 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

 pro-

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 encreaſed till the acid boiled, no more air could be got. He imagined therefore, that in this caſe the phlogiſton had, in fact, been ſupplied by ſome thing 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

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 becoming very black during the proceſs, a black ſubſtance, and of a thick conſiſtence, was formed, which ſwam on the ſurface of the acid.

It is very poſſible, that the analyſis of this ſubſtance may be a means of throwing light upon the nature of the black matter, formed by electric exploſions, in vitriolic acid air, as they ſeem to reſemble one another very much.

The electric ſpark or exploſion, taken in common air, confined by quickſilver in a glaſs tube, covers the inſide of the tube with a black matter, which, when heated, appears to be pure quickſilver. This, therefore, may be the caſe with the black matter into which he ſup-

poſed

posed the vitriolic acid air to be converted by the same process, though the effect was much more remarkable than in the common air. The explosion will often produce the diminution of common air in half the time that simple sparks will do it, the machine giving the same quantity of fire in the same time: also, the blackness of the tube is much sooner produced by the shocks than by the sparks. When the tube considerably exceeds three tenths of an inch in diameter, it will sometimes become very black, without there being any sensible diminution of the quantity of air.

Experiment CCXXVI.

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

rod by a wire. On difcharging the bottle, the needle with the wax was driven from the coating of the bottle, and fixed into the box oppofed to it. The diftance between the needles was then increafed to two inches and a half, which was the greateft ftriking diftance. The head of the needle, which was fixed to the bottle, was evidently melted in two or three places. If the charge was ftrong, and the wax was not ftuck faft to the coating of the bottle, both the wax and the needle would be driven fome inches from the bottle. On placing a ball of wax on the point of each needle, and paffing the difcharge through them, the ball was thrown from that connected with the bottle full two feet. Repeating this again, he could not produce the fame effect.

Mr. Marfham now fixed the needle, oppofed to that on the bottle, with wax on a brafs plate. On paffing the charge through them, when the needles were half an inch diftance from each other, the needle was thrown fix inches from the brafs plate, while the other remained in its fituation. On increafing the diftance, the effects were the fame, till it came to one inch and a half, when neither were thrown off. In many inftances, both were thrown off, leaving the wax behind them.

The

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 brass plate was also curiously melted, and the bottle broke.

On

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, that the last, if it is insulated, gives as strong signs of electricity as those of the electric itself. This electricity is not com-

* Memoirs de l'Academie de Berlin, for 1779.

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 its 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 inſtant reſtored, on account of the facility with which it penetrates each ſubſtance. For a reaſon nearly ſimilar, elec-

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 its dilating power alſo; and if we do not generally perceive it, it is becauſe the force with which bodies 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,

Electricity, as well as heat, accelerates evaporation.

Heat and electricity accelerate the motion of the blood. Least fear, constraint, or the attention to the experiment, might accelerate the pulse and this be attributed to electricity, Mr. Achard made the experiment on a dog when a sleep, 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, prove that electricity, as well as heat, favour the developement of those animals. The electric fluid, in common with fire, will throw metals into fusion.

If substances, with unequal degrees of heat, touch each other, the heat is diffused uniformly between them. In the same manner, if two bodies 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

end of a certain time, the fame degree of heat. There is a confiderable difference, however, in the fpace of time in which they acquire the temperature of the medium, ex. gr. metals take lefs time than glafs, to acquire or lofe an equal degree of heat.

On an attentive examination of the bodies which receive and lofe their heat fooneft, when they are placed in mediums of different temperature, they will be found to be the fame which receive and lofe their electricity with the greateft facility. Metals, which become warm or grow cool the quickeft, are the fubftances which receive and part with their electricity fooneft. Wood, which requires more time to be heated or cooled, receives and lofes electricity flower than metals. Laftly, glafs and refinous fubftances, which receive and lofe flowly the electric fluid, acquire with difficulty the temperature of the medium which furrounds them.

If one extremity of an iron rod is heated red-hot, the other extremity, though the bar is feveral feet long, will become fo warm in a little time that the hand cannot hold it; becaufe the iron conducts heat readily; though a tube of glafs, only a few inches long, may be held in the hand, even while the other end is melting. The electric fluid, in the fame 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 its electricity, determines the facility 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

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 balance, 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 balance; the degrees may be pointed out by a needle, or by the arms of the balance; 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 its inſide coating, three horizontal wires, VZ, XZ, and Z Y, are fixed; the ends of theſe wires are furniſhed with hollow braſs balls; the bottle U is ſo fixed to the board, that when the beam is horizontal, the ball B touches exactly the ball V, 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 VX; 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 P 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 X, the proportion between the weight of the arms of the lever, the weight P 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 X, 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 X.

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 V will repell 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 X, it will abſorb a quantity of electricity proportionable to its 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,

experiment, only ſubſtituting ſome other ſubſtance in the place of the body E; 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 5 to 8.

Fig. 98 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 its 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 phœnomena 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 phœnomena 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 enquirers 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

point out the links of the chain which connect it with the other phœnomena of the universe.

It is known by the works of Plato and Aristotle, that the antients were acquainted with the attractive and repulsive powers of the magnet; but it does nor appear, that they knew of its 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 discovered the polarity of the loadstone, a property which in a manner constitutes the basis of navigation, and gives being to commerce.

The loadstone, 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.

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.

