
FAIRE SANS DIRE


a
b
c
e
f
d

AN

# ESSAY ON ELECTRICITY,

*EXPLAINING*

The THEORY and PRACTICE of that uſeful SCIENCE;

and the mode of applying it

*TO MEDICAL PURPOSES.*

With an ESSAY on MAGNETISM.

*THE SECOND EDITION.*

*Corrected and conſiderably enlarged*

By GEORGE ADAMS,

Mathematical Inſtrument Maker to His Majeſty.

*LONDON:*

*Printed at the Logographic Preſs for the* Author, *and ſold by him at* Tycho Brahe's - Head, *N°60 Fleet Street.*

1785.

# ADVERTISEMENT.

BEING encouraged by the very rapid ſale of the firſt edition of this work, to offer another to the public, I have endeavoured to render it more perfect by ſuch additions and alterations, as either occurred to my own mind, or were ſuggeſted to me by others. The reader will find moſt of the chapters either enlarged by the addition of new matter, or improved by a different arrangement of the old; more particularly, the chapters on medical electricity and the Leyden phial.—The eſſay on magnetiſm is alſo conſiderably enlarged; for the preſent diſpoſition and order of treating it I am indebted to the ingenious and kind hints of Dr. Lorimer. The additions are illustrated by two new plates, and an engraved frontispiece.

PRE-

# 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

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. Prieſtley. Our view of things is ſo circumſcribed, and the myſteries of nature ſo profound, that it is not eaſy for us to determine, whether the received theory is founded on the baſis of truth, and conformable to nature, or whether we ſhall be conſidered, by future philoſophers, as mere children, amuſed and ſatisfied with imperfect opinions and ill-digeſted theories. When a variety of things are mixed together, which have little or no connexion, 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

and confined limits of my plan did not admit of much variety of obſervation, or a formal enumeration of every particular, yet few things, I hope, of uſe and importance, have been omitted.

As I do not wiſh to incur the imputation of plagiariſm, I with pleaſure acknowledge the aſſiſtance I have received from the different authors who have 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 explaining the various uſes of the different inſtruments in their preſent ſtate of improvement;

which,

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 mean to publiſh with all convenient ſpeed.

# TABLE

OF

# CONTENTS.



Chap.

THE-

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, being confined to the obſervation only, of thoſe phœnomena which nature preſented to their ſenſes, in the ordinary courſe of her operations; hence near two thouſand years elapſed, before any addition was made to the little which was known to Theophraſtus, and this branch of natural hiſtory remained uncultivated, till the happy period arrived, when the philoſopher was emancipated from the chains of hypothetic reaſoning, and the uncertainties of vague conjecture.

The exiſtence of this ſubtle, and in moſt caſes inviſible, power, was then traced, and many of 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, by delineating the gradual progreſs of its diſcoveries, deſcribing the different theories which have been invented to account for its effects, and pointing out the DESIDERATA which ſtill remain to be explored, has contributed in a high degree, to enlarge the boundaries of electricity, and to encreaſe the number of thoſe who cultivate it.

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

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

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

## EXPERIMENT I.

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

### EXPERIMENT II.

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

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

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

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

Amber, ſilk, jet, dry wood, and a variety of other ſubſtances, being excited, attract and repel light bodies; theſe are called ELECTRICS.

Such

Such ſubſtances, as metals, water, &c. the friction of which will not produce this power of attraction and repulſion, are called NON-ELECTRICS.

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

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

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

## EXPERIMENT III.

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

EXPERIMENT IV.

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

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

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

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

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

From the third and fourth experiments we learn, that excited electrics will communicate the

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

EXPERIMENT V.

Electrify, with excited glaſs or ſealing wax, two inſulated cork balls, ſuſpended by lines about ſix inches long, and the balls will ſeparate from and repel each other.

EXPERIMENT VI.

Electrify one ball with glaſs, the other with ſealing wax, and they will be mutually attracted.

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

The electric power produced by the excitation of glass, is called POSITIVE ELECTRICITY, and the power produced by the excitation of sealing wax is called NEGATIVE ELECTRICITY. This difference was at first thought to depend on the electric, and it was then supposed that the two kinds of electricities were essentially distinct; but it is now known, that each of these powers may be produced from the excitation of either glass or sealing wax.

Electricians have been engaged, by the discovery of the two foregoing distinctions to examine the electric properties of most bodies, to ascertain whether they possessed the positive or negative powers; by this means the catalogue of electrics has been considerably encreased, and it was soon found that every substance, we were acquainted with, had more or less affinity with the electric fluid*.

## CATALOGUE OF CONDUCTING SUBSTANCES.

### 1 *Stony Substances.*

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

* See Dr. Priestley's History. Cavallo on Electricity. Marât. Recherches sur l'electricitè.

Lime-

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 conducts very well, only the latter having a ſmoother ſurface takes a ſtronger ſpark.

A piece of aſbeſt from Scotland, juſt as it is taken from 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

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 of fragments, in all directions, with conſiderable violence.

Volatile ſal-ammoniac gives a ſmall ſhock.

Rock-ſalt conducts, but not quite ſo well as allum; the electric ſpark upon it is peculiarly red.

Sal-ammoniac exceeds rock-ſalt and allum in its conducting powers, but will not take the leaſt ſenſible ſpark; ſo that it ſeems made up of an infinite number of the fineſt points.

Salenitic ſalts conduct but poorly.

By

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 and Ores.*

A piece of gold ore from Mexico is hardly to be diftinguifhed in this refpect from the metal itfelf.

A piece of filver ore from Potofi, though mixed with pyrites, conducts very well.

Two pieces of copper ore, one the moft valuable

luable that is known, and another of only half the value, are hardly to be diſtinguiſhed from one another in their conducting powers.

Lapis-hæmatites conducts pretty well.

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

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

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

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

5. *Fluids.*

The fluids of an animal body.

All fluids, excepting air and oils.

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

Mr.

Mr. Cavendifh has fhewn, that iron wire conducts about four hundred millions of times better than rain or diftilled water; i. e. the electricity meets with no more refiftance, in paffing through a piece of iron wire four hundred million inches long, than through a column of water of the fame diameter only one inch long.

Sea water, or a folution of one part of falt in thirty of water, conducts an hundred times, and a faturated folution of fea falt feven hundred and twenty times better than rain water.

The effluvia of flaming bodies.

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

## ELECTRIC BODIES.

Amber, jet, pitch and fulphur; likewife all the precious ftones, as diamonds, rubies, garnets, topazes, hyacinths, chryfolites, emeralds, faphires, amethyfts, opals, and efpecially tourmalins: all refins and refinous compounds, wax, filk, cotton; all dry animal fubftances, as feathers, wool, hair, paper, &c. White fugar, air, oil, chocolate, calxes of metals, dry vegetables, &c.

I do not know whether it is altogether pro-

per

per to add to this liſt of electrics, the Torpedo and Surinam Eel, living electrics, whoſe electricity is put in action by the will of the animal.

The real and intrinſic difference between electrics and non-electrics, remain among the electric deſiderata; for, nothing more is aſcertained, than, that the conducting power, in ſome meaſure, depends upon, or is governed by heat. Glaſs, reſin, and many other articles, are made conductors by heat; while on the contrary, cold, if not attended with moiſture, renders every electric ſubſtance more electric.

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

and

and infers, agreeable to the ſyſtem of Mr. Euler, that the principal difference between conductors and non-conductors of electricity conſiſts in the ſize of the pores of the conſtituent parts of the body.

## A LIST 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. |

* 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.

| | | |
|---|---|---|
| Hare's ſkin | Poſitive | Metals, ſilk, loadſtone, leather, hand, paper, baked wood. |
| | Negative | Other finer furs. |
| White ſilk | Poſitive | Black ſilk, metals, black cloth. |
| | Negative | Paper, hand, hair, weaſel's ſkin. |
| Black ſilk | Poſitive | Sealing wax. |
| | Negative | Hare's weaſel'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 be black, it will never become pofitive, unlefs B be black likewife. With pieces of glafs the effect is contrary; for, if they are both equal, the piece A, which is drawn acrofs the piece B, becomes negative; and B, which fuffers the greateft friction, becomes pofitive. Heating by fire produces the fame effect as the greater friction. If one piece of glafs be thicker than the other, the former becomes pofitive, the latter negative. Coloured glafs, even when heated, becomes negative, if rubbed with common white glafs. If a piece of blue glafs is rubbed againft a green one, the blue glafs becomes ftrongly pofitive, &c.———Bergman, Swedifh Tran. 1765.

The electricities produced by hair and glafs rubbed together feem 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 glafs tube lengthways, is pofitive; and here, the glafs, which fuffers the greateft friction, is negative. But if the glafs tube be drawn acrofs the animal's back, or acrofs a fkain of hair newly cut, the glafs becomes pofitive. Old dry hair, rubbed on glafs or on living hair, always becomes negative; but if the hair is a little greafed with tallow, the ſame ſame effect is produced as with living hair. Wilke Swed. Tran. 1769.

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

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

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

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

It may be proper to obſerve here, that the two claſſes of electrics and non-electrics are not ſo ſtrongly marked by nature as to enable the electrician to arrange every ſubſtance with propriety: hence the ſame ſubſtance has been placed

placed by different writers in a different claſs. Beſides this, the electric properties of the ſame ſubſtance vary on a change of circumſtances; thus a piece of green wood is a conductor, the ſame piece, after it has been baked, becomes a non-conductor; charred and formed into charcoal, it again conducts the electric fluid; but when reduced to aſhes, is impervious to it. But further, the diſtinctions themſelves are very inaccurate, ſince every ſubſtance is in a certain degree a conductor of this fluid, tho' ſome reſiſt its paſſage more than others.

## CHAP. II.

### OF THE ELECTRICAL MACHINE; WITH DIRECTIONS FOR EXCITING IT.

AS ſoon as the properties of electricity were in ſome meaſure developed, the philoſopher and the artiſt concurred in contriving and executing a variety of machines to excite and accumulate this extraordinary agent. The greater part of theſe have been laid aſide, in proportion as the ſcience advanced, and 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.

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

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

The

1. The electric, as the glaſs cylinder.

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

3. The cuſhion and its appendages.

4. The conductor or conductors.

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

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

The cylinder of the machine which is repreſented in fig. 1; is put in motion by a ſimple winch, which is leſs complicated than the other, and not ſo liable to be out of order. Moſt practical electricians, however, prefer a machine which is moved by a multiplying wheel, as it fatigues the operator leſs than that which is moved by a ſimple winch; while a moderate increaſe of velocity in the cylinder augments the momentum of the electric fluid, and produces a greater quantity of it in the ſame time, which prevents its being abſorbed by the cuſhion. And farther, when the machine is fixed to a table, the poſition of the lower multiplying wheel is more advantageous than that of the winch, and may be turned with the right hand.

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.

D, E, The two perpendicular fupports, which fuftain or carry the glafs cylinder F G H I.

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 hole which is fitted into the top of the fupport E.

O P Is the glafs pillar to which the cufhion is fixed, T a brafs fcrew at the bottom of this pillar, which is to regulate the preffure of the cufhion againft the cylinder. This adjufting fcrew is peculiarly advantageous. By it the operator is enabled to leffen or increafe gradually, the preffure of the cufhion, which it effects in a much neater manner than it is poffible to do when the infulating pillar is fixed on a board.

g h i A piece of ſilk that comes from the under edge of the cuſhion, and paſſes over the cylinder, but between it and the cuſhion, proceeding regularly till it nearly meets 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 conductor is ſuppoſed to be fixed cloſe to the cuſhion, and to lie parallel to the glaſs cylinder. In fig. 1 it is brought forwards, or placed too near the handle, in order that more of it may be in ſight, as at R S; in fig. 2, the end R S only is ſeen.

Y Z Fig. 1 and 2, repreſents the poſitive prime conductor, or that which takes the electric fluid immediately from the cylinder, L M the glaſs pillar by which it is ſupported and inſulated, 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. It is moſt convenient to have both conductors fixed on ſeparate ſtands, unconnected with the machine, that their poſition may be more eaſily accommodated to the peculiar circumſtances of different experiments.

## DIRECTIONS FOR KEEPING THE MACHINE IN ORDER.

Before the electrical machine is put in motion, examine thoſe parts which are liable to wear from the friction of one ſurface againſt another; or to be injured by dirt, that may inſinuate itſelf between the rubbing ſurfaces: as the axes which work in the wooden ſupports D, E, and the axis of the large wheel c d, fig. 2.

If any grating or diſagreeable noiſe is heard, the place from whence it proceeds muſt be diſcovered, then wiped clean, and rubbed over with a ſmall quantity of tallow: a little ſweet oil or tallow ſhould alſo be occaſionally applied to the axis of the cylinder.

Examine the ſcrews that belong to the frame, and if they are looſe, tighten them.

The different working parts of the machine having been thus examined, and put in order, the glaſs cylinder, and the pillars which ſupport the cuſhion and conductor, ſhould then be carefully wiped, to free them from the moiſture which glaſs attracts from the air, being particu-

larly

larly attentive to leave no moiſture on the ends of the cylinder, as any damp on theſe carries off the electric fluid.

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

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

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

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

every conducting ſubſtance that is near it, if 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, and the true line of contact in ſome meaſure aſcertained. Hence I was naturally led to contract the breadth of the cuſhion

ſhion, and place it in ſuch manner that it might be eaſily raiſed or lowered.

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

The line of contact being found and the amalgam placed on it; the cylinder is to be rubbed with a piece of leather which is covered with amalgam; this renders the contact between the cylinder and cuſhion more perfect, by filling the ſmaller pores of the glaſs with amalgam, and depoſiting the ſuperfluous particles on the cuſhion; it is alſo probable that the amalgama, thus depoſited on the ſurface of the glaſs, forms a continued ſeries of conducting particles, which carry the fire to the prime conductor, and, under certain circumſtances, back again to the cuſhion. When the cylinder is

rubbed

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 machine has not been uſed for ſome time, it will be proper to place it, for a few minutes, before a fire, and then take off the cuſhion and dry the ſilk.

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

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

### EXPERIMENT VII.

When the cylinder is put into good action, a number of circular lines of fire will iſſue from the cuſhion; preſent a row of metallic points towards

towards thefe, and they will difappear. The conducting fubftance collects the electric fluid before it can take thofe appearances, or be diffipated into the air.

Hence we learn, that to prevent a lofs of the electric fluid which is excited, we muft prevent the air from acting on the fluid, which is put in motion by the excitation; for the air not only refifts the emiffion of the fluid, but alfo diffipates what is collected by means of the conducting fubftances, which are continually floating in it.

Thefe ends are effectually anfwered by letting a non-conducting fubftance, as a piece of black or oiled filk, proceed from the line of contact to the collecting points of the prime conductor, and placing thefe points within its atmofphere. The ftreams of fire which proceed from the cufhion over the cylinder, fhew whether the cufhion bears uniformly, againft the cylinder; for they are moft copious and denfe at thofe parts where the preffure is greateft, but are uniformly denfe, when the preffure is equable.

When the zinc amalgam is ufed, the filk will fometimes adhere fo ftrongly to the cylinder as to render it very difficult to turn; to obviate this, wipe the filk perfectly clean, and then rub it over

with

with a very ſmall quantity of aurum muſivum or a little whiting.

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

Two kinds of 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. To make the amalgam adhere cloſely to ſilk, it is neceſſary to greaſe this, then wipe off as much of the greaſe as you can, and afterwards ſpread the amalgam.

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 VIII.

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

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

EXPERIMENT IX.

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

EXPERIMENT X.

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

## EXPERIMENT XI.

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

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

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

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

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

EXPERIMENT XII.

Let one perſon ſtand on wax 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 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.

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

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

1. That

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

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

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

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

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

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

The following hypothesis is extracted from the analysis of a course of lectures by Mr. Atwood, to which, and Mr. Eeles's philosophical essays, I must refer the reader for a fuller account of it; in the course of this essay many observations will occur, which tend to confirm this, and refute the foregoing hypothesis.

## HYPOTHESIS.

1. That 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.

6. 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.

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

Fig. 1. Plate II. repreſents a common diſcharging rod; it is generally made of braſs wire, with a ball at each of its ends. To diſ-

charge

charge a Leyden bottle with it, hold the ſemi-circular part in the hand, place one ball of the diſcharging rod on the coating of the phial, then bring the other to touch the knob of the wire which communicates with the inſide when an exploſion will enſue, and the phial will be diſcharged.

Fig. 2. Plate II. is a joined 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 a convenient apparatus to enable a perſon to electrify himſelf; ſee fig. 87.

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

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

Fig. 5. Plate II. is Mr. Kinnerſley's electrical air thermometer; a b is a glaſs tube, on each end of which a braſs cup is cemented; c d is a ſmall glaſs tube, open at both ends, which paſſes through the upper, and deſcends nearly

to

to the under plate; a box fcalee, which is divided into inches and tenths of inches, is fitted to the upper part of this tube; g is a brafs wire with a ball on it, which is fcrewed to the under plate, a fimilar wire f h is made to pafs through a collar of leathers on the upper plate and may be placed at any convenient diftance from the lower wire.

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

An electrometer ought to have the following properties.

1. It fhould be fimple in its conftruction, and not compofed of many parts.

2. It fhould not be affected by the variations of the atmofphere.

3. It fhould indicate fmall as well as large degrees of electricity.

4. Not to be adjufted to any fixed meafure.

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

6. That

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.

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 centre 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

placed over one only, the electricity of this repels and counteracts the motion of the index. Other improvements and variations have been made in this inſtrument, which will be deſcribed hereafter.

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

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

CHAP.

## CHAP. III.

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

NATURAL philoſophers were originally incited to conſider the nature of electricity from 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 they are ſtill 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

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

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

6. Thoſe

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

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

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

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

## EXPERIMENT XIII.

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

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

tively electrified;—on the contrary, if repelled by the excited wax, they are negative, if attracted, positive.

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

## EXPERIMENT XIV.

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

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

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

The ſphere of action of an excited electric has been diſtinguiſhed into two parts, one termed the SPHERE OF INFLUENCE, in which the balls will ſeparate, but cloſe when the electric is removed; the other is called the SPHERE OF COMMUNICATION, in this the force acquired by the balls remains after the excited electric is removed.

EXPERIMENT XV.

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

EXPERIMENT XVI.

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

EXPERIMENT XVII.

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

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

EXPERIMENT XVIII.

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

EXPERIMENT XIX.

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

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

EXPERIMENT XX.

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

EXPERIMENT XXI.

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

## EXPERIMENT XXII.

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

## EXPERIMENT XXIII.

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



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

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 XXIV.

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

EXPERIMENT XXV.

Excited glass held at about one inch distance from the end B, of a solid cylinder of glass B, D, fig. 28. Plate III. which is six feet long, and about half an inch diameter, will force part of the fluid at the end B towards the remote end D; but, in doing this, the natural quantity belonging to the glass will undergo several alterations, which are discovered by the effect an excited

* Ibid. p. 8.

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 *.

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

It

* Ibid, p. 18.

It is not improbable that the attractive and repulſive motions of electrified bodies, are owing to the alternate condenſation and dilatation of the electric fluid on the ſurface of theſe bodies, as they are naturally carried where they meet with the leaſt reſiſtance.

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

## EXPERIMENT XXVI.

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

earth

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

## EXPERIMENTS ON THE ATTRACTION AND REPULSION OF EXCITED SILK RIBBON.

### EXPERIMENT XXVII.

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

### EXPERIMENT XXVIII.

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

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

### EXPERIMENT XXIX.

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

EXPERIMENT XXX.

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

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

EXPERIMENT XXXI.

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

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

When

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

EXPERIMENT XXXII.

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

EXPERIMENT XXXIII.

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

EXPERIMENT XXXIV.

Lay a number of ribbons of the ſame colour upon a ſmooth conducting ſubſtance, draw the ivory rule over them, take them up ſingly, and each

each will give a ſpark at the place where it is ſeparated from the other; the laſt will do the ſame with the conductor; they are all negatively electrified. Take them from the plate together, they will all cohere in one maſs, which is negatively electrified on both ſides.

EXPERIMENT XXXV.

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

The following very curious obſervations and experiments were made by Mr. Symmer. He had been accuſtomed to wear two pair of ſilk ſtockings, a black and a white, when theſe were pulled off both together no ſigns of electricity appeared; but, on pulling off the black ones from the white, he heard a ſnapping or cracking noiſe, and in the dark perceived ſparks between them. To produce this and the

the following appearances in great perfection, it was only neceffary to draw his hand feveral times backward and forward over his leg with the ftockings upon it.

When the ftockings were feparated and held at a diftance from each other, both of them appeared to be highly excited; the white ftocking pofitively, the black negatively. While they were kept at a diftance from each other, both of them appeared inflated to fuch a degree that they exhibited the intire fhape of the leg. When two black or two white ftockings are held in one hand, they repel one another with confiderable force. When a white and a black ftocking are prefented to each other they are mutually attracted, and rufh together, if permitted, with great violence. As they approach the inflation gradually fubfides, and their attraction of foreign objects diminifhes, but their attraction of one another increafes; when they actually meet, they become flat and joined clofe together, like fo many folds of filk; when feparated again, their electric virtue does not feem to be in the leaft impaired for having once met. The fame appearances will be exhibited by them for a confiderable time.

When the ftockings were fuffered to meet, they ftuck together with confiderable force;

at

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

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

CHAP.

## CHAP. IV.

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

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

### EXPERIMENT XXXVI.

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

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

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 XXXVII.

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

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

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

EXPERIMENT XXXVIII.

Prefent a fine thread towards an electrified conductor; when it is at a proper diftance, it will fly towards, and ftick to the conductor, and convey the electric fluid from it to the hand; remove the thread to a fmall diftance from the conductor, and it will fly backwards and forwards with great velocity, and in a very pleafing manner: prefent the fame thread towards one that hangs from the conductor, they will attract and join each other. Bring a non-electric body, as a brafs ball, near thefe threads, the ball will repel that held by the hand, and attract that which is affixed to the conductor: the upper thread renders the brafs ball negative, and therefore goes towards it; while the under thread, which is alfo 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 arifes from the effort the electric fluid makes to diffufe itfelf through them.

## EXPERIMENT XXXIX.

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

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 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 XLI.

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. 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;

* Philoſophical Eſſays. Preface, page 25.

"dry; this will therefore aſcend to the upper "plate and remain there. Reverſe the experiment; 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."

EXPERIMENT XLII.

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

### EXPERIMENT XLIII.

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

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

### EXPERIMENT XLIV.

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

### EXPERIMENT XLV.

Cut a piece of leaf braſs, with an obtuſe angle at one end, and a very acute one at the other, preſent the large end towards an electrified conductor, and when the leaf 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 XLVI.

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

EXPERIMENT XLVII.

Fig. 17 reprefents a fmall fet of bells, the two exterior ones are connected to the wire VY, by a braſs chain, the middle bell and the clappers are ſuſpended on ſilk.

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 braſs chain, which connects the two exterior bells to the conductor, conveys the electric fluid to them, which attracts the clappers; theſe, when they have received the electric fluid, are repelled by the exterior bell, and attracted by the middle one, on which they depoſit their electricity; they are then again attracted and repelled by the outer bells. Hold up, by a ſilk thread, the chain X, which proceeds from the middle bell, and the ringing will ceaſe, becauſe it cannot convey the electric fluid communicated by the clappers to the ground.

Fig. 18 repreſents a more elegant form of mounting the bells. When this is uſed, the 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

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 XLVIII.

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

## EXPERIMENT XLIX.

Bring a downy feather or lock of cotton near the end of an excited tube, or the knob of a charged Leyden phial, the feather will at first fly towards the tube, but when it is saturated with the electric matter, it will recede from it, and may be driven about the room by the excited

cited 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 L.

Put a pointed wire into one of 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

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 LI.

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

EXPERIMENT LII.

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

To account for any of the phenomena of electric attraction and repulsion, is very difficult, but more so to shew why bodies, which are

are electrified with the ſame power, repel each other, particularly thoſe which are negatively electrified. Philoſophers have invented various ſolutions of this difficulty; the following is eſteemed the beſt.

"* To underſtand why bodies, poſſeſſed of the ſame electricity, repel each other, the reader muſt be reminded of the following principle, viz. that the electric fluid proper to a body, can be neither augmented or diminiſhed on the ſurface of that body, except the ſaid ſurface is contiguous to an electric, which can acquire a contrary electricity at a little diſtance; from whence it follows, that no electricity can be diſplayed on the facing ſurfaces of two bodies, which are ſufficiently near each other, and both poſſeſſed of the ſame electricity, becauſe the air that lies between them, has no liberty of acquiring a contrary electricity. This being premiſed, the explanation of electric repulſion becomes eaſy. Suppoſe, for inſtance, that two ſmall bodies are freely ſuſpended by inſulated threads, ſo that when they are not electrified, they hang contiguous to each other: now ſuppoſe

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

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

"The

"* The difficulty is not, however, solved by this theory, which only explains one fact by another, which requires as much explanation as the first: but overlooking this, it is still insufficient: for granting that bodies negatively electrified, ought to repel each other, till the electricity is equally diffused over their surfaces, yet when this is accomplished, the repulsion ought to cease. Further, there is no reason for supposing the electrification to take place while the bodies are in contact, or nearly so. One may be electrified negatively in one corner of a room, and another in the other. The electrification may also be continued for any length of time we please. So that the electric matter must have diffused itself equally over the surfaces of both. Yet, if we attempt to bring these bodies together, they will repel each other, which ought not to be the case on the preceding supposition."

"† Positive electricity has been supposed by another, to consist of a vibratory motion in the air and electric fluid, in which the force of the vibration is directed outwards from the electric body: that in negative electricity, there,

* Encyclopædia Brittannica, p. 2683.
† Ibid, p. 2699.

there is alſo a vibratory motion, but the force is directed inwards. Now let us ſuppoſe a body poſitively electrified, ſuſpended by a ſmall thread, at a diſtance from any other, the vibratory motion being kept up by an equal preſſure on all ſides, the body is neither moved to one ſide nor another; but when a negatively electrified body is brought near, the force of the vibration being directed outwards in the one, and inwards in the other, the preſſure of the fluid in the intermediate ſpace between them is greatly leſſened, and conſequently the preſſure on the other ſide drives them both together, and they are ſaid to attract each other. If a body electrified poſitively, is brought near the firſt, the force of the vibrations are directly oppoſed to each other, and therefore the bodies recede from each other. The caſe is the ſame with two bodies negatively electrified; for here the vibration being directed towards both bodies, as towards two centers, muſt cauſe them to recede from each other, becauſe if they remained in contact, the vibratory motions would interfere with each other.

"When a ſmall body is brought within the ſphere of another's electricity, the equable preſſure of that vibratory or electrical ſphere, is ſomewhat leſſened upon the ſide near which the body

body is brought, and it is therefore impelled towards the firſt by the action of the ſurrounding fluid, in order to keep up the equilibrium. As ſoon as it arrives there, the vibrations of the fluid around the firſt body, being communicated to that within the pores of the ſecond, it acquires a ſphere of electricity as well as the firſt, and is conſequently repelled: the repulſion continues till the vibration ceaſes, either by the action of the air, or by the body coming in contact with another larger than itſelf, in which caſe its electricity is ſaid to be diſcharged. If, after this diſcharge, the ſecond body is ſtill within the ſphere of the firſt, it will be immediately attracted, and very ſoon after repelled, and ſo on alternately, till the electricity of the former totally ceaſes."

From ſeveral experiments of Beccarias, it appears, that, if the air is thoroughly exhauſted from a glaſs receiver, the attraction and repulſion of electrified light bodies within the receiver, grows languid, and ſoon ceaſes altogether. This is confirmed by an experiment of Mr. Cavallos. A pith ball electrometer was ſuſpended within a receiver of an air pump, by its braſs cap; this was then electrified; the balls diverged a little when the air was only rarified 100 times; when it was rarified 300 times,

times, the repulſion was ſcarce diſcernible: when the rarifaction was greater, they did not diverge at all; and that, whether a ſmall or large quantity of electricity was communicated to the cap.*

* Phil. Tranſ. vol. 73, p. 452.

## CHAP. V.

### OF THE ELECTRIC SPARK.

#### EXPERIMENT LIII.

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

The experiments in the foregoing chapter 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 ſound is occaſioned by the momentary agitation into which the air is thrown by the electric fluid.

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

When the quantity of electricity is ſmall, and incapable of ſtriking at any conſiderable diſtance the ſpark appears ſtrait; but when it is ſtrong, and capable of ſtriking at a greater diſtance, it aſſumes a crooked or zig-zag direction; and this, probably, becauſe the more 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. It will appear from this, as well as many other conſiderations, that the exceeding great velocity and ſtrength of the electric fluid, are not owing to a repulſive power among its particles, but to the mutual action of the air, and electric fluid upon themſelves and one another; and that its momentum is produced by the incumbent preſſure of the atmoſphere on the electric

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

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

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

EXPERIMENT LVI.

Mr. 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 thinneſt, would but juſt allow the light of a candle to be ſeen through it in the dark. In ſome parts the wax

was

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

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

### EXPERIMENT LIX.

The ſparks taken over a piece of ſilver leather, appear of a green colour

### EXPERIMENT LX.

E F, fig. 31, is a glaſs tube, round which, at ſmall, but equal diſtances, from each other; pieces of tin-foil are paſted in a ſpiral form, (hence it is called the ſpiral tube,) from end to end; this tube is incloſed in a larger one, fitted with braſs caps at each end, which are connected with the tin-foil of the inner tube. Hold one

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

tube, and preſent it to the conductor while the machine is in action, when a ſtrong ſpark will paſs between the conductor and the point.

EXPERIMENT LXIII.

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

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

Let

EXPERIMENT LXIV.

Let any perſon ſtand on the inſulating ſtool, and connect himſelf by wire or chain, with the prime conductor, he will then exhibit the ſame appearances which are obtained from the conductor, and will attract light bodies, give the ſpark, &c. and thus afford a pleaſing mode of diverſifying every experiment. It is abſolutely neceſſary, to the complete ſucceſs of this experiment, that no part of the cloaths touch the floor, table, &c. and that the glaſs feet be carefully dried: a ſheet of dry brown paper placed under the ſtool, will be found of conſiderable ſervice, by rendering the inſulation more 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, I, fig. 33, then pour a ſmall quantity of ſpirit of wine into it, and fix it by its handle

handle to the end of the prime conductor; or fire the ſpirits, and blow them out a few minutes before the experiment is made; take a ſpark through the middle of the ladle with a braſs ball, and the ſpirits will be fired by it.

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

## EXPERIMENT LXVI.

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

EXPERIMENT LXVII.

The ſpirits cannot be kindled by the inſulated perſon, becauſe as the electric cannot eſcape through him to the earth, he is incapable of drawing a ſpark ſufficiently ſtrong to inflame them, and hot iron will ſeldom or ever ſet ſpirits on fire.

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

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

EXPERIMENT LXVIII.

Inſulate a ſmall crucible, containing three or four lighted coals, throw a ſpoonful of water on the

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 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.

## OF INFLAMMABLE AIR AND THE PISTOL FOR INFLAMMABLE AIR.

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

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

Fig. 39. repreſents a braſs piſtol for inflammable air; a b is a chamber of braſs, to the mouth a c of which a cork is fitted, a perforated piece of braſs g ſcrews on to the bottom of this chamber, (this piece is repreſented by itſelf in fig. 40) a glaſs tube f is cemented into the perforation of this piece, and a braſs wire is alſo cemented into the glaſs tube; one end of this wire is furniſhed with a ball, the other extremity is bent, ſo as to come within about a tenth of an inch of the braſs piece. Fig. 41 is a braſs cap, which ſcrews on the piſtol, to preſerve the glaſs tube from any accident. The air with which the piſtol is to be charged ſhould be kept in a corked bottle: take out the cork, and

apply

apply in the ſame inſtant the mouth of the piſ-tol to the opening of the bottle, and the com-mon and inflammble air will mix together, be-cauſe the former being heavier than the latter will naturally deſcend; keep the piſtol in this ſituation about 15 ſeconds, then remove it, and cork both the bottle and piſtol with the utmoſt expedition.

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

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

This apparatus conſiſts of the following articles.

1. A glaſs funnel.

2. A ſmall glaſs tumbler.

3. A bladder tied to a ſtop cock.

4. A braſs pipe paſſing through a cork; which cork is made tapering, to fit the neck of a common wine bottle: the upper part of the pipe has a male ſcrew, to fit the ſcrew on the lower end of the ſtop cock.

5. An air piſtol, furniſhed with a valve at the end *b* fig. 39. the wire paſſing through a glaſs tube, and to which the ſpark is to be given,

is fitted into the ſide of the piſtol. At the end b of the piſtol is a male ſcrew which fits the lower end of the ſtop cock.

6. A box with iron filings.

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

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

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

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

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

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

## EXPERIMENT LXIX.

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

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

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

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

* Cavallo on Air, p. 818.

CHAP.

## CHAP. VI.

### OF ELECTRIFIED POINTS.

#### EXPERIMENT LXX.

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

#### EXPERIMENT LXXI.

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

#### EXPERIMENT LXXII.

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

To determine the direction of the electric fluid, has ever been an object of considerable importance to the electrician; as it would enable him to decide on the truth of those theories, which have been invented to account for its phenomena, and greatly assist him in the progress of future discovery: To this end much stress has been laid on the different appearance of the light, which is perceived on the pointed ends of electrified conducting substances; as these have been supposed to elucidate fully this interesting question.

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

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

To this it has been objected, that these rays may possibly be converging from so many points in the air towards the point, and not diverging from it; but, as there does not appear any reason why a visible ray should break out from one place in the atmosphere more than another,

ther, the former account ſeems more conformable to nature, and the known laws of other fluids. The air reſiſts the motion of the electric fluid equally. Therefore, when this fluid is coming from the air towards a pointed conductor, it would percolate ſlowly and inviſibly through the air, but equally on all ſides, till it comes ſo near as to be able to break through the intermediate ſpace; but as this will be equal or nearly ſo all around, the negative electricity muſt appear like a ſteady luminous globule on the point *. Notwithſtanding the apparent probability of the above reaſoning, it may ſtill be objected, that no deciſive concluſion can be drawn from theſe appearances, as they may be varied by augmenting or diminiſhing the volume of the pointed body, and by a variety of other circumſtances.

### EXPERIMENT LXXIII.

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

* Encyclopedia Britanica, 2699.

EXPERIMENT LXXIV.

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 LXXV.

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

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

EXPERIMENT LXXVI.

Put a wire, which has a ball at one end, into the hole at the end of a poſitive conductor, place a lighted candle ſo that the middle of the flame may be even with the middle of the ball, and about an inch from it; turn the machine,

chine, and place the ſame wire at the end of the negative conductor, the appearance will be reverſed, and the knob will ſoon be heated by the flame of the candle which is carried towards it.

## EXPERIMENT LXXVII.

Fix a pointed wire in the hole on the upper ſide of the conductor, then place the center of the braſs croſs K, fig. 34, upon the point, the ends of which croſs are all bent one way; electrify the conductor, and the croſs will turn upon 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 retrogade motion to the points of the wire.

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

EXPERIMENT LXXVIII.

Electrify the two insulated wires 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 LXXIX.

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

EXPERIMENT LXXX.

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

EXPERIMENT LXXXI.

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

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

If ſmall boats or little ſwans, &c. are made of cork or light wood, they may be attracted, and made to ſwim in any direction, by applying a finger toward them; a fine needle ſtuck into the end of the boats, in the manner of a bowſprit, will cauſe them to be repelled from the hand held over it, and they may be ſteered by it, ſtern foremoſt, to what point of the compaſs you pleaſe. The boats might have the addition of ſails to them, and might then be made to move briſkly before an electrical gale, from the point of a wire held in the hand.

The

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

When a few young perſons have nothing elſe to do, they might very innocently amuſe themſelves, by making a repreſentation of a kind of ſea engagement between theſe boats. Suppoſing each of them large enough to hold a ſmall coated phial without ſinking, theſe phials may be charged, ſome of them poſitively on the inſide, others negatively, they may then be placed at the bow of the boat, with the wire ball and uncoated part of the phial projecting over; a ſmall braſs chain ſhould be made to touch the outward coating of the phial, and the other end brought over the ſtern of the boat, and hang ſo as to touch the water. The boats being then put into a trough of water, and pretty highly charged, they will ſoon be in motion; thoſe that are electrified alike, will repel each other; and thoſe poſſeſſed of a contrary electricity, will be attracted;

attracted; till the balls of the two phials approach pretty near together; they will then discharge their contents with a loud explosion, and the boats will afterwards sheer from each other.*

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

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

CHAP.

## 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 LXXXII.

Place the braſs ball of a coated jar in contact with the prime conductor while the outſide communicates with the table, turn the cylinder, and the bottle will in a little time be charged

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 LXXXIII.

Charge the Leyden bottle, then touch the outside coating with one hand, and the knob with the other, the bottle will be discharged, and a sudden peculiar sensation will be perceived, that is called the electric shock. The shock, when it is taken in this manner, generally affects the wrists, elbows, and breast: when the shock is strong, it resembles an universal blow. This peculiar sensation is probably owing to the two-fold and instantaneous action of the electric fluid, which enters and goes out of the body and the various parts through which it passes at one and the same instant. It has been also observed, that nature has appointed a certain modification of the electric fluid in all terrestrial bodies, which we violate

violate in our experiments; when this violation is ſmall, the powers of nature operate in a genetle 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.

A given quantity of electricity, impelled through our body with a given force, produces a weaker ſenſation, than twice that quantity impelled with half that force, and conſequently the ſtrength of the ſhock depends rather more on the quantity of fluid, which paſſes through our body than on the force with which it is impelled—Yet, the force of an exploſion ſeems to depend more on the degree to which the fluid is compreſſed,

than

than on the quantity; hence a ſmall phial fully charged will act nearly as ſtrong as a larger jar which is half charged.

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

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

A Leyden jar very often recovers 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; for the effect of the Leyden phial depends entirely on the reciprocal action of the two furfaces, and does not take place, when either is touched feparately. By attending to this obfervation, jars of any fize may be handled with fafety. Indeed, the human frame makes fo little refiftance to the free paffage of this fubtle agent, that no other inconvenience will attend a fhock from a common-fized charged jar, than a tranfient difagreeable fenfation.

Touch the knob of a charged jar, no fhock will enfue; but the finger, or part that touches the ball of the jar, will be affected with a fharp fenfation, as if it had been pricked with a needle. The difcharge is filent and without an explofion, when the communication between the two fides of the jar, is made by imperfect conductors.

A charged phial fet upon electric fubftances, may be taken hold of without danger, either by the coating or the wire; a fmall fpark only will proceed from either.