Artificial magnets, whieh are made of steel, are now generally used in preference to the natural

tural 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.

The power poſſeſſed by the loadſtone, which is alſo communicable to iron and ſteel, is called Magnetiſm.

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 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, Its 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,

Thirdly, Its 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 magnet, and of magnetical bodies; and, ſecondly, an external agent or fluid, which acts upon and paſſes through theſe pores. This fluid he ſuppoſes to be the ſolar atmoſphere, or that ſubtil matter called ether, which fills our ſyſtem.

Indeed, moſt writers on the 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.

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*, nor overcome the reſiſtance of the groſſer ether, which occaſions and continues the motion. For ſuppoſing the pole A of a magnet, filled with ſeveral mouths or open ends of ſimilar tubes, the magnetic fluid, preſſed by the groſſer parts of the ether, will paſs towards B with an inconceivable rapidity, which is proportionable to the elaſticity of the ether itſelf; this matter which, till it arrives at B, is ſeparated by the tubes from the more groſs parts, then meets with it again, and has its velocity retarded, and its direction changed; the ſtream, reflected by the ether, with which it cannot immediately mix, is bent on both ſides towards C and D, and deſcribes, but with leſs 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 atmo-

atmoſphere which is viſible in the arrangement of ſteel filings on a piece of paper that is placed over a magnet.

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.

Theſe curious phœnomena may be illuſtrated by either of the magnets contained in the apparatus, as they will lift greater or ſmaller weights in proportion to their ſtrength.

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.

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.

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.

Suſpend a magnet under the ſcale of a balance, and counterpoiſe it by weights in the other ſcale, then preſent a piece of iron towards the

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.

The powers or properties of a magnet may be communicated to iron and 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 AB 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 its marked end on the unmarked end of A, and its 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 elevation,

vation, 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 B, fig. 101, may be oppoſite the unmarked end D, 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 on the bar C D, and then on the oppoſite

* That is the marked end of one is always to be againſt the unmarked end of the other.

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 its 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, homogenous, 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 permanent magnetiſm than ſoft ſteel, tho' 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 its 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 its force, therefore, the bars to be touched, ſhould neither be too long nor too ſhort, but in proportion to their thickneſs; if they are too long, the paſſage of the magnetic matter coming out of one pole, and proceed-

proceeding round the magnet to enter the other, will be impeded, and its 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 theſe occaſion irregularities in the circulation, and thus diminiſh its 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 touched needles has been encreaſed by leaving them for ſome time in linſeed 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 amongſt iron, or by ruſt; it may be injured alſo by fire, as each of theſe circumſtances will change, or confuſe the direction of the magnetic ſtream.

Place

Place a ſmall magnetic needle on the pivot of one of the ſmall ſtands, and put it between two magnetic bars, ſo that the north end of the bar may be near the ſouth end of the needle; the ſmall needle will, without any apparent cauſe, be thrown into a violent vibratory motion, and ſeem as it were animated, till it is ſaturated with magnetiſm, when it will become quieſcent. The vibratory motion is probably occaſioned by the irregularity of the impreſſions it receives from the magnetic fluid, and the difficulty that fluid finds in entering the needle.

All cauſes, that are capable of making the magnetic fluid move in a ſtream, will produce magnetiſm in thoſe bodies which are properly qualified to receive it.

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. Lightening

ening 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.

There are certain points in a magnet in which its virtues ſeem as it were concentrated.

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 moſt near the ends, evincing that the magnetic power is exerted there with the greateſt force.

Place the ſmall braſs weight, which is in the box, on the north end of the ſmall dipping needle, and then preſent the ſouth end of a magnet to the end of the arch, this will repel the end of the needle to a certain degree; then move the magnet progreſſively forwards, and the needle will fall down gradually till it comes to zero. If the magnet is moved farther, the index will be attracted towards it.

To

To find the Poles of a Magnet.

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.

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.

The poles of a magnet may be aſcertained with greater accuracy by means of the ſmall dipping needle; 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 balance each other, the center of the needle will ſtand over what is called the equator of the magnet, and the needle will be exactly parallel to the bar. If it is then removed towards either pole, it will be differently inclined according to its diſtance from the poles.

Hold a common ſmall ſewing needle (with ſome thread in its 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.

Let an iron rod be exactly balanced 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.

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 its ſituation; but will fix upon one, in preference to any other, one end pointing towards the north, the other towards the ſouth.

It

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 its top, is fixed in this perforation; this cap is hung on a ſteel pin, which is fixed to the bottom of the box; the box has a cover of glaſs, and is mounted on jimbals. At ſome future period, I mean to treat of the various modes that have been adopted in conſtructing ſea compaſſes, and of their various faults and excellencies.

It is by no means clearly decided who was the original inventor of the mariner's compaſs; by ſome it is attributed to Flavio Gioa, of Amalfi, in Campania, who lived about the beginning

ginning of the 14th century; fome fay it came from the Eaft; others that it was known even earlier in Europe.

The contrary poles of two magnets attract each other.

The north poles of two magnets, when brought contiguous, repel each other. The fouth poles alfo, when brought near, repel each other.

Thefe phœnomena are eafily illuftrated by a variety of pleafing experiments.

Sufpend on a point a touched needle, then prefent towards its 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.

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.

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 the north pole of the other, into fteel filings, then let the ends be brought near to each other, and the tufts of filings will unite, forming fmall circular arches.