## DR. FRANKLIN'S THEORY OF THE LEYDEN BOTTLE.

Glaſs is ſuppoſed to contain at all times, on its two ſurfaces, a large quantity of the electric fluid, which is ſo diſpoſed, that if you increaſe the quantity on one ſide, the other muſt throw off an equal proportion; or, when one ſide is poſitive, the other muſt be negative. Now, as no more of the electric fluid can be forced on one ſide, than can go off on the other, there is no more in the bottle, after it is charged, than was there before; the quantity is neither increaſed or leſſened on the whole, though a change may be made in its place and ſituation; i. e. we may throw an additional quantity on one of its ſides, if, at the ſame time, an equal quantity can eſcape from the other, and not otherwiſe. That this change is effected by lining parts of its two ſurfaces with a non-electric; through the mediation of which, we are enabled to convey the electric fire to every phyſical point of the ſurface we propoſe to charge, where it exerts its activity in repelling the electric particles naturally belonging to the other ſide; all of which have an opportunity of eſcaping by the lining in contact with this ſurface, which, for that purpoſe, muſt communicate with the earth: when the whole quantity belonging to this ſurface has been diſcharged, in conſequence of an equal quantity thrown upon the other ſurface, the bottle is charged as much as it can poſſibly be. The two ſurfaces are at this time in a ſtate of violence; the inner, or poſitive ſide, ſtrongly diſpoſed to part with 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 cotemporary participation of the other. That notwithſtanding the vicinity of theſe two ſurfaces, and the ſtrong diſpoſition of the electric fluid contained in one of them, to comunnicate its ſuperabundance to the other, and of that to receive it, yet there is an impenetrable barrier between them; for ſo impermeable is glaſs to the electric fluid, (though it permits one ſide of it to act upon the other,) that 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.

THE

THE LEYEDN PHIAL CONSIDERED IN A DIFFERENT POINT OF VIEW.

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

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

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

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

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

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

## COMBINED APPARATUS.

The apparatus represented fig. 49, will be found exceedingly convenient for making a variety of experiments on the Leyden phial. I have endeavoured to combine the parts of it in such manner, as to render the apparatus extensively useful, without being complicated. A is an insulated pillar of glass, which is screwed to the

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

the wooden foot B: all the different parts of the apparatus may be ſcrewed alternately on this pillar. C is an exhauſted tube of glaſs, furniſhed at each end with braſs caps: at the end D is a valve, properly ſecured under the braſs plate; a braſs 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 flaſk, repreſented at E, is called the Leyden vacuum. It is furniſhed with a valve under the ball E; this ball unſcrews, in order to come more readily at the valve: a wire, with a blunt end, projects a little below the neck of the flaſk; the bottom of the flaſk is coated with tin-foil; a female ſcrew is cemented to the bottom, in order to ſcrew it on the pillar A.

F is a ſyringe to exhauſt the air occaſionally, either from the luminous conductor, or the Leyden vacuum.* To do this, unſcrew the ball of the Leyden vacuum, or the plate of the luminous conductor, and then ſcrew the ſyringe in the place of either of theſe pieces, being careful that the bottom of the female ſcrew G, bears cloſe againſt the leather which covers the ſhoulders a b, cd, then work the ſyringe, and in a few minutes

* We have now hit upon a plan of rendering theſe glaſſes ſo perfectly air tight, that the ſyringe is ſuperfluous.

minutes the glasses will be sufficiently exhausted. H and I are two Leyden bottles, each of which has a female screw fitted to the bottom, in order that they may be conveniently screwed on the pillar A. The bottle H is furnished with a belt, that it may be screwed sideways on the pillar A. K and L are two small wires, which are to screw occasionally into either the ball E, the kobs 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.

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

### EXPERIMENT LXXXIV.

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

charging rod, and you will find it had received no charge; which ſhews clearly, that except the electric fluid can eſcape from one ſide of the jar, it can receive none on the other. If there are any points on the coating, or damp on the ſtand, the fluid will be carried off by them, and the jar will receive a ſmall charge. The air which ſurrounds the coating, will alſo ſometimes carry off a ſmall quantity of electricity.

EXPERIMENT LXXXV.

Place the ſame inſulated phial ſo that 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, and the jar will in a little time be charged, by adding electricity to one ſide, and taking it away from the other.

EXPERIMENT LXXXVI.

Screw the phial a, fig. 42, on the inſulated pillar d, and bring 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

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 LXXXVII.

Place the knob of an inſulated bottle in contact with a poſitive conductor, and connect the outer coating with the cuſhion, or a negative conductor, turn the cylinder, and the bottle will be charged with its own electricity; the fluid from the exterior coating being tranſferred to the interior one; the bottle is charged in this inſtance without any communication with the earth.

EXPERIMENT LXXXVIII.

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

EXPERIMENT LXXXIX.

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

EXPERIMENT XC.

Fix a quadrant electrometer to the ball of a Leyden bottle, and charge it negatively; when it has received a full charge the index will ſtand at 90 degrees; then place the bottle

with

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 XCI.

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

EXPERIMENT XCII.

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

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

## EXPERIMENT XCIII.

T V, fig. 46, 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 XCIV.

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 ſtring of ſhot to the bottom of the jar and let it communicate with the table, turn the machine, and a vivid ſpark will be ſeen between each of the ſhot, both within and without the bottle, as if the fire paſſed through the glaſs.

EXPERIMENT XCV.

Hold a phial in the hand which has no coating on the outſide, and preſent 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 XCVI.

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 XCVII.

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

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

The outer coating of the upper jar communicating with the infide of the under one, conveys the fluid from the conductor to the large jar, which is therefore charged pofitively; the upper jar does not charge, becaufe the

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 ſubſtances with the poſitive inſide of the jar B, if the ball of the diſcharging rod remains a ſmall time after the diſcharge on the knob of A, part of the fire of the inſide of A will eſcape, and be replaced by an equal quantity on the outſide from the jar B, by which means A is charged a ſecond time; the diſcharge of this produces the third, and of B the fourth exploſion.

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

A the upper bottle, B the under bottle.

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

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

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

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

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

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

1ft difcharge. Balls of difcharger from coating of B to knob of A.

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

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

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

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

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

1ft difcharge. Balls of difcharger from coating of A to knob of A.

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

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

4th difcharge. From coating of B to knob of A.

Go on thus alternately, and fifteeen, fixteen, or more difcharges may be produced.

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

EXPERIMENT XCVIII.

Screw the bottle H, fig. 49, with the belt fideways on the infulating ftand, as in fig. 48, and charge it pofitively, then touch the knob with a pair of pith balls, thefe will diverge with pofitive electricity; hold another pair to the coating, and they will feparate with negative electricity.

EXPERIMENT XCIX.

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

### EXPERIMENT C.

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

### EXPERIMENT CI.

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

EXPERIMENT CII.

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

EXPERIMENT CIII.

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

EXPERIMENT CIV.

Place a clean, dry, and excited pane of glass, about one foot square, on an insulated box with pith

pith balls, it will caufe the balls to diverge with pofitive electricity, and they will continue to repel each other upwards of four hours in dry air. When the balls come together, remove the glafs, and they will open with negative electricity; replace the glafs, and they will clofe; remove it, and they will open again; and thus alternately as long as any electricity remains in the glafs.

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

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

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

In Chap. VI. we obſerved, that the different appearances of light on electrified points was deemed a criterion of the direction of the electric fluid; that the luminous ſtar ſhews a point in receiving the electric matter, whilſt the luminous bruſh, or cone, indicates that it is proceeding from a point.

We ſhall now examine the ſtate of the different ſides of the Leyden bottle by theſe appearances.

### EXPERIMENT CV.

Screw the jar I on the inſulating pillar, and the pointed wire into the hole g, place another pointed wire at the end of the conductor, bring the knob of the jar near this wire, and then turn the cylinder, a pencil of rays will diverge from

from the pointed wire in the conductor to the knob of the jar, at the same time another pencil of rays will diverge from the point at the bottom into the air. See fig. 50.

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

EXPERIMENT CVI.

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

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

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

EXPERIMENT CVII.

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

EXPERIMENT CVIII.

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

EXPERIMENT CIX.

Fig. 53 is an electric jar, B B the tin-foil coating, C a stand which supports the jar, D a socket of metal which carries the glass rod E; a curved metallic wire, pointed at each end, is fixed to the end of the rod G, which

rod

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 illuminated with a ſmall ſpark, while the upper point of the wire will throw off a pencil of rays, diverging towards the upper ring of the coating.

## EXPERIMENT CX.

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

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

## EXPERIMENT CXI.

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

## EXPERIMENT CXII.

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

this on the insulated stand, with the pointed wire from the bottom. Fig. 56 represents the appearance of the fluid on the points when the bottle is charged negatively, at a conductor loaded with positive electricity.

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

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

## EXPERIMENT CXIII.

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

Place a charged jar on a small glass stand under the receiver of an air pump; as the receiver is exhausting the electric fire will issue from the wire of the phial, in a very luminous pencil of rays, and continue flashing to the coating till the air is exhausted, when the jar will be found to be discharged.

If the phial is charged negatively, the current of fire will appear to have a different direction from that which it had before.

From this experiment we may infer the effects of the atmospheric pressure upon the charge of the Leyden phial, and learn that it is the natural boundary to every charge of electricity we can give; and, consequently, that a phial would contain double the charge, in air doubly condensed, as it does in the common atmosphere, mofphere, fince it would increafe the intenfity of the electric atmofphere.

EXPERIMENT CXV.

Place a fmall lighted taper between the two balls of the univerfal difcharger, then pafs a very fmall charge of a pofitive phial through them, and the flame of the taper will be attracted in the direction of the fluid towards the coating. See fig. 63.

EXPERIMENT CXVI.

The fame fmall charge from a negative bottle will reverfe the appearance.

In both thefe experiments it is neceffary to ufe the leaft charge that can be given, juft fufficient to leap the interruption in the circuit.

EXPERIMENT CXVII.

Place a card on the table of the univerfal difcharger, and bring one of the points under the card, then connect this point with the coating of a jar pofitively 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

the circuit, by bringing a difcharging rod from the laft wire to the top of a bottle, and the electricity will pafs through the upper wire, along the furface of the card, till it comes to the point which is underneath, where it will make a hole in the card, and pafs thro' the wire to the coating of the bottle. See fig. 64.

EXPERIMENT CXVIII.

Four cork balls, A, B, C, D, being placed at equal diftances from each other, from the balls of the difcharging rod, and from the coating of a pofitively charged bottle; on making the difcharge, the ball A next the rod was repelled to B, which was again repelled to C, C remained immoveable, but D flew to the coating of the bottle.

EXPERIMENT CXIX.

Take a card, and paint both fides with cinnabar about the breadth of the finger, fix this card vertically by a little wax on the table of the univerfal difcharger, let the pointed ends of one of the wires touch one fide of the card, and the end of the other wire the oppofite fide; the diftance of the points from each other muft

be

be proportioned to the ſtrength of the charge; diſcharge a jar through the wires, and the black mark, left by the exploſion on the coloured band, ſhews that the electric fluid paſſed from the wire, communicating with the inſide of the bottle, to that which communicates with the outſide, againſt which it makes a hole.

## EXPERIMENTS WHICH SEEM TO MILITATE AGAINST THE RECEIVED THEORY OF ELECRTICITY.

### EXPERIMENT CXX.

Let the ſurfaces of an electric plate be very ſlightly charged and inſulated, let an interrupted circuit be formed, the two powers will be viſible, illuminating the points of the interrupted circuits, and each power will appear to extend farther from the ſurface contiguous to it, the ſtronger the charge is communicated to the plate; but, if the illuminations on each ſide meet, there will immediately follow an exploſion of the whole charge. The length of the interrupted circuit uſed for this experiment was twelve feet.*

* Atwood's analyſis of a courſe of lectures, p. 121.

EXPERIMENT CXXI.

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 CXXII.

If an exhausted receiver be made part of the electric circuit, and the charge should not be sufficient to cause an explosion, an electr c light will appear to proceed in opposite direction from the parts communicating with the negative and positive surfaces.

EXPERIMENT CXXIII.

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

*Fasten a pith ball electrometer by a little wax

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

wax to the outſide coating of a jar, charge the jar ſlightly with poſitive electricity, and ſet it on an inſulated ſtand; the ball will either not diverge, or only a very little; bring the knob of a bottle which is ſtrongly charged with poſitive electricity near the knob of the former, and the balls will diverge with poſitive electricity.

## EXPERIMENT CXXV.

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 CXXVI.

Charge a jar poſitively, and then inſulate it, charge another ſtrongly with negative electricity, bring the knob of the negative bottle near that of the poſitive one, and a thread will play between them; but, when the knobs touch each other, the threads, after being attracted, will be repelled by both. The negative

tive electricity is fome how fuperinduced on the pofitive, and, for a few minutes after they are feparated, both will appear negatively electrified; but, if the finger is brought near the knob of that bottle on which the negative electricity was fuperinduced, it will inftantly be diffipated, a fmall fpark will ftrike the finger, and the bottle will be pofitively charged as before.

One of the pofitions which fupport the Franklinian hypothefis, has been already confidered; we are now at a proper ftage for pointing out fome of thofe deficiencies which have been obferved in other parts of it. To fupport this hypothefis, it is neceffary to maintain THAT GLASS AND OTHER ELECTRIC SNBSTANCES, THOUGH THEY CONTAIN A GREAT DEAL OF ELECTRIC MATTER, ARE NEVERTHELESS IMPERMEABLE TO IT.

This pofition appears contradictory at the the firft view, for it is not eafy to conceive, that any fubftance can be full of a fluid and yet impermeable by it. Efpecially when a confiderable quantity of this fluid is taken from one fide, and added to the other; and what is more furprifing, the thinner the glafs, and the lefs quantity it is capable of containing,

the

the more we are able to put into, and the ſtronger will be the charge.*

The following among other experiments, has been adduced as a ſtrong argument in favour of the impermeability of glaſs. Let a coated phial be ſet upon an inſulated ſtand, and the knob of another coated phial be brought near it; now for every ſpark diſcharged from the prime conductor to the knob of the firſt jar, a ſpark will paſs from the coating of the firſt to the knob of the ſecond: now a common obſerver generally imagines that the fire runs through the glaſs; Dr. Franklin concludes it does not, becauſe there is found a great accumulation of electricity on the inſide of the jar, which manifeſts itſelf when the inſide and outſide are made to communicate with each other. But we cannot from this and ſimilar experiments conclude that glaſs is impermeable, except we ſuppoſe the electric matter to be accumulated on one ſide of the glaſs, and deficient on the other; but this has never yet been proved, it has indeed been ſaid, that if glaſs was permeable to this fluid, it could never be charged, but this reſts wholly on the ſuppoſition, that there is an accumulation of the fluid in bodies poſitively electrified, and

* Encyclopedia Britannica, p. 2687.

a deficiency in thoſe which are negatively ſo.*

Mr. Wilſon, to prove the permeability of glaſs, took a very large pane of glaſs a little warmed, and holding it upright by one edge, while the oppoſite edge reſted upon wax, he rubbed the middle part of the ſurface with his finger, and found both ſides electrified PLUS; he accounted for this from the electric fluid paſſing through the glaſs from his finger. But Dr. Prieſtley ſays this appearance ought to take place on Dr. Franklin's principles; for the fire given to the glaſs by the finger on one ſide, repels an equal quantity from the other, which ſtands as an atmoſphere, ſo that both ſides appear poſitively electrified. Mr. Wilſon tried alſo another experiment, which ſeems more deciſive than the former. Having by him a pane of glaſs, one ſide of which was rough, and the other ſmooth; he rubbed it on one ſide, upon doing this both ſides were electrified MINUS. Dr. Prieſtley attempts to reconcile this to Dr. Franklin's hypotheſis, as the electric fluid, contained in the glaſs, ſays he, was kept equal on both ſides by the common repulſion. If the quantity on one ſide is diminiſhed, the fluid on the other ſide being

* Ibid, p. 2687.

lefs repelled retires INWARD, and leaves that furface MINUS. But furely thofe words militate ftrongly againft the fyftem he means to eftablifh. The quantity of fluid in one fide being diminifhed, that on the other, he fays, RETIRES INWARD. But, into what does it retire? If into the fubftance of the glafs, then is the glafs permeable by it, which is the very thing Dr. P. argues againft.*

Dr. Franklin's theory refts upon the following pofition, "That pofitive electricity is an "accumulation, or too great a quantity of "electric matter contained in a body; and "negative electricity is when there is too "little." Of this however there is not one proof, and all the attempts that have hitherto been made to prove it, are only arguing in a circle, or proving the thing by itfelf. Thus, for inftance, a body electrified pofitively, attracts one that is electrified negatively, becaufe the firft has too much and the other too little electric matter. But how do we know that one has too much and the other too little electricity? Becaufe they attract each other.

Again, it has been proved, that when a jar is electrified pofitively, there is as conftant a ftream of fire from the outfide coating, as

* Ibid, p. 2688.

there is from the conductor to the inside coating. Therefore, it is said, the outside has too little, and the inside too much electricity. But how is this known to be the case? Because in the above experiment one side has too much and the other too little electricity. Thus, in every instance, the arguments for Dr. Franklin's hypothesis return into themselves, and no conclusion can be drawn from them.*

If the reader wishes to investigate this subject further, he may consult Eeles's Philosophical Essays, Wilson's short View of Electricity, Màràt's Rècherches Physique sur l'Electricité, Milner's Observations, Lyons' Observations and Experiments on Electricity, and the Encyclopædia Britannica.

* Ibid, p. 2691.

CHAP.

# CHAP. VIII.

## OF THE ELECTRICAL BATTERY, AND THE LATERAL EXPLOSION OF CHARGED JARS.

TO increaſe the force of the electric exploſion, ſeveral Leyden phials are connected together in a box; this collection is termed an electrical battery. Fig. 65 repreſents one of the moſt approved form.

The bottom of the box is covered with tin-foil, to connect the exterior coatings; the inſide coatings of the jars are connected by the wires b, c, d, e, f, g, which meet in the large ball A; C is a hook at the bottom of the box, by which any ſubſtance may be connected with the outſide coating of the jars; a ball B proceeds from the inſide, by which the circuit may be conveniently 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 refiduum of a charge.

If one jar in a battery is broke it is impoffible to charge the reft till the broken jar is removed *.

To prevent the jars of a large battery breaking at the time of the explofion, it has been recommended not to difcharge a battery through a good conductor, except the circuit is at leaft five feet long; but what is gained on one hand by this method is loft on the other, for, by lengthening the circuit the force of the fhock is weakened proportionably.

I have been informed, that it is very difficult to break by an explofion the jars which are made of green glafs, fabricated at Newcaftle, but have had no opportunity to make any experiments on this glafs myfelf.

The force of a battery may be confiderably increafed by concentrating the fpark from the explofion, which is effected by caufing it to pafs through fmall circuits of non-conducting

* A cracked jar may be made to receive a charge, by taking away the external and internal coatings which were over the crack, fo as to leave a fpace of about one fourth of an inch, between the crack and remaining tin-foil.

fubftances.

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 in diameter, it will be leſs diſſipated, more compact and powerful. If the part round the hole is wetted with a little water, the ſpark, by converting this into vapour, may be conveyed to a greater diſtance, with an increaſe of rapidity, attended with a louder noiſe than common.

Mr. Morgan, by attending to theſe and ſome other circumſtances, has melted wires, &c. with ſmall bottles. I hope he will be induced to communicate this, as well as the reſt of his important diſcoveries, to the public.

## EXPERIMENT CXXVII.

Paſs the charge of a ſtrong battery through two or three inches of ſmall wire, it will ſometimes appear red hot, firſt at the poſitive ſide, and the redneſs will proceed regularly towards the other end.

EXPERIMENT CXXVIII.

Difcharge a battery through a quire of paper, a perforation will be made through it; each of the leaves is protruded by the ftroke 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 paffage, and the hole is fmall. If that part of the paper, through which the explofion is made, is wet, the hole is larger, the light more vivid, and the explofion louder.

EXPERIMENT CXXIX.

The difcharge of a battery through a fmall fteel needle will, if the charge is fufficient, communicate magnetifm to the needle.

EXPERIMENT CXXX.

The difcharge of a battery through a fmall and flender magnetic needle, will generally deftroy the polarity of the needle, and fometimes invert

invert the poles thereof. To ſucceed in this experiment, it is often neceſſary to paſs ſeveral ſtrong charges through the needle before it is removed from the circuit.

It appears, from Beccaria's experiments, that the magnetic polarity, which is communicated to the needle by electricity, depends on the poſition of the needle when the charge is ſent through it, and is not regulated by the direction of the electric matter in entering the needle.

EXPERIMENT CXXXI.

Let a quire of paper be ſuſpended by a line in the manner of a pendulum from any convenient altitude, ſo that its plane may be vertical. Let the largeſt charge from a battery be cauſed to paſs through it, while quieſcent in an horizontal direction perpendicular to the plane, the rods of communication not touching the paper; the phenomena are: firſt, the aperture mentioned in Exp. CXXVIII, the leaves being protruded both ways from the middle: ſecond, not the ſmalleſt motion is communicated to the paper from the force of the diſcharge.

A quire

A quire of the thickeſt and ſtrongeſt paper was made uſe of for this experiment, the height from which it was ſuſpended ſixteen feet. It is an extraordinary appearance on the hypotheſis of a ſingle electric fluid, that a force ſufficient to penetrate a ſolid ſubſtance of great tenacity and coheſive force, ſhould not communicate the ſmalleſt motion to the paper, when a breath of air would cauſe ſome ſenſible vibration in it. But this difficulty is not unanſwerable: for a velocity may be aſſigned, with which a body impinges againſt and paſſes through a pendulum of any given weight and reſiſting force, ſo that a ſmaller angular velocity ſhall be communicated to it, than any that ſhall be propoſed, and we know no limit to the velocity of the electric power or powers. But the other phenomenon, i. e. the oppoſite direction in which the leaves are protruded, tends very much to ſtrengthen the opinion of two oppoſite currents: perhaps either of thoſe phenomena conſidered ſimply, may admit of an eaſy ſolution from the hypotheſis of a ſingle power, when they are taken both together, it ſeems more difficult to reconcile this hypotheſis with matter of fact *.

* Atwood's Analyſis.

## EXPERIMENT CXXXII.

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 fifteen feet, but at twenty feet diftance he could only make fix inches of it red hot, fo that metals refift with confiderable force the paffage of the

the electric fluid, and therefore in estimating the conducting powers of different substances, their length must be particularly attended to.

EXPERIMENT CXXXIII.

Inclose a very slender wire in a glass tube, discharge a battery through this wire, and it will be thrown into globules of different sizes, which may be collected from the inner surface of the tube: they are often found to be hollow, and little more than the scoria of the metal.

Many experiments have been made, in order to try the different conducting powers of metals, by passing the discharge of a battery through them; but it has not yet been determined, whether the greater facility with which some metals are exploded depends on the ease with which the fluid passes through them, or whether it poceeds 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 CXXXIII.

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

EXPERIMENT CXXXIV.

Take two pieces of window glafs, of about 3 by 2 inches, place a flip of brafs or gold leaf between them, leaving the metallic leaf out beyond the glafs at each end; then place the two pieces of glafs in the prefs of the univerfal difcharger, bring the points of the wires E T, EF, fig. 33, to touch the ends of the leaves, and pafs a difcharge through them, which will force part of the metal into the glafs, and ftain it with a colour which differs from the metal that is made ufe of. The metallic leaf fhould be made narroweft in the middle, becaufe the force of the electric fire is in proportion to its denfity, which is increafed when the fame quantity of fire is compelled to pafs through fewer conducting particles.

The

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.

EXPERIMENT CXXXVI.

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 in-formed

formed 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.

Place a piece of very dry white wood between the balls of the univerſal diſcharger, the fibres of the wood to be in the ſame direction with the wires, paſs the ſhock through them, and the wood will be tore to pieces, or run the points into the wood, and then paſs the ſhock through them.

## EXPERIMENT CXXXVII.

If the diſcharge is paſſed under the piece of ivory with the weights upon it, without any glaſs between the piece of ivory and the table GH of the univerſal diſcharger, the weights will be lifted up by the lateral force of the diſcharge; the number of weights muſt be proportioned to the force of the exploſion.

## EXPERIMENT CXXXVIII.

Fig. 66, a, repreſents an inſulated rod, nearly touching a charged jar, b is another inſulated rod, placed in a line with and near to the former; make the diſcharge by the rod e, from which a chain hangs that does not touch the bottom of the jar, and the rod b will receive an electric ſpark, which quits it again almoſt in the ſame inſtant, becauſe the fineſt threads hung upon it will not be electrified by the ſpark.

This electrical appearance, without the circuit of a diſcharging jar, is called the Lateral Exploſion.

If pieces of cork, or any light bodies, be placed 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 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

greater the fuſion, the greater is the diſperſion of light bodies near it.

EXPERIMENT CXXXIX.

If circuits, different in length and of different ſubſtances, form a communication between two charged ſurfaces of an electric plate, it is obſerved, the diſcharge will be made through the beſt conductors, whatever be the length of the others.

2. If circuits of the ſame ſubſtance be different in length, the diſcharge will be made through the ſhorteſt of them.

3. If the circuits be the ſame in every reſpect, the diſcharge will be made through many of them at the ſame time.*

If one circuit conſiſts of undried wood, and is of conſiderable length in compariſon of another which conſiſts of metal, the diſcharge will be made wholly through the latter, unleſs the charge ſhould be very great, in which caſe ſome ſmall part will paſs through the wood.

If a ſhort metallic rod and any part of the human body form two circuits between the ſame charged ſurfaces, the diſcharge will, in general, be made wholly through the metallic rod; but

* Atwood's Analyſis, p. 119, 120.

if the charge is very great, or if the rod is very ſlender, or if it ſhould be very long, in either of theſe caſes the diſcharge may be perceived to paſs through that part of the body which forms one of the circuits.

This will be the caſe when the charge is ſmall, but it may be ſo increaſed as to paſs through both the longer and ſhorter circuits.

I have been informed by a gentleman, that it was his cuſtom to make a variety of circuits for the diſcharge of a large jar or battery; and, that having a ſufficient number of theſe, he could introduce himſelf into one of them, and take his part of the ſhock without inconvenience, it even was not diſagreeable; and he could by this means leſſen the ſenſation almoſt to nothing.

EXPERIMENT CXL.

Mr. Henly made a double circuit, the firſt by an iron bar, one inch and a half in diameter, and half an inch thick; the ſecond, by four feet and a half of ſmall chain. On diſcharging a jar, containing five hundred ſquare inches of coated ſurface, the electricity paſſed in both circuits, ſparks being viſible on the ſmall chain in many places. On making the diſcharge of three jars, containing together ſixteen

teen ſquare feet of coated ſurface, through three different chains at the ſame time, fig. 67, bright ſparks were viſible in them all. The chains were of iron and braſs, of very different lengths; the ſhorteſt ten or twelve inches, the longeſt many feet in length. When thoſe jars were diſcharged through the iron bar before-mentioned, together with a ſmall chain, three-quarters of a yard in length, the whole chain was illumined, and covered throughout with beautiful rays, like briſtles, or golden hair. Having placed a large jar in contact with the prime conductor, and affixed to the coating of it an iron chain, which was alſo connected with a plate of metal, on which was made the diſcharge by the diſcharging rod: this done, he hooked another chain, much longer, and of braſs, to the oppoſite ſide of the jar, and brought the end of it within eight inches and an half of the metal plate. In contact with this end a ſmall oak ſtick was laid, eight inches long, which was covered with ſaw-duſt of 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 CXLI.

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 CXLII.

Take a glaſs tube, the bore of which is about one quarter of an inch, fill it with water, and ſtop the ends with cork, inſert two wires through the corks into the tube, ſo that their ends may nearly touch, make the ends of theſe part of a circuit from a battery; on the diſ-

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

charge,

charge, the water will be difperfed in every direction, and the tube blown to pieces by the difcharge.

The electric fluid, like common fire, converts the water into an highly elaftic vapour. Dr. Franklin, on repeating this experiment with ink, could not find the leaft ftain upon the white paper, on which the tube had been placed. Beccaria paffed the fhock through a drop of water, which was fupported, in the center of a folid glafs ball, between the ends of two iron wires, and the ball was fhivered in pieces by the explofion. On this principle he contrived what he calls an electrical mortar, which will throw a fmall leaden ball to the diftance of twenty feet. It is clear, from feveral of the foregoing experiments, that the electric fluid endeavours to explode in every direction the parts of the refifting fubftances through which it paffes.

### EXPERIMENT CXLIII.

Place a building, which is formed of feveral loofe pieces of wood, on a wet board in the middle of a large bafon of water, let the electric flafh from a battery be made to pafs over the board, or over the water, or over both; the

the water will be ſtrongly agitated, and the building thrown down. The report is louder than when the exploſion paſſes only through the air. The electric fluid endeavours to paſs near the ſurface of the water where it meets with more reſiſtance, than if it is forced to paſs through it. This partly ariſes from the power the electric fluid has of raiſing an expanſive vapour from the ſurface of the water, which drives off the reſiſting air.

A diſcharge paſſed over the ſurface of a piece of ice will leave on it ſmall unequal cavities, exhibiting the ſame appearance as if a hot chain had been placed on it.

A diſcharge ſent through a green leaf tears the ſurface in various directions, leaving an image in miniature of ſome of the effects of 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 pro-

portion

portion as the parts of any body are more readily driven into vapour or duſt, the ſpark will run to a greater diſtance.

EXPERIMENT CXLIV.

If a wire is ſtretched by weights, and a ſhock is ſent through it that will render it red hot, it is found to be conſiderably lengthened after the diſcharge. When the wire is looſe, it is ſaid to be ſhortened by the exploſion.

EXPERIMENT CXLV.

If a long narrow trough of water is made part of the circuit in the diſcharge of a battery, and a perſon's hand be immerged in the water at the time of the exploſion, he will feel an odd vibration in the water, very different from an electrical ſhock. The quick ſtroke from the repercuſſion of the air and the vapour, is communicated to the hand by the water, and the hand receives a ſhock ſimilar to that received by a ſhip at ſea during an earthquake.

EXPERIMENT CXLVI.

Place a plain piece of metal between the points

points of the univerſal diſcharger, paſs ſeveral exploſions of a battery through the wires, and the diſcharges will gradually form on the metal different circles, beautifully tinged with the priſmatic colours. The circles appear ſooner, and are cloſer to each other, the nearer the point is to the ſurface of the metal. The number of rings, or circles, depend on the ſharpneſs of the point; the experiment therefore ſucceeds better if a ſharp needle is faſtened to one of the points of the diſcharger.

Several very curious experiments were made by Dr. Watſon and others, to aſcertain the diſtance to which the electric ſhock might be conveyed, and the velocity with which it moves. In his firſt experiment, the ſhock was given and ſpirits fired by the electric matter which had been conveyed through the river Thames. In the next experiment, the electric fluid was made to paſs through a circuit of two miles, croſſing the New-river twice, going over ſeveral gravel-pits, and a large field. It was afterwards conveyed through a circuit of four miles. It paſſed over theſe ſpaces inſtantaneouſly as to ſenſe. This ſenſible 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

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 the 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 CXX, CXXI, CXXII 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

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 the chain, we should find they did not follow the order *o*, *n*, *m*, *l*, but were felt simultaneously, first at the two extremities *o* and *a*, then at *n* and *b*, *m* and *c*, &c. advancing towards the middle of the chain. Agreeable to this, if the bottle is small, the longer the circuit is made, those who are furthest from the extremities find the shock weaker.

To

To render this account more clear, feparate the circuit, and form on a dry floor two rows, *a*, *b*, *c*, *d*, — *e*, *f*, *g*, *h*, interrupted in the middle; let *e* grafp the bottle by the outfide, and *a* excite the difcharge by touching the knob of the bottle; now, if the electric fire was obliged to take the fhorteft courfe to come to the exterior and negative furface, it ought to defcend to the feet of *e*, pafs over the boards to the feet of *e*, and then through him to the outfide, without acting on *f*, *g*, *h*, which would be out of its circuit. But, contrary to this, the fluid goes out of the direct courfe, to follow that of the conducting perfons, which afford it a proper receptacle, and comes to the outfide by another fource. The fire which goes from the infide from *e* to *f*, *g*, *h*, gives them a fenfible fenfation in their hands and their heels, fhewing itfelf by a fpark, if the hands and the feet are feparated a little from each other, and finifhes by diffipating itfelf in the common refervoir. In the fame manner *d*, who firft gives the fire to the outfide, receives it fucceffively from *c*, *b*, *a*, who all draw it in from the floor. The ftream therefore which proceeds from the knob of the bottle, paffing through the conducting fubftance, lofes itfelf in the general fource; while, from the fame fource, 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 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.

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, that the ſurpriſing phenomena 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 theſe conductors;

tors; and among thoſe who underſtand the ſubject well, it has been diſputed, whether the preference ſhould be given to a conductor with a pointed end, or to one which has an obtuſe termination.

The experiments which have been made on this ſubject are very numerous; but the greater part appear to me very inconcluſive, and preſent only a very partial view of the ſubject. Among theſe we may reckon thoſe in which different ſubſtances have been introduced, to repreſent the action of conductors on clouds; ſince the various ſubſtances made uſe of in theſe experiments, were cohering maſſes, in which they differ eſſentially from the clouds which float in the air. It appears alſo, from many inſtances, that lightening does not paſs in one undivided tract, but that neighbouring bodies carry off their ſhare, according to their quantity and conducting power.

A pointed conductor, which communicates with the earth, has not any particular power of attracting electricity, and acts only as any other conducting ſubſtance, which does not reſiſt the paſſage of the electric fluid.

It is true, that electricity paſſes with more eaſe from an electrified body to a conductor which is pointed, than to one which is flat or globular;

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 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.

Beſides, the electric powers muſt be ſeparated before any body can be electrified; and the point muſt be in a ſtate to give one kind of electricity, before it can receive the other.

N They

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

They cannot act beyond the electric atmosphere of the body to which they are presented, and their action is differently modified by the state of the air.

Fig. 68 represents the gable end of a house, fixed vertically on the horizontal board F G; a square hole is made in the gable end at h i, into which a piece of wood is fitted; a wire is inserted in the diagonal of this little piece; two wires are also fitted to the gable end; the lower end of one wire terminating at the upper corner of the square hole; the top of the other wire is fixed to 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 CXLVII.

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 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 communica-
tion

tion 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.

EXPERIMENT CXLVIII.

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

this wire hung a chain, twelve 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 CXLIX.

The same gentleman connected a jar, containing 509 square inches of coated surface, with the prime conductor; see fig. 68. If the jar was so charged as to raise the electrometer to 60°, by bringing the ball on the wire of the thunder house, to half an inch distance from that connected with the prime conductor, the jar would be discharged, and the piece in the thunder house thrown out to a considerable dis-distance. Using a pointed wire as a conductor

to

to the thunder houfe, inftead of the knob, the charge being the fame, the jar was difcharged filently, though fuddenly, and the piece was not thrown out.

EXPERIMENT CL.

He afterwards made a double circuit to the thunder houfe; the firft by a knob, the fecond by a fharp pointed wire, at an inch and a quarter diftance from each other, but exactly the fame height. The charge being the fame, the knob was firft brought under the prime conductor, which was half an inch above it, and followed by the point at an inch and a quarter diftance, yet no explofion fell upon the ball, as the point drew off the charge filently, and the piece in the thunder houfe remained unmoved.

EXPERIMENT CLI.

He infulated a large jar, and connected, by chains, with the external coating, on one fide, a knob, on the other a fharp pointed wire, both being infulated, and ftanding five inches from each other, (fee fig. 70,) and placed an infulated copper ball, eight inches in diameter, fo as to ftand exactly at half an inch diftance both from the knob and the point; the jar was them 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 CLII.

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

EXPERIMENT CLIII.

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 CLIV.

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 reprefents an oval board, three feet long and two feet broad, coated on both fides with tin-foil, and fufpended by filk lines from a double hook; this turns on an axis, which is faftened to one arm of a nice balance, and counter-poifed at the other arm by a weight; part of the table underneath the board, is to be covered with tin-foil, and communicate to the floor by a chain.

## EXPERIMENT CLV.

Connect the pendulous board with the prime conductor by a fmall wire, a few turns of the machine will electrify the apparatus. When this experiment was made, the board was attracted by the table at fifteen inches diftance, and difcharged itfelf with a ftrong fpark. The fame 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 difcharging itfelf by a fpark. If a point is fixed on the board inftead of a knob, the pendulous board, though it begins to approach, ftops at about four or five inches from the table, and it will not approach nearer, or give a fpark: a fmall light is feen 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 fame as before. The counterpoife was now held, that the board might not defcend till it had received a full charge: when fet at liberty, it was not only attracted by, but alfo gave a loud explofion on the point, infomuch, that the tin-foil round it was ftained by the overflowing of the fire.

The following experiment is extracted from "An Account of Experiments made at the Pantheon, on the Nature and Ufe of Conductors," by Mr. Wilfon. It was made in order to point out what he deemed erroneous in an experiment of Mr. Henly, which is the 151ft of this Effay.

The circuit of communication was divided into two parts:

A bent rod of brafs, with a ball of the fame metal, three quarters of an inch in diameter, fcrewed on to the upper extremity of it, and a copper ball, five inches in diameter, fcrewed on to the lower end, forms one of the parts. This part was fupported by a ftand of wood that had a cap of brafs at the top, into which the brafs rod was occafionally fcrewed.

The

The other part of the circuit consisted of a brass rod also; one end of which branched out in the form of a fork, with two prongs that pointed towards the center of the copper ball; and those prongs were so constructed, that either of them could be made longer or shorter, just as the experiment required. On the end of one of the prongs was fixed a ball of brass, three quarters of an inch in diameter, and on the other a sharp steel point or needle. The shoulder of this fork screwed into a small plate of iron, that was fixed on the inside of a wooden vessel, which contained the greatest part of a cylindrical glass jar, twelve inches three quarters high, and about four inches in diameter. This glass was rather thick than otherwise, and the coating of it (which was tin-foil) measured nearly 144 square inches on each surface. Besides this coating, part of the inside of the wooden vessel was coated also with tin-foil, for the purpose of making a secure communication between the iron plate and the outward coating of the jar. Within the jar itself, was fitted a cylinder of wood, that was covered with tin-foil also, to make a communication between the inside coating of the glass and a brass rod, that was fixed upright in the center of the wooden cylinder. This upright rod having a ball of brass at the end,

end, three quarters of an inch in diameter, was bent towards the firſt part of the circuit; ſo that the two balls A and B, in fig. 73, being upon a level, looked towards each other, but were placed from time to time at different diſtances, as occaſion required; and thus anſwered the purpoſe of an electrometer.