Place

Place the cylindric magnet, which forms part of the apparatus, on a ſmooth horizontal plane, and bring the ſteel fiſh near and parallel to it, with its head towards the marked end of the magnet, and the round bar will roll from it; turn the fiſh ſo that the tail may be towards the marked end, and the magnet will follow it.

This curious property of the magnet was the foundation of the experiments that were ſhewn in London ſome years ſince by Comus, a great variety of them are deſcribed in "Hooper's Rational Recreation." To explain the nature of theſe, a piece of braſs, filed into the ſhape of an heart, is included in the apparatus; a magnet is inſerted in this piece of metal; put the heart into its box, and place a compaſs over the box with the north point towards the middle of that part of the box where the cover ſlides out; obſerve the direction of the needle; then take out the metal, invert it, put it in its place again, and obſerve the direction of the needle; by keeping theſe obſervations in mind, you may readily diſcover which ſide of the heart is uppermoſt, though put in unknown to you.

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.

Put one of the glaſs panes over a magnetical bar, ſift ſteel filings on the glaſs, then ſtrike the

the glaſs gently, and the filings will diſpoſe themſelves in ſuch 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 its 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.

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

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 thro' 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 its 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 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.

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.

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.

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.

Put into motion one of the ſmall whirligigs with an iron axis, and then take it up by a magnet; it will preſerve its 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.

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.

If a large piece of iron is held at one pole of a magnet, it will encreaſe the attraction of the other

other pole, and enable it to lift more than it would otherways do.

Magnetic Repulſion ariſes from the accumulation of the magnetic fluid, and the reſiſtance formed to its entrance in the magnet.

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 to turn back, and circulate round its own magnet, and thus form two atmoſpheres, which act againſt each other, in proportion to the force and quantity of the ſtream which paſſes through the magnets.

Take a ſteel needle, with a very fine point, and rub it from the eye to the point five or ſix times with the north pole of a magnetic bar; the eye will be the north, and the point the ſouth pole of the needle.

The attraction and repulſion of magnets is not hindered or encreaſed by the interpoſition of any body whatever.

Dip the point of the needle in ſteel filings, and it will take up a conſiderable quantity. Take the magnetic bar in one hand, and the needle with the filings in the other, hold them parallel

parallel to the horizon, with the point of the needle near the ſouth pole of the magnet, and the ſteel filings will fall from the point of the needle; as ſoon as the filings drop off from the point, withdraw it from the ſphere of action of the magnet, and the point will be ſo far deprived of its attractive quality, that it will not again attract the ſteel 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 *.

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 its 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

* Farther Proofs, &c. by Mr. Lyon, p. 60.

yond the polar surface, the unaltered power, in the remaining part of the stone, is able, by its contrary force, to restore the confused part of the stone in a few days.

It does not appear that there is any certain law of attraction peculiar to magnetism; for in different pairs of magnets, the force will vary at different distances. The magnetic attraction is not to be computed from the center of the magnets, but from the center of the pole.

Tho' many experiments have been made to discover, whether the force by which two magnets are repelled or attracted, acts only to a certain distance; whether the degrees of its action within, and at this distance, is uniform or variable, and in what proportion, to the distances it encreases or diminishes; yet we can only infer from them, that the magnetic power extends further at some times, than it does at others, and that the sphere of its action is variable.

The smaller the loadstone or the magnet is, the greater is its force, *cœteris paribus*, in proportion to its size. Though when the axis of a magnet is short, and of course its poles very near, their action on each other weakens the magnetic force. A variety of other causes will also occasion great irregularity in the attraction of magnetism. If one end of a magnet is dipped in steel filings, we shall find that they are very 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 poles of the ſame name, but its force is overpowered by the attraction of the ſtronger.

If a touched needle is placed near a magnet, its direction to the magnetic meridian is ſuſpended, and it aſſumes a direction relative to its 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 its 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 its 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 its virtue by receiving ſeveral ſmart ſtrokes of a hammer; indeed, whatever deranges, or diſturbs the internal pores of a magnet, will injure its magnetic force, as the bending of touched iron, wires, &c.

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.

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.

If a magnet be cut through the axis, the ſegments, which were joined before, will avoid and fly from each other.

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. Ecles 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 mag-

netiſm

netifm is excited in two different pieces of fteel by the fouth pole of a magnet, the ends repel each other; but if one piece be excited by the north pole, and another by the fouth, they will attract each other. He further fuppofes, that a magnet attracts, and is attracted, not entirely according to its own ftrength, but according to the quantity of iron to be attracted; and that magnetifm is a quality inherent in all iron, and of which it cannot be divefted; for fire, which will deftroy a fixed magnetifm, does not deprive it of its natural quantity; on the contrary, it will give it a polarity, or fixed magnetifm, according to the manner of heating or cooling the iron.

In an unarmed magnet, the magnetic ftream is carried back, on all fides, in curved lines to the contrary poles; but when armour, or plates of iron, are applied to each pole, the direction of the magnetic fluid is changed, and it is conducted, united, and condenfed, at the feet of the armour; fo that if the feet are connected by another piece of iron, which is called a lifter, the ftream proceeding from one pole is carried by the lifter to the other, which caufes it to adhere with confiderable force. A chain of balls may be formed between the two feet inftead of a lifter.