Mr. Wilſon began the experiments where the electrometer was ſtruck at the greateſt diſtance, and then adjuſted the diſtances of the ball accordingly; ſo that if the point was ſtruck when they were adjuſted, the moving of the ball the thirty-ſecond part of an inch would occaſion the ball to be ſtruck in preference to the point, and *vice verſa*. Afterwards he leſſened the ſtriking diſtance of the electrometer, in every experiment, till he attained the leaſt diſtance.

Upon reverſing part of the apparatus, and fixing the ball to the bottle, and the fork to the ſtand, all thoſe experiments were repeated again; the copper ball being put neareſt to the glaſs, in the place of the forked part, and the forked part in the place of the copper ball. This ſet of experiments being compleated, he made others, where the ball only was oppoſed; and after them, where the point only was oppoſed 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 conſtitute the electrometer; and the numbers oppoſite to the words *ball* and *point*, ſhew the greateſt diſtance at which they were reſpectively ſtruck.

| | *Ball and Point oppoſite the Leyden Phial.* | | *Ball only.* | *Pt. only.* | *Apparatus reverſed.* | *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 |

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

EXPERIMENT CLVI.

If an interruption is made in each of two fimilar circuits, which form communications between the charged furfaces of an electric plate, and if the fpace of air in one of the interruptions is terminated by points, and in the other by balls, the difcharge will be made through the circuit of which the points make a part, although the length of the interrupted fpace of air is confiderably greater than that in the other circuit.

Before any difcharge takes place, the two powers are fufpended on the oppofite furfaces of the charged electric.

An electric plate may be difcharged two ways, either filently in fome fenfible portion of time, or by explofion in an inftant: in either cafe experiments abundantly fhew that *cæteris paribus*, the difcharge will be made through a pointed body in preference to a round termination.

When a pointed body is prefented to any charged furface, a cylindrical plate of air, of evanefcent diameter, is charged with the contrary electricities ftrongly attracting each other through it; and the quantity of air being fo fmall, ſmall, there will be little reſiſtance to their union; the diſcharge will be made by exploſion in preference to the gradual diſcharge, according as the oppoſite ſurfaces (the pointed body and the ſurface oppoſed to it) are larger, as they are nearer each other, and as the charge is greater; for it will be obſerved that a point, or very ſmall ſpherical termination, which is in a phyſical ſenſe a point, will diſcharge any quantity of electricity ſilently and gradually without exploſion, while it is at a ſufficient diſtance from the oppoſite charged ſurface: by bringing it nearer, the method of diſcharge will be altered; which will now be a ſucceſſion of ſmall exploſions very quickly following each other. The reaſon of this ſeems to be, that when the charged ſurfaces are very near, there is not ſufficient time for the contrary powers to unite gradually, nor ſufficient room in which they may be diffuſed among the ſurrounding air.

This is confirmed by again removing the two oppoſed ſurfaces to ſuch a diſtance that the diſcharge may be made gradually; in this caſe if the parts of the apparatus are ſo diſpoſed by any kind of contrivance, that the diſcharge muſt neceſſarily be made ſuddenly, the method of diſcharge will be again altered, becoming now

now a fucceffion of explofions inftead of a gradual current between the oppofed furfaces: this fuddennefs of the difcharge may be effected by a proper ufe of interruptions in the circuit; it may alfo be caufed by motion; if either furface be moved brifkly toward the other, the explofion of the charge will be promoted.

Elevated conductors applied to buildings as a fecurity from the effects of lightning, will contribute to difcharge the electricity from a cloud that paffes over them: and a greater quantity of the difcharge will pafs through a pointed conductor, than through one which is terminated by a ball; but whether the difcharge will be made by a gradual current, or by explofion, will depend on the fuddennefs of the difcharge, on the proximity of the cloud, its motion, and the quantity of the electricity contained in it. If a fmall cloud hangs fufpended under a large cloud loaded with electric matter, pointed conductors on a building underneath will receive the difcharge by explofion in preference to thofe terminated by balls, the fmall cloud forming an interruption which allows only an inftant of time for the difcharge. If a fingle electric cloud is driven with confiderable velocity near to a pointed conductor, the charge may be caufed to explode upon it by the motion of the charged body. In other cafes, pointed conductors contribute to difcharge a thunder cloud gradually without explofion.

Mr. Wilfon's experiments, publifhed in the Philofophical Tranfactions 1778, have contributed greatly to explain the effects of points in difcharging the electric matter.

If a conical pointed body were inferted into a fimilar hollow cone, formed into an electrified folid, the furfaces of the two cones being equi-diftant, no greater difcharge of the electrics would follow, than if the two conical furfaces had been plain, and oppofed to each other at the fame diftance.

### EXPERIMENT CLVII.

If two electric plates be charged, and a communication formed between the pofitive fide of one, and the negative fide of the other, no difcharge will follow; unlefs a communication be formed between the other two furfaces at the fame time.

The natural electricity in the atmofphere is frequently difcharged in this manner: Two

clouds

clouds being electrified with oppofite powers, the furfaces of the earth immediately under them are likewife electrified with powers contrary to thofe in the clouds above them; and the moifture of earth forming a communicacation between the two contiguous charged furfaces, whenever the two clouds meet, there will follow a difcharge, both of the clouds and furfaces on the earth oppofed to them. If the earth fhould be dry, and confequently afford a refiftance to the union of the two electricities accumulated on or under its furface, there will follow an explofion in the earth as well as in the atmofphere, which will produce concuffions and other phœnomena which have frequently been obferved to happen in dry feafons, particularly in thofe climates which are the moft liable to ftorms of thunder and lightening.

## OBSERVATIONS ON THE ACTION OF CONDUCTORS.

"Ever fince the difcovery of the identity of electricity and lightening, it has been allowed by all parties, that conductors of fome kind are in a manner neceffary for the fafety of buildings in thofe countries where thunder ftorms are very frequent. The principle on which

 they

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 metalline rod, in preference to a passage of any other kind. But it is necessary to observe here, that electricity never strikes a body merely for the sake of the body itself, but as by means of that body it can arrive at the place of 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 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,

earth, prefented to the prime conductor, than the whole effort of the electricity is directed againft that body; not merely becaufe it is a conductor, but becaufe 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 prefented. That this is the cafe we may eafily fee, by prefenting the fame conducting fubftance in an infulated ftate to the prime conductor of the machine, when we fhall find only a fmall fpark will be produced. In like manner, when lightning ftrikes a tree, a houfe, or a thunder-rod, it is not becaufe thefe objects are high, or in the neighbourhood of the cloud, but becaufe they communicate with fome place below the furface of the ground, againft which the impetus of the lightening is directed, and at that place the lightning would certainly arrive, though none of the above-mentioned objects had been interpofed.

"When the atmofphere begins to be electrified, either negatively or pofitively, the earth, by means of the inequality and moifture of its furface, but efpecially by the vegetables which grow upon it, abforbs that electricity, and quickly becomes electrified in the fame manner with the atmofphere; this abforption, however, ceafes in a very fhort time, becaufe it cannot be continued without fetting in motion the whole of the electric matter contained in the earth itfelf. Alternate zones of pofitive and negative electricity will then begin to take place below the furface of the earth, for reafons given in the courfe of this effay. Between the atmofphere and one of thefe zones the ftroke of lightening will always be. Thus, fuppofing the atmofphere is pofitively electrified, the furface of the earth will, by means of trees, &c. quickly become pofitively electrified alfo, we will fuppofe to the depth of ten feet: the electricity cannot penetrate further, on account of the refiftance of the electric matter in the bowels of the earth. At the depth of ten feet from the furface, a zone of negatively electrified earth begins, and to this zone the electricity of the atmofphere is attracted; but to this it cannot get, without breaking through the pofitively electrified zone, which lies uppermoft, and fhattering to pieces every bad conductor which lies in its way. We are therefore fure, that in whatever place the outer zone of pofitively electrified earth is thinneft, there the lightening will ftrike, whether a conductor happens to be prefent or not. If there is a

con-

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 poſitive 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, Beccaria 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, and a few bricks moiſtened with the rain to the ſide of the metalline conductor, than

through

through the forty-ſix feet of air to its point, for the former was the way in which the lightening actually paſſed.

"The zig-zag kind of lightening is the moſt dangerous, becauſe it muſt overcome a very violent reſiſtance of the átmoſphere, 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 balls fly off ſlowly, and have no particular deſ-

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 battery paſs for a conſiderable way over the ſurface of raw fleſh, water, &c. In theſe caſes, if, while the electric flaſh paſſed over the ſurfaces of the fleſh, it had been poſſible to interrupt the metallic circuit by taking away the chain, the electric matter diſcharged would have been preciſely in the ſituation of one of the above-mentioned fire-balls; i. e. it

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

and ſteeples in the neighbourhood have eſcaped *. The reaſon of this is, that in thunderſtorms 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,

* 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.

&c.

&c. which grow 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.

## CHAP. X.

### TO CHARGE A PLATE OF AIR.

As air is an electric, it will receive a charge like all other electric fubftances. To this property may be afcribed many of the phœnomena which are obferved in the courfe of the common electrical experiments; for the air which furrounds an electrified non-electric is always in fome degree charged with the fluid, and thus acts upon the atmofphere of the electrified conductor, not only by its preffure, but alfo by its acquired electric powers; and that it pervades the air to a confiderable diftance is evident, from the different methods by which the air of a room may be electrified.

Cover two large boards with tin-foil; fufpend one by filk ftrings from the cieling, and then connect it with the conductor; place the other board parallel to the former, on an infulating ftand that may be eafily raifed or lowered, to regulate the diftance of the plates from each other. Or place the boards in a vertical fituation, on infulating ftands of the fame height. In moft cafes this form will be found the moft convenient. Thefe boards may be confidered

as

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

EXPERIMENT CLVIII.

Connect the upper board with the positive conductor, and the other with the ground; turn the cylinder, and the upper one will be electrified positively, and the under one negatively; the space of air between the two plates acts as a plate of glass, it separates and keeps asunder the two electric powers. Touch the negative plate with one hand, and the upper one with the other, and a shock will be received similar to that from the Leyden phial.

The electric shock will always be felt whenever a quantity of the fluid passes through any body in an instantaneous manner, and the force of the shock will be proportional to the quantity of electricity accumulated, and the ease with which it can escape; for the whole energy of the electricity depends on 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

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 thunderſtorm. 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 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 CLIX.

Turn that ſide of the upper board on which the gilt leather is paſted towards the lower one; place one or two ſmall metal hemiſpheres on the lower board; connect the upper board with the poſitive conductor, and the lower one with that which is negative, put the machine in action, and the upper board will diſcharge the whole of its contents on one of the hemiſpheres in a ſtrong flaſh, attended with a ſmart exploſion; vivid coruſcations of electric light will be ſeen darting in various directions on 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 CLX.

Place the wire, fig. 10, with the feathers tied to it in the middle of one of theſe large boards, their divergence will not be near ſo much in this ſituation as when they are at the edge of the board. If a piece of down or a feather is placed near the edge of the board, it will fly off to the neareſt non-electrified body; but, if it is placed in the middle, it will be a conſiderable time before it will move, and it will ſcarcely ſhow any ſigns of attraction.

EXPERIMENT CLXI.

Place bran, or ſmall pieces of paper, near the center of the lower board; when the machine is put in action theſe will be alternately attracted and repelled with great rapidity, and agitated in an amazing manner. A pleaſing variation is made in this experiment by taking off the chain from the lower board, and now and then touching it with the hand; touch both boards at the ſame time and the motion ceaſes. But the moſt ſurprizing appearance in this experiment is, that ſometimes, when the electricity is ſtrong, a quantity of paper or bran will accumulate in one place, and form a kind of column between the boards, it will ſuddenly acquire a ſwift horizontal motion, moving like a whirling pillar to the edge of the boards, and from thence fly off, and be ſcattered about the room to a conſiderable diſtance.

### EXPERIMENT CLXII.

Take two phials, the one charged poſitively, the other negatively, place them on the inſulated board, but as far from each other as the board will permit; inſert a range of candles in a piece of wood, about two inches diſtance from each other, ſo that the flame of each may be exactly parallel; when theſe candles are quickly introduced between the knobs of the phials, the ſpark will be ſeen to dart through all of them, and will have the appearance of a line of fire, variegated in a thouſand different curves.

CHAP.

# CHAP. XI.

## OF THE ELECTROPHORUS

FIG. 73 repreſents an electrophorus. This inſtrument was invented by Mr. Volta, of Coma in Italy.* It conſiſts of two plates of a circular form, the under plate is of braſs covered over with a ſtratum of an electrical ſubſtance, generally of ſome negative electric, as wax, ſulphur, &c. the upper plate is of braſs, with a glaſs handle ſcrewed on the center of its upper ſurface.

Reſinous electrics generally ſucceed better for an electrophorus than thoſe made only of glaſs, not only as they are leſs affected by the humidity of the air, but as they ſeem to have the power of retaining longer the electricity which is communicated to them.

To uſe this apparatus, firſt excite the under plate c, by rubbing its coated ſide with a piece of clean dry flannel, or hare-ſkin; when this plate is well excited, it is to be laid on the table with the electric uppermoſt. Secondly,

 place

* Mr. Wilck, in Auguſt, 1762, contrived a reſinous apparatus, to which he gave the name of a perpetual electrophorus. 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 CLXIII.

Mr. Achard placed horizontally a circular plate of glass, which was about two tenths of an inch in thickness, and one foot in diameter, on a tin plate, which only touched the glass in a few places; having excited the upper surface of the glass, it produced all the effects of the electro-

electrophorus; from whence he infers, that it is not neceſſary that the inferior metallic plate ſhould touch exactly in all its ſurfacethe electric coating.

EXPERIMENT CLXIV.

He inſulated, in a horizontal poſition, a plate of glaſs of one foot diamtier, 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, it retains all its properties.

EXPERIMENT CLXV.

Having excited the upper ſurface of an electrophorus of wax, he placed the upper plate on it, and after ſome time lifted it off by 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; which proves, that the electrophorous cannot render the upper plate electric, unleſs it is touched by a body which is capapable of giving or taking electricity from it.

### Experiment CLXVI

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

### Experiment CLXVII.

Place one of the ſmall braſs conductors with its pith balls on the upper plate, and then put them both on the electrophorus, the balls will immediately ſeparate a little; touch the upper plate with the finger and the divergence ceaſes; but

but on lifting this plate from the electrophorous by its glafs handle the balls diverge with great force, forming a very large angle ; on taking a fpark from the plate they immediately clofe. The feparation of the balls fhews clearly that the upper plate either abforbs a quantity of electricity, or imparts a portion of its natural fhare to the under one; it alfo fhews that the former, as foon as it is laid on the electrophorus, acquires a fmall degree of electricity, which it lofes on being touched with the finger; but it again becomes electrical when it is feparated from the electrophorus.

### EXPERIMENT CLXVIII.

Infulate an electrophorus, and fufpend a pith ball by a linen thread, in fuch a manner that it may be about one quarter of an inch from a piece of metal which is connected with the bottom plate; the ball does not move when the upper plate is laid on the electrophorus, but when this is touched by the finger the ball is attracted. As foon 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 alfo attracted if the

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 befere it is placed on the electrophorus.

EXPERIMENT CLXIX.

Electrify the under ſide of the electrophorus, by connecting the under plate with the conductor of a machine; the upper plate will give ſtrong ſparks to the hand, or any other non-electric. Touch the upper plate with one hand, and the under one with the other, a ſhock will be received. The ſame effect is produced, if the upper plate is electrified by the machine. See fig. 74.

EXPERIMENT CLXX.

Inſulate an electrophorus which is not excited, and place the upper plate upon it, then electrify the under plate by a chain from the prime conductor; take a ſpark from the chain, and the electrophorus acquires all the properties which are given to it by exciting the upper ſurface.

### EXPERIMENT CLXXI.

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

### EXPERIMENT CLXXII.

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

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

### EXPERIMENT CLXXIII.

Mr. Achard placed the upper plate on an excited electrophorus, and a cube 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 expriment, and touching

touching the upper plate before the cube was taken off, it did not appear in the leaſt electrical.

### EXPERIMENT CLXXIV.

By examining the electrophorus with ſmall pith balls, we find,

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

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

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

The electrophorus may be conſidered as formed of ſeveral horizontal ſtrata; ſo that when the upper one is excited, either by friction or communication, it is inſulated by the inferior ſtrata. Now all inſulated electrics preſerve their electricity a conſiderable time, and it is from that cauſe that the electricity of the electrophorus 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 electrophorus, 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 electrophorus 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 expriments 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 electrophorus) as it is a caſe which admits of a ſome-

what

what 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 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 CLXXV.

Place a piece of metal on an excited electrophorus, it may be of any shape; a pair of triangular compasses are very convenient for this purpose. Electrify the piece of metal with the power which is contrary to that of the electrophorus, and then remove it by means of some electric, and afterwards sift upon the electrophorus some finely powdered resin, which will form

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 CLXXVI.

To recover the force of an electrophorus by itſelf. Place the metallic cover on the reſinous cake, touch it as uſual; then take it up, and diſcharge it on the knob of a Leyden phial; repeat this operation ſeveral times, and then place the bottle on the cake, and move it over its ſurface, holding the bottle by the knob; this will augment the force of the electrophorus and by reiterating the operation it will become very powerful.

EXPERIMENT CLXXVII.

Inſulate a metal quart mug, and ſuſpend a pair of ſmall pith balls by ſilk, ſo that the whole of the electrometer may be within the mug, electrify the mug, and the electrometer will

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 CLXXVIII.

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 CLXXIX.

Connect a pair of pith balls with an inſulated metal veſſel, in which a metal chain is placed, raiſe the chain by means of a ſilk thread, and the divergence of the balls will diminiſh in proportion as the chain is raiſed and diſplayed; ſhewing, that the electricity is rarified, and 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 CLXXX.

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 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 electrophorus used for this purpose may with propriety be termed a micro-electrometer, or condenser of electricity.

Whenever the atmospherical conductor gives sufficient signs of electricity, then the condensing apparatus becomes useless. For when the electricity is strong, it often happens that part of the electricity of the metal plate is impressed upon the other, in which case the apparatus acts as an electrophorus, and becomes unfit for our purpose.

The apparatus adapted for this purpose consists of the upper plate of an electrophorus, and a semi-electric, or an imperfect conducting plane, which will only hinder in a certain degree the passage of the fluid. Many conductors of this kind may be formed; such as a

clean

clean dry marble ſlab, a plate of wood, covered with a coat of varniſh, &c. The ſurface of thoſe bodies not contracting electricity, or if any ſhould adhere to them it ſoon vaniſhes, on account of their ſemi-conducting nature; for which reaſon they cannot anſwer the end of an electrophorus, but are fit to be uſed as condenſers of electricity.

Care ſhould be taken however in chooſing this plane, that it be not of too free a conducting nature, nor likely to become ſo by uſe, it being abſolutely neceſſary that the electricity ſhould find a conſiderable reſiſtance in pervading 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 electrophorus is preferable to all bodies unprepared.

The worſt ſort of marble, if coated with copal, amber, or lac-varniſh, and then kept in an oven for a ſhort time, will anſwer very well, even without previouſly warming for the experiment.

This, in fact, it may be ſaid, is returning to the electrophorus: as marble, wood, &c. varniſhed, if they are hot, may be excited by a very ſlight friction, and ſometimes by only laying the metal plate on them; to prevent which they ſhould be uſed without warming.

The advantage plates of this kind have over the common electrophorus are, 1. That the varniſh is always thinner than the common reſinous ſtratum of an electrophorus; and 2. That the varniſh acquires a ſmoother and plainer ſurface: hence the metal plate can with more advantage be adapted to it.

Any ſort of plane, covered with dry and clean oil-cloth, or oiled-ſilk, or ſattin, and any other ſilk 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,

metal, a book, or any other conductor with a flat ſurface.

Nothing more is requiſite in theſe experiments than that the electricity, which tends to paſs from one ſurface to the other, ſhould meet with ſome reſiſtance or oppoſition in one of the ſurfaces, as will be evident in the ſecond part.

It is immaterial whether the non-conducting or ſemi-conducting ſtratum be laid upon one or the other of thoſe planes; all that is neceſſary is, that they ſhould coincide together, which renders it proper to uſe two planes that have been ground together, and one of them varniſhed. A ſingle metal plate, covered with ſilk, with three ſilk ſtrings faſtened to it by way of handle, may be conveniently uſed for ordinary experiments.

To uſe the apparatus, the upper metal plate muſt be placed upon the unelectrified plate and in perfect contact with it.

The plates being thus placed, let a wire, communicating with the conductor, be brought to touch the metal plate of the electrophorus, and that only.

The apparatus being left in that ſituation a certain time, will acquire a ſufficient quantity of electricity, but very ſlowly.

Remove the communicating wire from the metal plate, and, by means of its insulated handle, separate it from the under one; it will now attract a thread, electrify an electrometer, and, if it is strong, will give sparks. &c. though the atmospherical conductor shewed no, or only small, signs of it.

It is not easy to determine the exact time necessary for this apparatus to remain in contact with the conductor, as it will depend on many circumstances; for, if there are no signs of electricity in the conductor, it will require eight or ten minutes, but if it attracts a fine thread, as many seconds will be found sufficient.

It is difficult also to determine the precise degree to which the electricity may be condensed, or how much the electrical 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 electrophorus, as as not only to actuate an electrometer, but even dart ſtrong ſparks. But if the electricity of the atmoſpherical conductor is ſtrong enough to afford ſparks, or to raiſe the index of the electrometer to 5 or 6 degrees, then the receiving plate of the electrophorus, according to this method, will raiſe 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 eharged, and then difcharged by touching its coated fides with the difcharging 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 condenfer, (fituated upon an imperfect conducting plane) and immediately take up the plate, it will be found to give very confpicuous figns of electricity. But, if juft fufficient charge is left in the phial to attract a fine thread, and the metal plate is then brought to touch the knob for a moment, it will, when lifted up give a ftrong fpark, and if touched again, a fecond fcarce fmaller than the former; and thus, fpark after fpark may be obtained for a long time.

This method of producing fparks, by means of a phial which is not charged fo high as to give fparks of itfelf, is very convenient for various pleafing experiments; as to fire or light the inflammable air-piftol, or lamp; efpecially when a perfon is provided with one of thofe phials contrived by Mr. Cavallo, which, when charged, may be carried in the pocket a long time. Thefe phials, as they retain a fenfible charge for feveral days, will retain an infenfible one for weeks and months; or, fuch a one as cannot eafily be difcovered without the condenfer, in which cafe it becomes more than fenfible

ble, 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) 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 electicity.

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 elecan electrometer, it will be found confiderably electrified, although the body rubbed may have acquired little or no electricity. The quality, whether pofitive or negative, may eafily be afcertained, fince the electricity of the metal plate muft be the contrary of that body on which it was rubbed. Mr. Cavallo made ufe of this method to difcover the electricity of many bodies. But ftill a better method may be ufed in cafe the bodies to be examined cannot eafily be adapted to the metal plate, viz. The metal plate being laid on the imperfect conducting plane, the body to be tried is rubbed againft, or repeatedly ftroaked upon it, which done, the plate is taken up and examined by an electrometer. If the body tried is leather, a ftring, cloth, velvet, or other imperfect conductor of the like fort, the plate will certainly be found electrified and incomparably more by this means than if it were ftroaked by the fame bodies, whilft ftanding infulated in the air. In fhort, by either of thofe 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 fome electricity. Electricity may

often

often be obtained by ſtroaking the plate with the naked hand.

The metal plate has a much greater power to retain electricity when it lies upon a proper plane, as mentioned in the foregoing experiments, than when quite inſulated.

It is eaſy to comprehend, that where the capacity of holding electricity is greateſt, there the intenſity of the electricity is proportionably leſs, for it will then require a greater quantity to raiſe it to a given degree of intenſity; ſo that the *capacity* is inverſely as the *intenſity*; by which we mean, that endeavour, by which the electricity of an electrified body tends to eſcape from all parts of it; to which tendency or endeavour, the electrical phœnomena of attraction and repulſion, and eſpecially the degree of elevation of an electrometer correſpond.

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

## EXPERIMENT CLXXXI.

Take two metal rods of equal diameter, the one a foot, the other five feet long; let the firſt

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 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

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

## Experiment CLXXXII.

Take the metal plate of an electrophorus, hold it by its handle in the air, and electrify it so, that the index of an electrometer annexed to it may be elevated to 60°, then lower the plate by degrees to a table, or other plane conducting surface, the index will gradually fall

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

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 CLXXXIII.

Electrify two flat conductors, either both poſitively or negatively, then bring them gradually towards each other, and it will appear, by two annexed electrometers, that the nearer they approach each other, the more their denſities will increaſe, as all elaſtic bodies re-act in proportion as they are acted on; which ſhews that either of the two *conjugate* powers has a much leſs capacity to receive more fluid now than when ſingly inſulated, and out of the influence of the other. This experiment explains, why the tenſion of the electric atmoſphere on an electrified conductor is greater when it is contracted into a ſmaller bulk; and alſo, why a long extended conductor

ductor 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 CLXXXIV.

Electrify one of theſe flat conductors poſitively, the other negatively, and the effects will then be juſt the reverſe of the preceding, viz. the intenſity of their electricities will be diminiſhed, becauſe their capacities, or their power and facility of expanding are increaſed the nearer the conductors come to each other.

Apply the explanation of this laſt experiment to that mentioned before, viz. the bringing the electrified metal plate towards a conducting plane, which is not inſulated; for, as this plane acquires a contrary electricity, it follows that the intenſity of electricity in the metal plate muſt be diminiſhed, and the annexed electrometer is depreſſed according as the capacity of the plate is increaſed, or as the denſity of its atmoſphere is diminiſhed; and conſequently the

the plate in that ſituation is capable of receiving a greater quantity of electricity.

This will be rendered ſtill clearer by the following experiment.

## EXPERIMENT CLXXXV.

Inſulate the conducting plane whilſt the other electrified plate is upon it, and afterwards ſeparating them, both the metal plate and conducting plane, which may be called the inferior plane, will be found electrified, 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 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

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, the electricity will accordingly paſs but ſlowly to the inferior plane. But the caſe is different, if, in performing this experiment, the electrified metal plate touches the inferior plane edgewiſe, for then its intenſity being greater than when it is laid flat, as appears by the electrometer

trometer, 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 metal were perfect conductors. But, since we do not know of any perfect conductor, the metal or finger oppose a sufficient resistance to retard the immediate dissipation of the electricity of the plate, which is in that case actuated by a very small degree of intensity, or power of expansion; so that, suppose for instance, the piece of metal or finger touching the plate took off so much of its electricity as to reduce

the

the intenfity of the remainder to the 50th part of a degree, this remaining electricity would be then nothing; but when the plate, by being feparated from the inferior plane, has its capacity fo far diminifhed as to render the intenfity of its electricity 100 times greater, then the intenfity of that remaining electricity would become of two degrees or more; viz. fufficient to afford a fpark.

Having confidered in what manner the action of electric atmofpheres modifies the electricity of the metal plate in its various fituations, we fhall now confider the effects which take place when the electricity is communicated to the metal plate, whilft ftanding upon a metal plane. As the whole bufinefs has been proved in the preceding pages, it is eafy to deduce the applications from it; neverthelefs, it will be ufeful to exemplify it by an experiment.

## EXPERIMENT CLXXXVI.

Suppofe a Leyden phial or a conductor, fo weakly electrified that its intenfity is one half a a degree, or even lefs: if the metal plate of the condenfer, when ftanding 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 uſe in many caſes where the electricity is ſo ſmall as not to be at all, or not clearly, obſervable by one condenſer only, as has been fully proved. Sometimes the uſual metal plate of a condenſer acquires ſo ſmall a quantity of electricity, that being afterwards taken from the inferior plane, and preſented to an extremely ſenſible electrometer, made by Mr. Cavallo, it did not affect it. In this caſe, if the ſaid plate, thus weakly electrified, was made to touch the other ſmall plate properly ſituated, and was afterwards brought near an electrometer, the electricity was then generally ſtronger than was ſufficient merely to aſcertain its quality.

Now if, by the help of both condenſers, the intenſity of the electricity has been augmented 1000 times, which is by no means an exaggeration, how weak muſt then be the electricity of the body examined! how ſmall the quantity of electricity that is produced by rubbing a piece of metal with one's hand! ſince when it is condenſed by both condenſers, and then communicated to an electrometer, it will hardly affect that inſtrument, and yet is ſufficient to afford conviction that the metal can be electrified by the friction of a perſon's hand.

Before

Before the discovery of the condenser and Mr. Cavallo's very sensible electrometer, we were far from being able to discover such weak excitations; whereas, at present, we can observe a qnantity of electricity, incomparably smaller than the smallest observable at those times.

CHAP.

## CHAP. XII.

### OF ATMOSPHERICAL ELECTRICITY.

IT is now univerſally acknowledged by every philoſopher, that the electric fluid is diſſeminated through the whole atmoſphere: it is alſo known that the motion of this fluid is reſtrained when it acts in denſe air, but it moves with the greateſt liberty in a vacuum or rarified air as in an exhauſted receiver. Therefore at a great height, where the air is equally, if not more rarified than in our receivers, its motion muſt be exceeding free, and hence capable of the greateſt effects: becauſe it can be moved from one place to another with extreme eaſe and rapidity, and in great quantities; and if, as many philoſophers believe, the electric fluid is that ether or ſubtil matter which fills the intervals between the planets, how great muſt be the force of an agent which fills theſe immenſe ſpaces! Be this as it will, we know that the upper ſtrata of air are filled with this fluid, and that it moves there freely.

Again, we know that water, whether in ſubſtance or in vapour, is a conductor of electricity; that

that in proportion as air is loaded with it, it resists less the motion and diffusion of the electric fluid: consequently, if vapour rises to a great height, it becomes a conductor and canal of communication between this immense reservoir, this ocean of free electric fluid, and the entire mass of our globe. If then this fluid is more restrained at one part of our globe than it is in corresponding parts of the higher regions the vapours will be the medium to restore the equilibrium. But this equilibrium will not last long, for it is natural to suppose this immense fluid subject to a flux and reflux, currents, &c. which will alter its local density. Thus also this fluid which is contained in our globe, cannot be long uniformly spread through its mass, as there are ten thousand agents, which will either accumulate or rarify it: consequently vapour will scarce ever rise without serving as a vehicle to maintain the equilibrium between our globe and the fluid in the higher regions of the atmosphere.

This theory is so natural a consequence of the most immediate and certain principles of electricity, that it seems almost superfluous to confirm it by the phœnomena which it explains. It is the only one that accounts for the following fact, that vapours never rise to a great height without

without producing the moſt terrible meteors. All conſiderable volcanic productions are accompanied with lightening. The fire which riſes from the earth ſeems to light that of heaven. The column of vapour which proceeds from the bowels of a volcano is continually traverſed by lightening *, which ſometimes ſeems to proceed from the higher regions, ſometimes from the column itſelf. Hail, which neceſſarily ſuppoſes the aſcenſion of vapour to a conſiderable height, is always accompanied with electricity. The aurora borealis is alſo electrical; its light ſeems to be produced by the electric fluid, at the inſtant it is condenſed in paſſing in the columns of elevated vapour.

Waterſpouts, whirlwinds, and even earthquakes, are in a great meaſure the effects of torrents of the electric matter, attracted from the higher regions by torrents of vapour. In a word, can the electricity of the clouds be attributed to a more natural or probable cauſe † ?

For the ſubject of this chapter we are principally indebted to P. Beccaria, who has for

* The younger Pliny obſerved theſe lightenings in the eruption which killed his uncle. Sir William Hamilton has alſo obſerved them ſeveral times.

† Sauſſure's Eſſais ſur l'Hygrometrie, p. 275.

many

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.

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,

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.

Air balloons will probably enable us to diſcover with certainty the electricity of the different ſtrata of the atmoſphere. Mr. de Sauſſure has already made the experiment with a balloon made of taffety, containing two hundred cubic feet of air, and which was raiſed by the heat from the flame of ſpirit of wine: with this, in cloudy but calm weather, he obtained a ſtrong poſitive electricity *.

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

* Faujas de St. Fond, Deſcription des Experiences Aeroſtatiques, tom. II. p. 271.

In

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 it is negative, and then it is brought over by the wind from ſome part of the atmoſphere, (perhaps very diſtant from the place of obſervation) where there is either fog, ſnow, rain, or clouds. The whole ſeries of obſervations which P. Beccaria has made confirm this poſition. He ſeems to have met with only three or four inſtances to the contrary.

Dr. Franklin has obſerved, that the clouds are ſometimes negative, which is certainly true; becauſe they will at times abſorb, at and through the apparatus, a large and full bottle of poſitive electricity, of which the apparatus could not have received and retained the hundredth part. And it is eaſy to conceive, how a ſtrongly charged large poſitive cloud may reduce ſmaller clouds to a negative ſtate.

The electricity of the atmoſphere is very much connected with the ſtate of the air, as to moiſture and dryneſs; ſo that it is neceſſary to attend to the hygrometer, in order to form a proper

proper judgment of the different degrees of electricity at different times. That invented by Mr. Coventry, which is made of hatters' paper, will anſwer beſt; it is very ſenſible, abſorbs moiſture ſoon, and parts with it eaſily. Comparative obſervations may alſo be made with it. It is alſo neceſſary to place a thermometer near the hygrometer, to aſcertain what quantity of moiſture the air can keep in ſolution with a given degree of heat: though this object will more probably be obtained by obſerving accurately the quantity of moiſture evaporated from a given ſurface at different times. It is alſo to be obſerved, that the different degrees of denſity in the air will affect the quantity of moiſture which is retained in the air.

The moiſture in the air is the conſtant conductor of the atmoſpheric electricity during clear weather; and the quantity of electricity is proportioned to the quantity of moiſture which ſurrounds the exploring wire; except there is ſo much as to leſſen the exactneſs of the inſulation of the wire and of the atmoſphere. In a dry ſtate of the air it will ſometimes be above a minute before the balls will manifeſt any electricity after the wire has been touched; though in a damper ſtate, a ſecond will ſcarce elapſe before rapid oſcillations of the balls may be be obferved between the finger and the plate of brafs to which they are affixed *.

The electricity, when the weather clears up, is always pofitive. When the weather is clearing up, and becomes dry quickly, the electricity rifes to a great degree of intenfity, and affords frequent opportunities for repeating the obfervations. It fometimes happens, that the electricity, caufed by the clearing up of the weather, continues in its ftate of intenfity for a long while; and alfo, after being interrupted, it begins afrefh. Thefe accidents feem to be owing to the electricity being brought over by the wind from great diftances.

P. Beccaria fays, that whenever he obferved that the thick low clouds which were over his head began to break, and the rare even clouds, which are above the former, became dilated, that the rain ceafed, and the balls diverged with pofitive electricity, he always wrote down CERTAIN TENDENCY TO CLEAR WEATHER.

Prior Ceca fays, that a ftrong pofitive electri-

* In making obfervations on the electricity of the atmofphere in clear weather, it is effential to repeat them very frequently; i. e. to obferve the velocity with which the electricity rifes after it has been annihilated; which P. Beccaria generally eftimated by the number of feconds elapfed before the balls began to manifeft their electricity.

city 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,

trary, if the rare extenſive cloud is gradually formed of ſmaller clouds, like locks of wool, which are continually joining to, and parting from each other, the poſitive electricity commonly continues.

Low and thick fogs (eſpecially when as they riſe the air above them is free from moiſture) carry up to the exploring wire an electricity which will give ſmall ſparks repeatedly, and produce a divergence of the balls from 20° to 25°, or even 30°. If the fog grows ſluggiſh, and continues round the exploring wire, the electricity ſoon fails; but, if it continues to riſe, and another cloud ſucceeds, it electrifies again the wire, though leſs than before. Sky-rockets ſent through ſuch thick, low, and continued fogs, often afford ſigns of electricity. P. Beccaria, under any one of the circumſtances above deſcribed, never met with an inſtance of negative electricity; except, perhaps once, when he ſent a ſky-rocket, to which a ſtring was fixed, through a low thick fog; though he had afterwards every reaſon to think that he had miſtaken A FALSE LITTLE STAR FOR A TRUE ONE.

Mr. Ronayne obſerved, that the air in Ireland was generally electrified in a fog, and even in a miſt, and that both day and night, but principally in winter; ſeldom in ſummer, except from 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

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.

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 diſcernible electricity will be perceived before, or even for a little while after, the riſing of the ſun.

As the air is generally damp in the night, electricity is ſeldom obſerved before the ſun riſes. During three months obſervations P. Beccaria found the electricity before the ſun roſe only eighteen mornings; and from the whole of his numerous obſervations it appears, that the appearance of electricity in winter before ſun-riſe is more frequent 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 began before ſun-riſe or only after, gradually increaſes. This gradual increaſe of the morning electricity begins ſooner if the hygrometer continues after ſun-riſe to indicate a greater degree of increaſing dryneſs. The intenſity and the riſe of the electricity (after it has been annihilated by touching the exploring wire) laſts in ſerene days, in which no impetuous wind takes place, and the hygrometer is ſtationary at the higheſt degree it has attained that day, till the ſun draws near the place of 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 differ-

ent

ent days, yet the electricity will appear fooner after being deftroyed on fome days than on others; and this is in a great meafure proportioned to the increafe of heat. The electricity moreover commences on fuch days later in the morning, and falls fooner in the evening.

The friction of winds againft the furface of the earth is not the caufe of atmofpheric electricity. Impetuous winds leffen the intenfity of the electricity in clear weather. If they are damp they leffen its intenfity in proportion to the diminution they caufe in the exactnefs of the infulation both of the wire and atmofphere.

### OF THE ELECTRICITY PRODUCED BY THE EVENING DEW.

In cold feafons, if the fky is clear, little winds and a great degree of increafing drynefs, an electricity of confiderable intenfity arifes after fun-fet, as foon as the dew begins. The *frequency* of fuch electricity is moreover greater than that of the *daily* electricity, and it vanifhes flowly.

In temperate or warm feafons, if the fame circumftances 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 riſes in the evening, when the dew begins, is leſs in proportion to the diminutions of the exactneſs of the inſulation of both the exploring wire and the atmoſphere; but correſpondently to the greater quantity of dew, the frequency of the electricity is greater.

The electricity of dew ſeems to depend on the quantity of dew, and to follow in 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 CLXXXVII.