Place the armed magnet under a glafs plane, ftrewed over with fteel filings, and thefe will be arranged in curves which go from one foot to the other.

The armour ſhould be formed of ſoft homogenous 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 encreaſes.

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 its point upward, he kept it cloſe to the bar, holding only one finger under its 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.

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 the upper one,

will

will attract the north pole of the needle that it repelled before; the case is the same, if the bar is placed horizontally in the magnetic meridian, the end towards the south will be a north pole.

Iron bars of windows, which have remained long in a vertical position, acquire a fixed polarity. Mr. Lewenhoek mentions an iron cross, which was supposed to have stood on the steeple of a church, at Velft, about 200 years, which had acquired a strong fixed magnetism.

The needle of the mariner's compass, does not point exactly to the north, but is observed to change its azimuth, pointing sometimes towards the east, and sometimes to the west of the meridian.

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 is of the same name, its 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 its 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 Sebastian 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.

If a needle, which is accurately balanced, 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, which is called the dip of the needle, was discovered by Robert Norman, about the year 1576.

It is clear, that the magnetic power exerts itself in two manners on a compass needle; by one force it is directed towards the magnetic meridian; by the other, it forms an angle with the horizon.

The position of a dipping needle, when at rest in the magnetical meridian, is called the magnetical line.

Various kinds of round magnets, termed Terellas, have been constructed with a view to investigate the phœnomena of the variation, and the dip of the needle, by obſerving the poſition of a compaſs at different parts of the Terella, and comparing theſe poſitions with the obſerved ſtate of the magnetic needle on the earth. Little progreſs has been made with theſe on account of the imperfection of their conſtruction; one has, however, been invented by Mr. Magellan, which bids fair to be of real uſe, in diſcovering the laws by which theſe myſterious properties are regulated. It will be found that moſt of the phœnomena attending the direction of the needle, correſpond to what happens to a needle placed on the Terella.

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 its 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 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 encreaſing, from about* 8 *or* 9 *o'clock in the morning, till about* 1 *or* 2 *in the afternoon,* when the needle became ſtationary

tionary for ſome time; after that, the variation weſtward was decreaſing, and the needle came back again to its 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 or twice in a month, and are always accompanied with an aurora borealis.

The attractive power of a magnet will decreaſe while it is heating, and encreaſe while it is cooling; the greater the force of the ſame magnet, the more it will loſe in a given degree of heat.

Experiment I.

About ENE from a compaſs, a little more than three inches in diameter, Mr. Canton placed a ſmall magnet two inches long, half an inch broad, and three-twentieths of an inch thick, parallel to the magnetic meridian; and at ſuch a diſtance, that the power of the ſouth end of the magnet was but juſt ſufficient to keep the north end of the needle to the NE point, or to 45 degrees.

The

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 its former fituation, and ftood at 45°.

Experiment II.

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° $\frac{3}{4}$. It was then ftationary for fome time; but, in twenty-four minutes from the beginning, it came back to 2° $\frac{1}{2}$, and in fifty minutes to 2° $\frac{1}{4}$. He then filled

filled the weſtern weight with boiling water, and in one minute the needle came back to $1^{\circ}\frac{1}{4}$; in ſix minutes more it ſtood half a degree eaſtward; and after that, in about forty minutes, it returned to the magnetic north, or its firſt ſituation.

It is evident, that the magnetic parts of the earth in the north on the eaſt ſide, and the magnetic parts of the earth in the north on the weſt ſide of the magnetic meridian, equally attract the north end of the needle. If then the eaſtern magnetic parts are heated faſter by the ſun in the morning, than the weſtern, the needle will move weſtward, and the abſolute variation will encreaſe; when the attracting parts of the earth on each ſide of the magnetic meridian have their heat encreaſing 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

its

its 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 heat, 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 obſer-"vation; 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, where there were "drains dug, and covered with earth, where

"the

"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
"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.

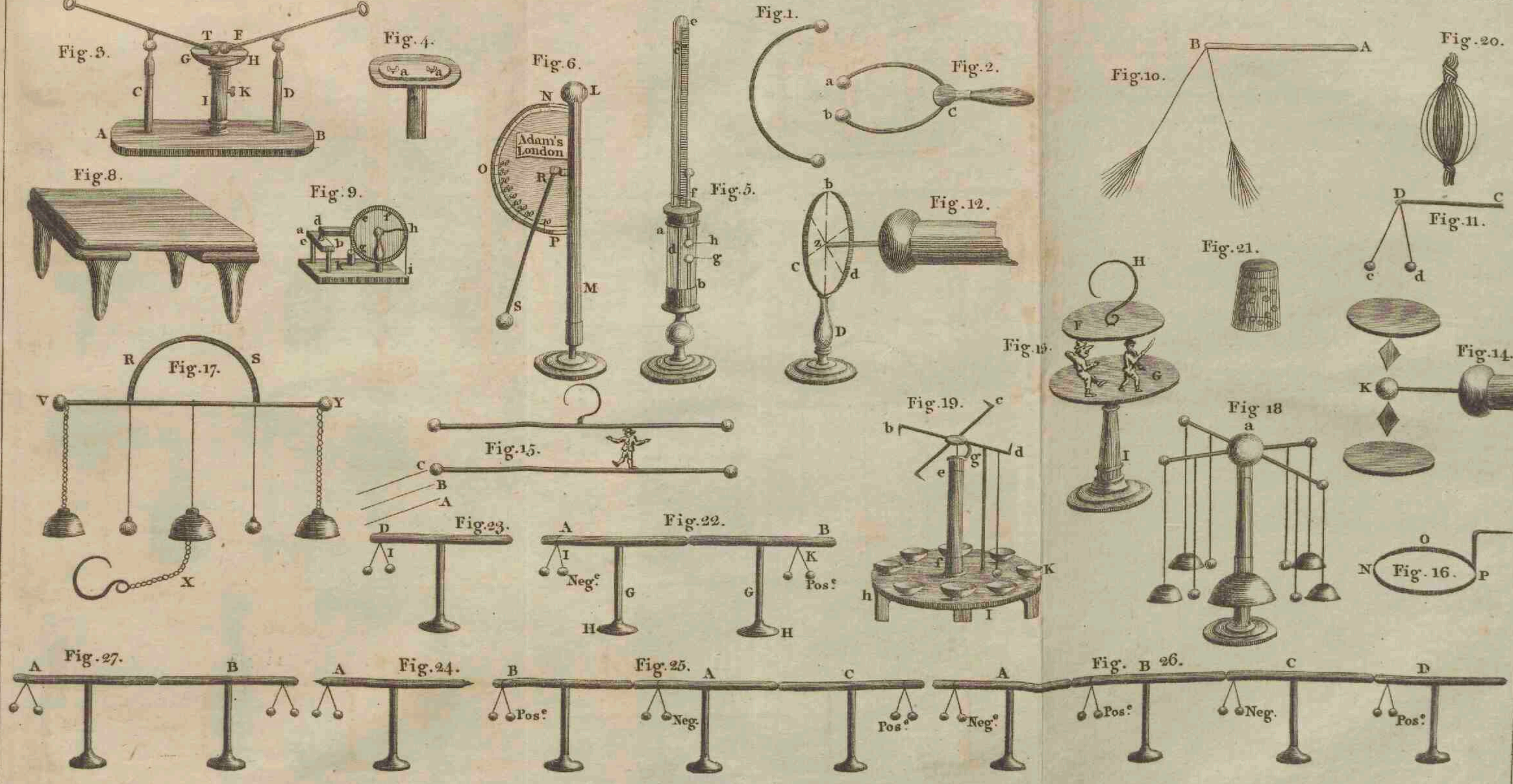
The aurora borealis, which happens at the time the needle is diſturbed by the heat of the earth, is ſuppoſed to be the electricity of the heated air above it; and this will appear chiefly in the northern regions, as the alteration in the heat of thoſe parts will be greateſt. This hypotheſis will not 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 encreaſe or diminution of its 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 its 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.

FINIS.

PLATE. II.



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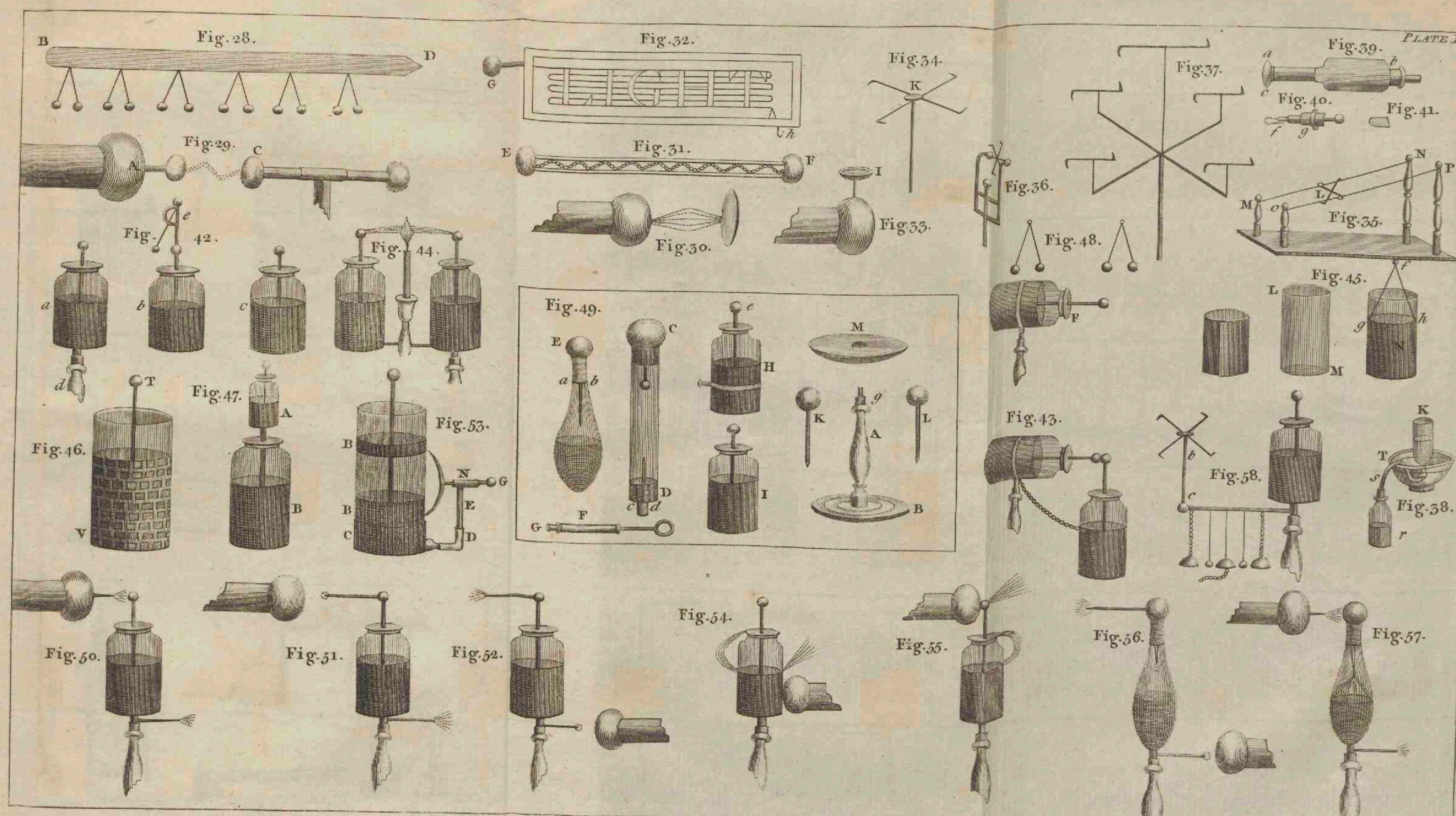