Let the air in a well-clofed room be electrified; that is to fay, the moifture and other vapours diffufed in it: then let a bottle, filled with water colder than the air in the room, and infulated on a tube of glafs, be raifed pretty high in this room. Care muft be taken to preferve the infulation of the glafs, with warm cloths. The electric figns that will arife in two threads fufpended to fuch bottle will exactly reprefent the electricity of dew; and they will exhibit the different manner after which this electricity takes place, according as the electrified vapours in the room are more or lefs rare; as the difference between the heat of the air in the room, and that of the water in the bottle is lefs or greater, and the infulation of the bottle is more or lefs exact.

In a thunder-ftorm Mr. Ronayne obferved, that the flafhes would caufe fudden changes. Sometimes the electricity would be extended, fometimes diminifhed; at other times iucreafed, and fometimes even changed to the contrary again, though none was perceived before; it would come on fuddenly with a flafh of lightening

ening. 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 ſchoolboy's kite with this ſtring anſwers the purpoſe as well as any other. When a kite conſtructed in this manner was raiſed, Mr. Cavallo ſays he always obſerved the ſtring to give ſigns of electricity, except once; the weather was warm, and the wind ſo weak, that the kite was raiſed with difficulty, and could hardly be kept up for a few minutes: afterwards, when the wind increaſed, increafed, he obtained as ufual a ftrong pofitive electricity.

If this kite was raifed 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 ftring, and let the other end fall on the ground, and placed himfelf alfo on an infulating ftool. Except the kite is raifed in a thunder-ftorm, there is no great danger that the operator will receive a fhock. Although he raifed his kite hundreds of times without any precaution whatever, he feldom received even a few flight fhocks in the arms. But it is not adviseable to raife it while ftormy clouds are overhead. This is alfo lefs neceffary, as the electricity of the atmofphere may then be eafily obferved by other means.

When the kite was raifed, he often introduced the ftring through a window into a room of the houfe, and faftened it by a ftrong filk lace to a heavy chair in the room. Fig. 78, A B repre-prefents part of the ftring of the kite which comes within the room, C the filk lace, D E a fmall prime conductor, which, by means of a fmall wire, is connected with the ftring of the kite; F a quadrant electrometer, fixed upon an infulating ftand, and placed near the prime conductor; G a glafs tube about 18 inches long,

gn

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 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;

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 ufual manner, and then take out the wire from the glafs tube by means of the glafs handle. This may be done without difcharging the phial; and, as the fire cannot now efcape eafily, the charge of a phial may be preferved for many weeks.

Fig. 80 reprefents a very fimple inftrument (contrived by Mr. Cavallo) for making experiments on the electricity of the atmofphere, and which, on feveral accounts, appears to be the beft for the purpofe. A B is a common jointed fifhing rod, without the laft or fmalleft joint: from the extremity of this rod proceeds a fmall glafs tube C, covered with fealing-wax, a cork D is fixed at the end of it, from which an electrometer with pith balls is fufpended. H G I is a piece of twine faftened to the other extremity of the rod, and fupported at G by a fmall ftring F G. At the end of the twine T a pin is faftened, which, when pufhed into the cork D, renders the electrometer E uninfulated. When the electricity of the atmofphere is obferved with this inftrument, thruft 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 houfe, raifing the end of the rod

with

with the electrometer, fo as to make an angle of 50 or 60 degrees with the horizon. Keep the inftrument in this fituation for a few feconds, then pull the twine at H, and the pin will be difengaged from the cork D; which operation caufes the ftring to drop in the dotted fituation K L, and leaves the electrometer infulated, and electrified with an electricity contrary to that of the atmofphere. This being done, you may draw the electrometer into the room, and examine the quality of the electricity, without obftruction either from wind or darknefs.

Fig. 81 is an electrometer for rain, contrived by Mr. Cavallo. A B C T is a ftrong glafs 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 outfide furface of the tube from A to B is covered with fealing-wax, and fo is the part of it which is covered by the funnel. FD is a piece of cane round which brafs wires are twifted in different directions, fo as to catch the rain eafily, and at the fame time to make no refiftance to the wind. This piece of cane is fixed into the tube, and a fmall wire proceeding from it goes through the tube, and communicates with the ftrong wire A G, which

is

is thruft into a piece of cork, faftened to the end A of the tube. The end G of the wire A G is formed into a ring, from which a fenfible pith ball electrometer is to be fufpended. This inftrument is faftened to the fide of a window frame, where it is fupported by ftrong brafs hooks at C B; which part of the tube is covered with a filk lace, in order to adapt it better to the hooks. The part F L is out of the window, with the end F elevated a little above the horizon. The remaining part of the inftrument comes through a hole in one of the lights in the fafh, within the room, and no more of it touches the fide of the window than the part C B. When it rains, efpecially in paffing fhowers, this inftrument is frequently electrified; and by the divergence of the electrometer, the quantity and quality of the rain may be obferved without any danger of a miftake. With this inftrument, in rainy weather, Mr. Cavallo has been able to charge a fmall coated phial at the wire A G. It fhould be fixed in fuch a manner that it may be eafily taken off from the window, and replaced again, as occafion requires; as it will be neceffary to clean it often, particularly when a fhower of rain is approaching.

DE-

## DESCRIPTION OF A SMALL PORTABLE ATMOSPHERICAL ELECTROMETER, INVENTED BY MR. CAVALLO.

The principal part of this inſtrument is a glaſs tube C D M N, cemented at the bottom into the braſs piece A B, by which part the inſtrument is to be held when uſed for the atmoſphere; and it alſo ſerves to ſcrew the inſtrument into 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, being alſo covered with ſealing-wax, projects a ſmall way within the tube C D M N; into this ſmaller tube 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.

I M and K N are two narrow ſlips of tinfoil, ſtuck to the inſide of the glaſs C D M N, and

and communicating with the braſs bottom A B. They ſerve to convey that electricity which, when the balls touch the glaſs, is communicated to it, and, being accumulated, might diſturb the free motion of the balls.

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 A B to preſent it to the air a little above his head, ſo that he may conveniently ſee the balls P, which will immediately diverge if there is any electricity; i. e. whether poſitive or negative may be aſcertained, by bringing an 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

higher than 20°, the perſon who takes the ſpark will feel the effects of it in his legs; it appears more like the diſcharge of an electric jar, than the ſpark taken from the prime conductor of an electrical machine.

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

7. When the weather is damp, and the electricity is pretty ſtrong, the index of the electrometer, after taking a ſpark from the ſtring, or preſenting the knob of a coated phial to it, riſes ſurprizingly quick to its uſual place, but in dry or warm weather it riſes exceedingly ſlow.

It appears, from the obſervations which have been made on the electricity of the atmoſphere, that nature makes great uſe of this fluid in promoting vegetation.

1. In the ſpring, when plants begin to grow, then temporary electrical clouds begin to appear, and pour forth electric rain. The elec-

tricity of the clouds and of the rain continues to increafe till that part of the autumn in which the laſt fruits are gathered.

2. It is this fluid which ſupplies common fire with that moiſture by the help of which it actuates and animates vegetation: it is the agent that collects the vapours, forms the clouds, and is then employed to diſorder and diſſipate them in rain.

3. From the ſame principle may be explained the proverb, that *No watering gives the country ſo ſmiling a look as rain.* The clouds of rain, by extending their electric atmoſphere to the plants, diſpoſe the pores of the latter to receive with greater facility the water which is impregnated with this penetrating and dilating fluid. Beſides, it is natural to ſuppoſe, that the poſitive electricity which continually prevails in ſerene weather, will contribute to promote vegetation, ſince this has been found to be the effect of even artificial electricity.

OF

## OF THE IMPERFECTIONS OF METEOROLOGY, SO LONG AS BAROMETRICAL, THERMOMETRICAL, AND HYGROMETRICAL OBSERVATIONS ARE NOT ACCOMPANIED WITH THE REGULAR OBSERVATION OF THE ELECTRICITY OF THE ATMOSPHERE, OF THE ELECTRICITY OF RAIN, SNOW, MISTS, AND AQUEOUS METEORS IN GENERAL. BY MR. ACHARD.

As it is now clearly aſcertained, that electricity is a cauſe of various meteorological phænomena, it is rather 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 phænomena, occaſioned by the concurrence of various cauſes, without being acquainted with them all; for if any one is neglected, it will be abſolutely impoſſible thoroughly to explain the phænomena. If electricity is not the ſole cauſe of ſeveral meteorological appearances, it is undoubtedly concerned more or leſs in their formation; ſo that by neglecting to obſerve it, as well as the barometer, &c. we loſe the fruits of other, even very exact, meteorological obſervations.

The influence of electricity on vegetation is proved by a ſet of obſervations made by different philoſophers; but it evidently appears that the botanic meteorological obſervations alone will never be ſo uſeful as might be expected, till we unite thoſe made by an inſtrument which will indicate the electric ſtate of the atmoſphere, to thoſe made with other inſtruments. It is owing to this cauſe, perhaps, that it is impoſſible to draw any concluſion from the botanical meteorological obſervations of Meſſrs. Gautier and Duhamel, which were continued from 1751 to 1769.

Mr. Achard has had an opportunity of making a few obſervations, but they were ſufficient to convince him of the intimate connection that ſubſiſts between the formation of the moſt part of meteors, and atmoſpherical electricity.

To diſcover if the atmoſphere was electrical, he made uſe of a pair of light pith balls which were attached to a reſinous rod. This electrometer, from its ſimplicity, is almoſt preferable

able to any other for merely discovering that electricity exists in the atmosphere.

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 io 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 electrometer did not alter in the leaſt, except towards ſun-ſet, when it increaſed in a ſmall degree.

It is remarkable, that in thoſe days in which he obſerved no electricity in the air, there was no dew at night; while on the other nights, it fell in greater or leſs quantities. He does not think thoſe obſervations are ſufficient to determine that the dew is occaſioned by electricity, but it may, he thinks, be fairly inferred, that the elevation and fall of the dew is obſtructed or promoted by the electricity of the air. It is eaſy to point out in what manner electricity may produce the effect. Let us ſuppoſe the air to be either poſitively or negatively electrified, but the ſurface of the globe where we are not to be ſo; the aqueous and volatile parts of the vegetables exhaled by the rays of the ſun, and ſuſpended in the air, will become electric by communication. The air cooling by the abſence of the ſolar heat, will not, after the ſetting of the ſun, retain the aqueous particles with the ſame force; and theſe being attracted by the non-electric bodies which are on the ſurface of the earth, their ſuperficies will be covered with dew. Again, let us ſuppoſe that the ſurface of the earth is electrical, but that the

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 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.

NECES-

## 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.

DE-

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

truncated part of the cone Mr. Achard faſtens a ſquare iron branch, on which he places a thermometer and two electrometers; the one very light, and thus capable of being ſet in motion by ſmall degrees of electricity; the other heavier, and which, conſequently, only riſes when the electricity becomes too ſtrong to be meaſured by the light electrometer. Beſides theſe two electrometers, Mr. Achard tied to the iron bar a thread, which indicates, by 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.

ſible. At the end of the metal bar, which paſſes through the receiver, hollow tin pipes may be placed, of a ſmall diameter, to render them as light as poſſible, and they may be raiſed to the height of 10, 20, or 30 feet. The upper end of the pipe terminates in an iron point, extremely ſharp and well gilt; the gilding is neceſſary to hinder the point, which muſt be always even and ſmooth, from contracting ruſt. With reſpect to the elevation that it may be proper to give to the tin-pipe, this muſt vary with the height of the buildings or trees in the different places where obſervations are made; for the height of the pipe muſt always exceed, at leaſt by ſix feet, the elevation of all the bodies that are near it. Mr. Achard joins a thermometer to this machine, which may be obſerved at the ſame time, and be the means, perhaps, of diſcovering the relations, if any there be, between electricity and the temperature of the air. A barometer and hygrometer may, with facility, be added to this inſtrument for the ſame purpoſe.

In order to know whether the electricity of the air be poſitive or negative, Mr. Achard ſuſpends a ball of cork, by a linen thread, on the wire which communicates with the iron bar, and which paſſes through the roſin, with which

which the bafe of the truncated cone is covered. The wire muft be of fuch a length, that bodies pofitively or negatively electrical may be commodioufly brought near the cork-ball, which is fufpended on it; and it is according as thefe bodies attract or repel the ball, that the obferver learns whether the electricity which the inftrument has received from the air, be pofitive or negative.

That the obferver may be in no danger from fudden accumulations of electricity, which fometimes happen, Mr. Achard faftens to the bafe of the pedeftal an iron bar, which not only communicates with, but even enters into, the ground, feveral feet deep. This bar, whofe upper part terminates in a round knob or ball, muft be only at the diftance of an inch from the cone. When the electrical fluid is fo accumulated that the inftrument can no longer contain it, it will difcharge itfelf againft this metal bar, which will conduct it under ground. The fame thing would happen, if the lightning fell upon the inftrument, and the obferver would be in no fort of danger, even at the diftance of a few feet. When the inftrument is placed in a garden, this method of forming a communication with the ground is fubject to no inconveniency; but if it fhould be judged proper to employ the

the inftrument in a houfe, (which may be done by making the tin pipe pafs through a hole in the roof, and placing the inftrument in a garret) the manner above-mentioned of forming its communication with the earth would not be fo eafily executed: in this cafe, the communication muft be effected by means of a bar of metal defcending from the garret to a depth of fome feet under ground; and for greater fecurity againft the too great proximity of a thunder-ftorm, it would be proper to place the metallic bar in contact with the cone of tin: thus the inftrument would become a real conductor, which, inftead of expofing the houfe to danger, would, on the contrary, preferve it from all the accidents that are occafioned by lightning.

When the inftrument is placed in a garret, or on the platform of a houfe, no inconvenience is to be apprehended from afcending dews; but when it is placed in a garden, the dew adheres to the rofin which covers the truncated bafe of the cone, and forming thus a communication between the cone and the earth, makes the inftrument lofe the electricity with which it may have been charged. To prevent this accident, it is neceffary to pave the ground on which the inftrument is placed, and THAT in fuch a manner, that the pavement may extend itfelf

on

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 lightning, which is not produced by the diſcharge of the electrical matter of the air, but by that of the vapours which float in the atmoſphere. Hence it follows, that rain, ſnow, hail, miſt, and dew, muſt be very often electric. As it appears to Mr. Achard a matter of great conſequence to know and obſerve exactly the electricity of thoſe meteors, he has conſtructed a machine that is adapted to diſcover both 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, 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

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 diffufed in it. If, during rain, hail, fnow, or mift, the atmofpherical 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 muft then be inquired, whether they be fo in the fame degree; if this be the cafe, it is only to the rain or fnow, &c. that the electricity muft be attributed. I need not obferve (concludes Mr. Achard) that when there is neither rain, fnow, hail, or mift, the atmofpherical electrometer will always indicate the electricity of the air.

## CHAP XIII.

### ON THE DIFFUSION AND SUBDIVISIONS OF FLUIDS BY ELECTRICITY.

WE are chiefly indebted to the Abbé Nollet for what is known on the ſubject of this chapter, which was inveſtigated by him with incredible induſtry and patience. I have only ſubjoined the principal reſult of his experiments, and muſt refer the reader, for a more ample account, to the Abbé's own writings, or Dr. Prieſtley's Hiſtory of Electricity.

Electricity augments the natural evaporation of fluids; ſince, excepting mercury and oil, all the others which were tried ſuffered a diminution that could not be aſcribed to any other cauſe than electricity.

It increaſes the evaporation of thoſe fluids moſt which naturally tend to evaporate readily. Volatile ſpirits of ſal-ammoniac loſt more than ſpirits of wine, this more than water, &c.

Elec-

Electricity acts ſtrongeſt upon the fluids when the veſſels which contain them are non-electrics. The evaporation was greateſt in the moſt open veſſels, but did not increaſe in proportion to their apertures. It does not make any liquor evaporate through the pores either of metal or glaſs.

To extend theſe principles further, the Abbé made a great variety of experiments on electrified capillary tubes, and found, that the ſtream would be ſub-divided, but it is not ſenſibly accelerated, if the tube is not leſs 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.

From ſome very accurate experiments made by Mr. de Sauſſure with his new hygrometer,

 it

it appears, that the foregoing theory, which asſerts that electricity always promotes evaporation, is only true under certain reſtrictions. It increaſes the evaporation from thoſe bodies which are ſuperſaturated, but does not occaſion any evaporation in thoſe which do not contain a ſuperabounding quantity of water.

EXPERIMENT CLXXXVIII.

Fig. 77 repreſents a metal phial, to which a capillary tube is adapted, which will only permit water to paſs through it in interrupted drops. Fill the pail with water, and ſuſpend it from the prime conductor, then turn the cylinder, and the water will paſs through the tube in a continued ſtream; this will ſeparate into other ſtreams, that will appear luminous in the dark.

EXPERIMENT CLXXXIX.

Suſpend one pail from a poſitive conductor, and another from a negative one, ſo that the end of the tubes may be about three or four inches from each other, and the ſtream proceeding from

from one will be attracted by that which iſſues from the other, and form one ſtream, which will be luminous in the dark.

If the pails are ſuſpended on two poſitive, or two negative conductors, the ſtreams will recede from each other.

EXPERIMENT CXC.

Place a metal baſon on an inſulating ſtand, and connect it with the prime conductor; then pour a ſmall ſtream of water into the baſon, which in the dark will have a beautiful appearance, as the ſtream will be divided into a great number of lucid drops.

EXPERIMENT CXCI.

Dip a ſponge in water, and then ſuſpend it from the conductor: the water, which before only dropped from it, will now fall faſt, and appear in the dark like fiery rain.

EXPERIMENT CXCII.

Hold a pail, which is furniſhed with ſeveral capillary tubes placed in various directions, near an electrified conductor, and the water will ſtream out of thoſe jets near the conductor, while it will only drop at intervals from thoſe which are oppoſite to it.

EXPERIMENT CXCIII.

The knob of a charged jar will attract a drop of water from a ſaucer, &c. This drop, the moment the bottle is removed from the ſaucer, aſſumes a conical ſhape, and if it is brought near any conducting ſubſtance, it is driven forcibly away in ſmall ſtreams, which are luminous in the dark.

It appears by this experiment, that the electric fire not only tends to ſeparate the particles of water and to diſſipate them into vapour as common fire, but that it effects this with uncommon rapidity.

EXPERIMENT CXCIV.

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

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 CXCV.

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 CXCVI.

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 ſpark will be conſiderably longer than can be obtained from the conductor without the water.*

* Nicholſon's Introduction to Philoſophy.

EXPERIMENT CXCVII.

Stick a piece of ſealing-wax on the conductor, in ſuch a manner that it may be eaſily ſet on fire by a taper; while it is flaming turn the cylinder, the wax will become pointed and ſhoot out an almoſt inviſible thread into the air, to the length of a yard and more. If the filaments that are thrown out by the wax are received on a ſheet of paper, the paper will be covered by them in a very curious manner, and the particles of the wax will be ſo far ſub-divided as to reſemble fine cotton. To faſten the piece of wax conveniently to the conductor, ſtick it firſt on a ſmall piece of paper, then twiſt the end of the paper ſo as to fit one of the holes which are made in the prime conductor; when it is thus placed, it may be readily fired by a taper.

EXPERIMENT CXCVIII.

Inſulate a fountain made by condenſed air, and which emits only one ſtream; electrify the fountain and the ſtream will be ſeparated into

a great

a great number; theſe will diffuſe themſelves equally over a large ſpace of ground. By laying a finger upon the conductor, and taking it off again, the operator may command either the ſingle ſtream or the divided one, at pleaſure.

EXPERIMENT CXCIX.

Electrify two ſmall inſulated fountains with the different electric powers; the ſtreams of both will be diſperſed into very minute particles, which will run together at the top, and come down in heavy drops, like a ſhower of rain.