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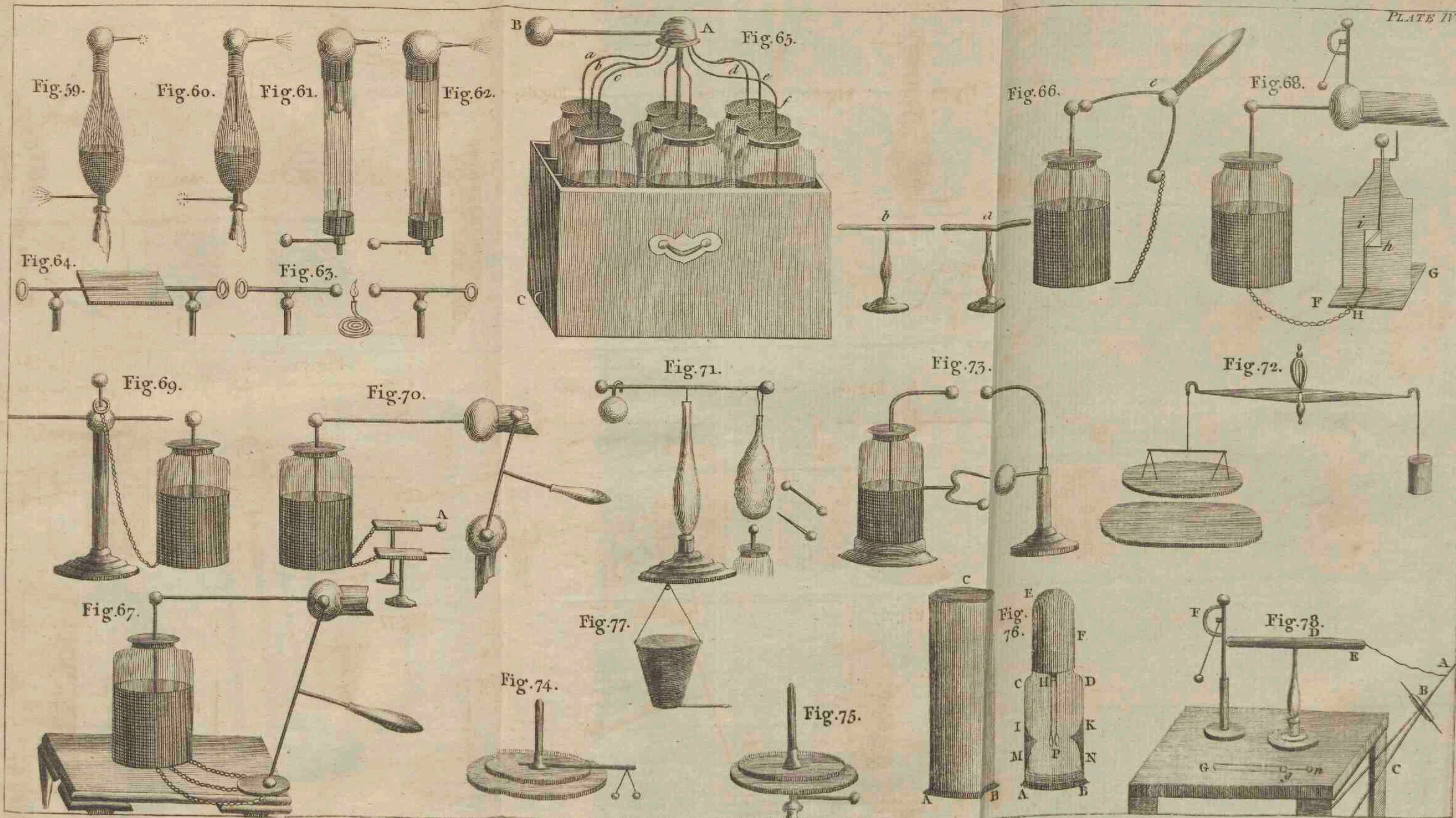
PLATE IV.
Fig. 59.
Fig. 60.
Fig. 61.
Fig. 62.
Fig. 63.
Fig. 64.
Fig. 65.
Fig. 66.
Fig. 67.
Fig. 68.
Fig. 69.
Fig. 70.
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Fig. 72.
Fig. 73.
Fig. 74.
Fig. 75.
Fig. 76.
Fig. 77.
Fig. 78.
Jn. Lodge sculp.

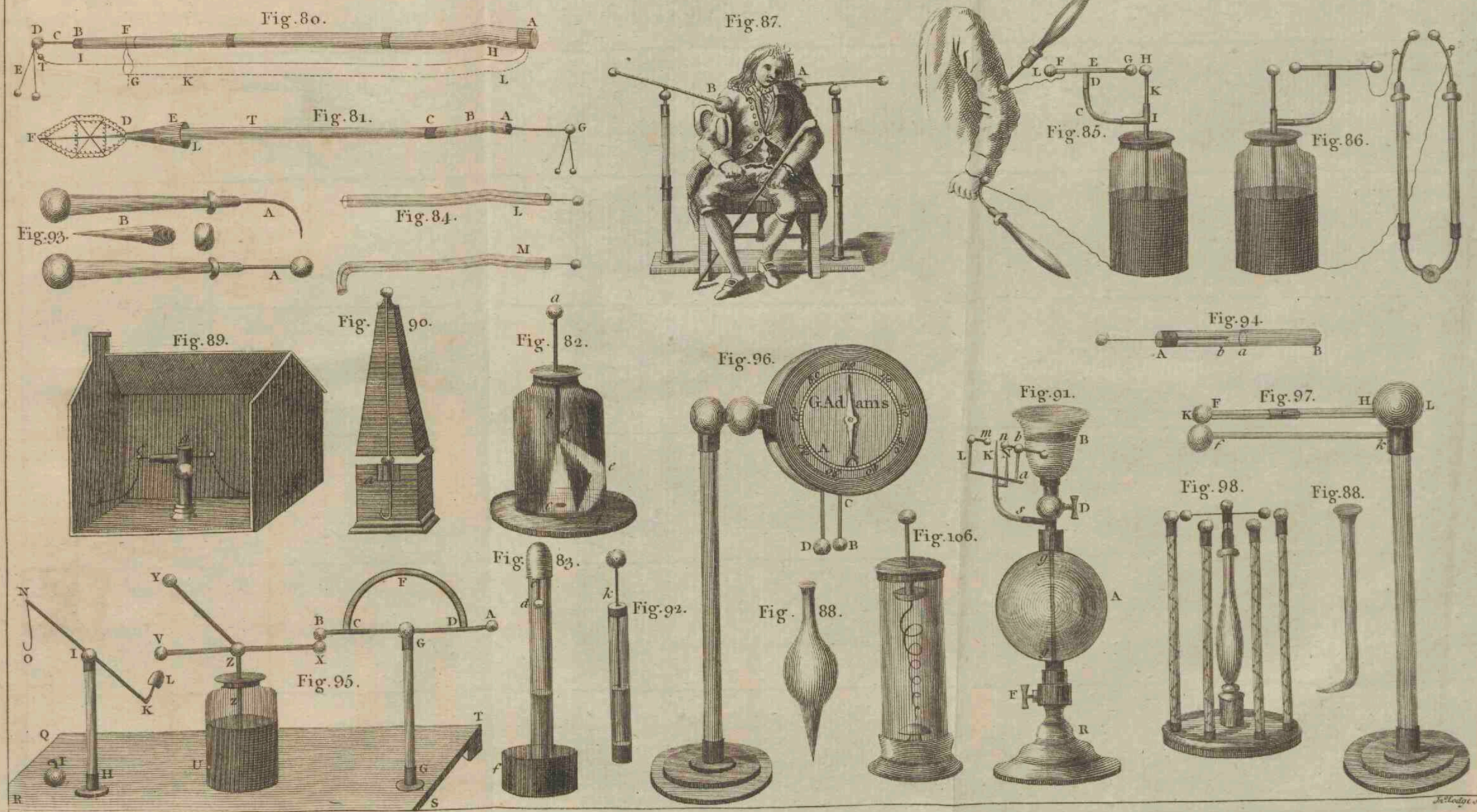

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Fig. 100.

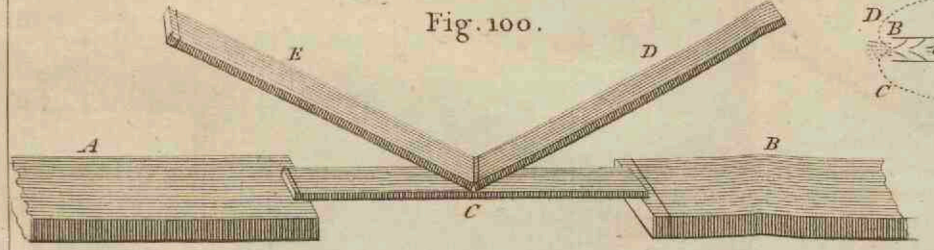


Fig. 99.

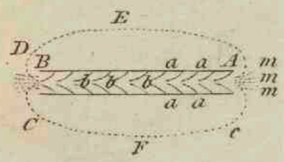


Fig. 101.

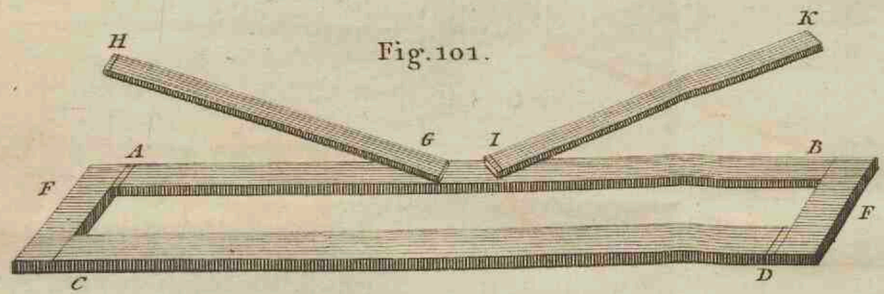


Fig. 102.

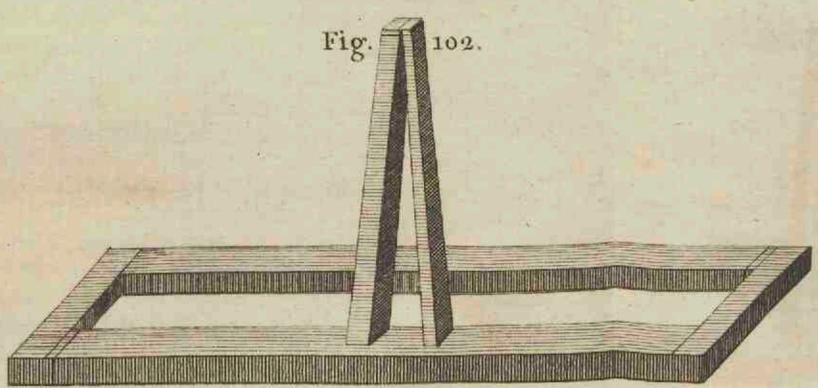


Fig. 103.

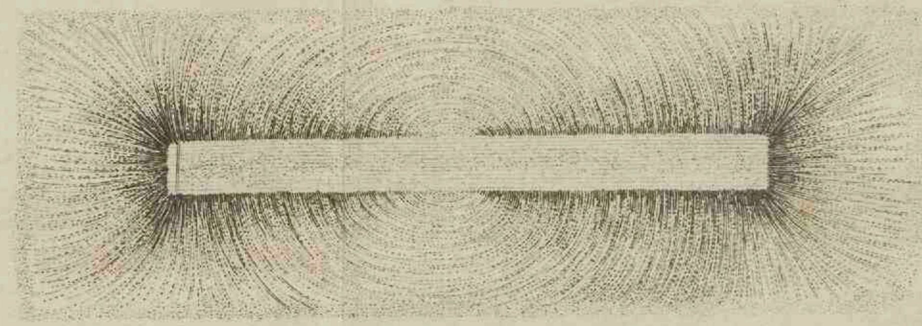


Fig. 104.

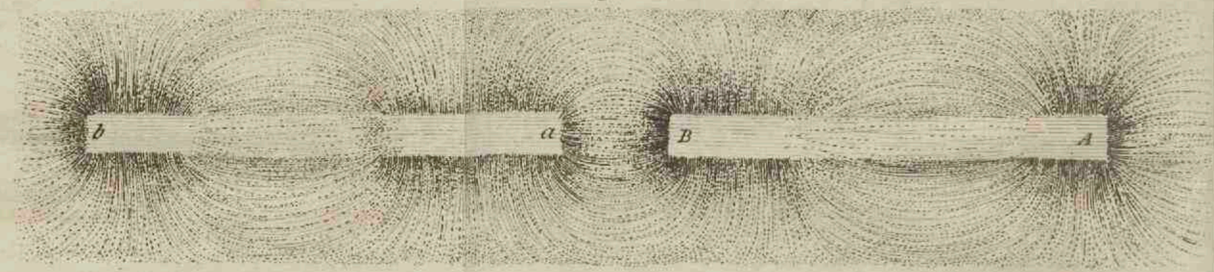
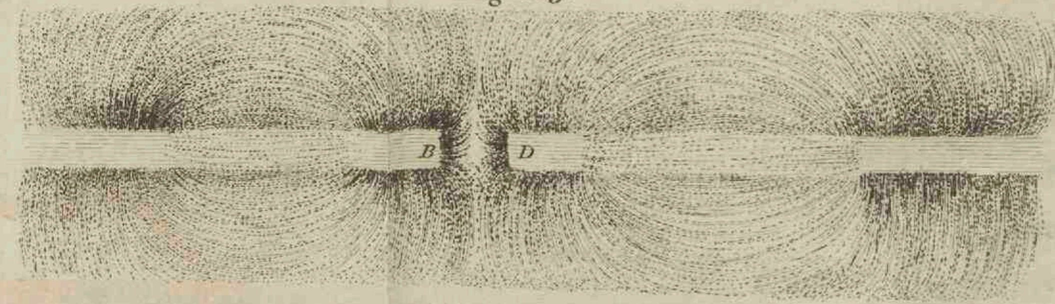


Fig. 105.



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An apparatus for making experiments on accelerated, retarded, and rotatary motion			
A magnetical apparatus from 5l. 15s. to	10	10	0
Hydrodaſtic apparatus, from 2l. 12s. 6d, to	10	10	0
Conductors for ſhips to preſerve them from lightening —— ——	5	5	0