CHAP.

## CHAP. XIV.

### OF THE ELECTRIC LIGHT IN VACUO.

#### EXPERIMENT CC.

TAKE a tall dry receiver, and inſert in the top, with cement, a wire with a rounded end, then exhauſt the receiver, and preſent the knob of the wire to the conductor, and every ſpark will paſs through the vacuum in a broad ſtream of light, viſible the whole length of the receiver, moving with regularity, unleſs it is ſolicited and bent out of its way by ſome non-electric, then dividing itſelf into a variety of beautiful rivulets, which are continually dividing and uniting in a moſt pleaſing manner. If the veſſel is graſped by the hand, at every ſpark a pulſation is felt, like that of an artery, and the fire bends itſelf towards the hand. This pulſation is even felt at ſome diſtance from the receiver, and in the dark, a light is ſeen between the hands and the glaſs. The ſtreams of light paſs ſilently through the receiver, becauſe the air is removed by whoſe vibration ſound is produced.

From

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 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 CCI.

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 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, 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.

By conſidering the experiments made with the electric fluid IN VACUO, we attain a clear idea of the reſiſtance the air continually makes to its paſſage, and ſee that the divergence of its rays is not to be attributed to an imaginary repulſion, but to the reſiſtance of the ambient air, for the divergence ceaſes, and the rays unite when this reſiſtance is removed.

## EXPERIMENT CCII.

Before the air was exhauſted from the receiver, if the wire at the top of it was electrified, a di-

verging

verging brufh proceeded from it, about an inch long, but little of the fluid paffing off, and even that little requiring a ftrong impulfive force to pufh it forward. On exhaufting the receiver the following changes took place: firft, the rays of the brufh became longer; fecondly, the rays diverged lefs, were fewer in number, and the fize of the remaining rays was increafed; thirdly, they all united at laft, and formed a continued column of light, from the wire to the plate of the air pump.

From this experiment it is clear, that the air is the agent by which, with the affiftance of other electrics, we are able to communicate electricity on electrics, as well as non-electrics; for when this is removed, the fluid pervades the vacuum, and flies off to a confiderable diftance.

## EXPERIMENT CCIII.

To diftinguifh with great accuracy the changes in the form and length of the electric fpark when it is paffing through a receiver, the air of which is more or lefs rarified; fix a ball to the rod, let another proceed from the plate of the air-pump; the balls are to be placed about

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 CCIV.

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

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 Torricellian vacuum in a glass tube about three feet long, and then sealed hermetically. Hold one end of this tube in the hand, and apply the other to the conductor, and immediately the whole tube will be illuminated from end to end, and will continue so for a considerable time after it is removed from the conductor, flashing at intervals for many hours.

## EXPERIMENT CCV.

Screw on a ball, of about an inch diameter, to the rod of the plate of the collar of leather of an air-pump; place this on a tall receiver; connect the exterior part of the rod with the conductor; place some cylindrical pieces of metal on the plate of the pump, then exhauſt the receiver in part, and electrify the rod at intervals, and luminous jets of fire like fulminating meteors will fly from the ball to the cylinders of metal.

EXPERIMENT CCVI.

Another beautiful appearance may be produced in the dark, by inſerting a ſmall Leyden phial into the neck of a tall receiver, ſo that the outward coating may be expoſed to the vacuum. Exhauſt the reeeiver, 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 CCVII.

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 of mercury; the bent part of the tube above the mercury forms a compleat vacuum. If a bottle is discharged through this ſpace, the light appears uniform through the whole ſpace, but is moſt vivid when the diſcharges are ſtrong. Dr. Watſon inſulated this apparatus, and then made one of the baſons 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 baſons was connected with the inſulated cuſhion, the fire appeared to pervade the vaeuum in a different direction.

## EXPERIMENT CCVIII.

Fig. 83 repreſents a glaſs tube, ſuch as is generally uſed for barometers; on the end *b* a ſteel cap is cemented, from which a wire and ball *c d* proceed into the tube. Fill this tube with quickſilver, and then, by ſending up a large bubble of air, and repeatedly inverting the tube, free the quickſilver and iron ball from air, according to the ordinary mode of filling barometers; then place a ſmall drop of æther on the quickſilver, and put the finger on

 the

the end of the glaſs tube, invert the tube, and then inſert the end *f* in a baſon of quickſilver, taking care not to remove the finger from the end of the tube, till the end is immerged half an inch under the ſilver. When the finger is removed, the quickſilver will deſcend, and the æther will expand itſelf, leſſen the vacuum, and depreſs the mercury in the tube; now preſent the metallic top of the tube to a large charged conductor, and a beautiful green ſpark will paſs from the ball to the quiekſilver. By admitting a ſmall quantity of air into the vacuum, an appearance ſomething ſimilar to a falling ſtar is obtained. I am indebted for this valuable experiment to Mr. Morgan, of the Equitable Aſſurance Office.

## EXPERIMENT CCIX.

Place the braſs cap of a well exhauſted receiver, at about half an inch from the prime conductor, ſo that when the machine is in action, ſparks may paſs from the conductor to the braſs cap of the receiver. Mr. Cavallo, in relating the circumſtances attending an experiment of this kind made by him, obſerves that

that when the receiver was exhaufted, the fpark paffed from the cap to the plate of the pump through the receiver, illuminating its whole cavity; that the vacuum became a better conductor of electricity in proportion as it was more perfect, and that the electric light was more equally diffufed, but it was by no means faint when the receiver was exhaufted to the utmoft. The light changed according as the receiver was more or lefs exhaufted. The appearances were as follows.

| DEGREE OF RAREFACTION, AS SHEWN BY THE GAGE. | APPEARANCES OF THE ELECTRIC LIGHT WITHIN THE RECEIVER. |
| --- | --- |
| Air rarified 40 times. | Light in large, long, but divided ftreams. |
| 70 | Fine diffufed light of a white colour. |
| 80<br>100<br>400 | Beautiful diffufed light inclining to red or purple, and filling the whole receiver. |
| When the gage fhewed the utmoft degree of exhauftion. | A diffufed light filled equally the receiver; it had hardly any reddifh hue *. |

* Phil. Tranf. vol. lxxiii. part ii. p. 451.

See alſo EXPERIMENT CXII, CXIII, CXXI, CXXII, of this Eſſay, for further obſervations on the appearance of the electric light IN VACUO.

CHAP.

## CHAP. XV.

### OF MEDICAL ELECTRICITY.

THE Abbé Nollet ſays, that he received more pleaſure when he diſcovered that the motion of fluids in capillary tubes and the inſenſible tranſpiration of animated bodies were augmented by electricity, than by any other diſcovery he had made; becauſe they ſeemed to promiſe ſuch abundant advantages to mankind, when properly applied by a ſkilful hand. But how much would this pleaſure have been augmented, if he had lived to ſee his hopes realized, and this branch of electricity obtain the ſame medical certainty as the bark in intermittents!

It is true, that like every other ſimple medicine which has proved beneficial to mankind, electricity met with much oppoſition from the intereſted views of ſome, and the ignorance of others; has been treated with contempt, and injured by miſplaced caution. I ſhall recommend to thoſe who thus oppoſe it, not to condemn a ſubject of which they are ignorant, but to hear the caufe before they pafs fentence; to take fome pains to underftand the nature of electricity; to learn to make the electrical machine act well, and then apply it for a few weeks to fome of thofe difcorders in which it has been adminiftered with the greateft fuccefs; and there is no doubt but they would foon be convinced that it deferves a diftinguifhed rank in medicine, which is the offspring of philofophy,

The fcience of medicine and its practitioners have been reproached with the inftability 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 fafhion, and influenced by prejudice. On this ground it has been predicted, that however great the benefits which may be derived from electricity, it would ftill only laft for the day of fafhion, and then be configned to oblivion. I muft confefs, that I cannot be of this opinion, nor eafily led to think a fet of men whofe judgment has been matured by learning and experience, will ever neglect an agent, which probably forms the moft important part of our conftitution. Electricity is an active principle, which is neither generated nor deftroyed; which is every where, and always prefent, though latent and unobferved; 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 that deſcends in a ſtorm is ſtrongly impregnated with electricity, and thus brings down what the heated vapours carried up into the air, till the deficiency of the earth is ſupplied from the ſuperfluity of the heavens. A variety of other cauſes concur to vary continually the equilibrium of this fluid; as the perpetual inteſtine and oſcillatory motion, which contributes ſo much towards carrying on the operations of nature. Further, if a particular portion of this fluid is diſtributed to every ſubſtance, then every alteration of its capacity, which is continually changing by heat or cold, muſt move or operate on it.

As heat, or fire in action is the firſt mover in the animal machine, and the chief active principle during its exiſtence, and as electricity exhibits ſo many phænomena, which cannot be diſtinguiſhed from thoſe of fire, we are natually 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 aſcer-

tains

tains the quantity which is acting in a peculiar manner.

It is known that this vivifying principle haſtens the vegetation of plants. Myrtle-trees, which were electrified, budded ſooner than others of the ſame kind and ſize, and in the ſame green-houſe. Seeds, daily electrified, have ſhot up, and grown more in three or four days than others of the ſame kind, and alike in all other circumſtances, have done in eleven or twelve days. In the ſame manner Mr. Achard has ſhewn, that it may be uſed as a ſupplement for heat, to hatch the chickens 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

are arrefted by the earth; an idea which is ftrongly corroborated by the obfervations made on atmofpherical 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 exiftence in animated nature, has been fully proved by the experiments that have been made on the torpedo and the Gymnotus Electricus; for the fimilitude eftablifhed between the electrical fluid of the Torpedo and that of nature at large, is fuch, that, in a phyfical fenfe, they may be confidered as precifely the fame. Mr. Hunter has well obferved, fays Sir J. Pringle, and I think he is the firft who has made the obfervation, that the magnitude and number of the nerves beftowed on thofe electric organs in proportion to their fize, muft appear as extraordinary as their effects; and that, if we except the important organs of our fenfes, there is no part, even of the moft perfect animal, which, for its fize, is more liberally fupplied with nerves than the Torpedo: nor yet do thefe nerves of the electric organs feem neceffary for any fenfation that can belong to them: and with refpect to action, Mr. Hunter obferves, that there is no part of any animal, however ftrong and conftant its action may be, which enjoys fo large a portion of 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, 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. Add to this the eaſe with which the natural equilibrium is deſtroyed, and we may readily conceive, that any alteration in the quantity or intenſity of action of this powerful fluid will produce correſponding changes in the habit or health of the body: the following is a remarkable inſtance of the agen-

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

cy of the fluid in the human frame, and of the eafe with which it is put in action. Mr. Brydone mentions a lady, who, on combing her hair in frofty weather in the dark, had fometimes obferved fparks of fire to iffue from it; this made him think of attempting to collect the electrical fire from hair alone, without the affiftance of any other electrical apparatus. To this end, he defired a young lady to ftand on wax, and comb her fifter's hair, who was fitting in a chair before her; foon after fhe had begun to comb, the young lady on the wax was furprifed to find her whole body electrified, and darting out fparks of fire againft every object that approached her. Her hair was ftrongly electrical, and affected an electrometer at a confiderable diftance. He charged a metallic conductor from it, and in the fpace of a few minutes collected a fufficient quantity of fire, to kindle common fpirits, and, by means of a fmall jar, gave many fmart ftrokes to all the company.

Mr. Cavallo obtained, by means of a fmall condenfing plate, very fenfible figns of electricity from various parts of his own body, and the head of almoft any other perfon.

When the difcoveries in this fcience, fays Mr. Brydone, are further advanced, we may find, that what we call fenfibility of nerves, and many ny 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 ſurpriſing, if it is from the different ſtate of this fire in the human body, that the ſtrictum and laxum proceeds, and not from any alteration in the fibres themſelves, or their being more or leſs braced up, (among which bracers cold has been reckoned one) though the muſcular parts of an animal are more braced when they are hot, and relaxed when they are cold.

Mr. Jalabert and Profeſſor Sauſſure, when paſſing the Alps, were caught among thunder-clouds, and found their bodies full of

electrical

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.

The perpetual electricity of the atmosphere is no longer a problem: the existence and continual agency of it in that mass of air which surrounds our globe has been ascertained by numerous clear and decisive experiments, and it seems by no means improper to infer, that this fluid cannot exist in the atmosphere without exerting a certain influence on all the beings contained in it, and principally on organized bodies, among which man holds the highest rank.

## EXPERIMENT CCX.

Pass the charge of a large jar, or battery, from the head to the back of a mouse; this, if the shock is sufficiently strong, will kill the animal. After its death, make the discharge in the same manner, and the fluid will pass visibly

ſibly over the body, and not through it; evincing, 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 œcnoomy, as well as electricity.

The following experiment ſhews, that the electric fluid paſſes through that ſeries of muſcles which form the ſhorteſt paſſage for it, and whoſe conducting power, or electric capacity, is moſt favourable to it.

### EXPERIMENT CCXI.

Let A graſp a Leyden phial with his right hand, and touch, with a braſs rod held in his left hand, the naked right foot of B; let the left foot of B communicate by a braſs rod with the right foot of C; let D with his right hand hold the left ear of C, and touch the knob of the bottle with his left hand: A will feel the ſhock in the muſcles of the right hand and arm, of the thorax, and of the left hand and arm; B will feel the commotion in the muſcles of his right foot, right leg and thigh, and thoſe which

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;

* Dr. Cullen ſays, that Electricity, when properly applied, is one of the moſt powerful ſtimulants that can be uſed to act upon the nervous ſyſtem of animals.

or,

or, that the progrefs of the cure has often been ftopped by the impatience, or prejudice, of the difeafed: but at the fame time, it muft be acknowledged, that even in its infancy, when it had to combat againft fear, prejudice, and intereft, its fuccefs was truly great: we have furely then the higheft reafon to expect a confiderable increafe of fuccefs, now that it is cultivated and promoted by profeffional men of the firft merit.

## EXPERIMENT CCXII.

This experiment fhews, that the electric powers may be put in action by heat and cold. It was originally made by Mr. Canton. He procured fome thin glafs balls, of about an inch and a half diameter, with ftems or tubes, of eight or nine inches in length, and electrified them, fome pofitively on the infide, others negatively, and then fealed them hermetically; foon after he applied the naked balls to his electrometer, and could not obferve the leaft fign of their being electrical; but holding them at the fire, at the diftance of five or fix inches, they became ftrongly electrical in a fhort time, and more fo when they were cooling. Thefe 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 CCXIII.

Insulate a sensible mercurial thermometer, and place the bulb between two balls of wood, one affixed to the conductor, the other communicating with the ground, and the electric fluid, in passing between the two balls, will raise the mercury in the thermometer considerably. With a cylinder of about seven inches and a half in diameter, the fluid passing from a ball of lignum vitæ to a ball of beech, and thence to the ground, elevated the quicksilver in the thermometer from 68° to 110°, repeatedly to

105.

105. The thermometer was raiſed from 68° to 85°, by the fluid paſſing from a point of box to a point of lignum vitæ; from 67° to 100°, from a point of box to a ball of box; from 66° to 100°, from a ball of box to a braſs point; from 69° to 100°, from ball to ball; the bulb of the thermometer covered with flannel.

Mr. Morgan, in his examination of Dr. Crawford's Theory of Heat, was the firſt perſon who proved that the mercury in the thermometer might be raiſed by electricity.

The public have long expected that ſome ſyſtem of the application of Medical Electricity would be produced; but the gentlemen into whoſe hands the chief practice has fallen, know the fallacy of ſyſtems too well to hazard any which is not built on experience.

In a ſhort courſe of lectures which were read on this ſubject laſt winter by Mr. Birch, ſomething like a ſyſtem was thrown out for the conſideration of future electricians. The application of electricity to medicine was divided into three forms; namely, the fluid, the ſpark or friction, and the ſhock. The firſt mode he conſidered to act as a Sedative, the ſecond he ranked under the title of a Stimulant, and the laſt as a Deobſtruent. As the diſtinctions were the reſult of many experiments and much obſervation, they may ſafely be adopted for the preſent. That gentleman being now engaged in the practice of a great hoſpital, where his electrical experiments have already gained ſome reputation, we may hope the ſcience will be more univerſally diffuſed, and being taught under the cautious eye of public ſcrutiny, we may truſt its merits will ſoon give it an eſtabliſhed rank in the art of healing.

From hence we may perceive that in medicine, electricity is applicable to palſies, rheumatiſms, intermittents; to ſpaſm, obſtruction, and inflammation. In ſurgery it has conſiderable ſcope for action; where contractions and ſprains, tumours, particularly of the glandular ſort, waſting of the muſcles, and other incidents, form a catalogue of viſible diſeaſes as diſtreſſing to the ſight of others as to the patients themſelves. The gout, and the ſcrophula, or king's evil, two diſeaſes which have tormented mankind, and been the diſgrace of medicine to the preſent time, are ranked among thoſe to which this remedy is applicable; and in the commencement of the complaints, I am informed, has been wonderfully ſucceſsful. To remove ill-placed fits of the gout, it ſhould ſeem to be a more rational application than any medicine,

dicine, 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, 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 rarified or condenſed, confined to one ſpot, or applied in a more diffuſive manner, at the diſcretion of the operator.

THE APPARATUS NECESSARY FOR THIS PURPOSE IS SIMPLE, AND CONSISTS OF THE FOLLOWING ARTICLES:

1. An electrical machine, with an inſulated cuſhion, properly conſtructed to afford a continued and ſtrong ſtream of the electrical fluid. (The machine repreſented in the plate which faces the title-page of this Eſſay, is the kind which Mr. Birch recommended to medical practitioners in his lectures.)

2. A ſtool with inſulating feet, or rather an arm chair fixed on a large inſulating ſtool. The inſide part of the back of the chair ſhould move on a hinge, that it may occaſionally let down to electrify conveniently the back of the patient: the arms of the chair ſhould alſo be made longer than uſual.

3. A Leyden bottle with an electrometer.

4. A pair of large directors, with glaſs handles, and wooden points.

5. A few glaſs tubes of different bores, ſome of them with capillary points.

To theſe may be added, an univerſal diſcharger on a large ſcale, a pair of ſmall directors with ſilver wires, and a pair of inſulating forceps.

Fig. 93 repreſents the directors; the handles are of glaſs. A is a braſs wire with a ball on 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.

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.

Fig. 86 repreſents the electric forceps: ſome gentlemen think it is a very convenient inſtrument for communicating a ſhock. Its uſe is evident from an inſpection of the figure.

Fig. 85 is the medical bottle, furniſhed with an 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 ſtronger in proportion as the diſtance between the two balls is increaſed.

It is obvious, that when the electrometer is thus connected, it acts in the ſame manner as a common diſcharging rod, and forms the communication between the outſide and the inſide of the bottle; with this difference only, that the diſtance of the end which is to communicate with the inſide may be limited and regulated.

It

It has been found more convenient, to ſeparate the electrometer from the bottle, and apply it to the conductor: ſee in the frontiſpiece to this Eſſay, where *a*, *b*, repreſents the electrometer, *c*, *d*, the Leyden bottle, ſuſpended at a ſmall diſtance from it; a glaſs tube *e*, *f*, is fixed in this bottle, a ſmall part of the lower end of which is coated; two wires paſs through the braſs ball C on the top of this tube, one of which goes down to the bottom of the exterior bottle, and touches its internal coating, the other only goes to the coating of the tube: theſe wires may be removed at pleaſure. The bottle is to be ſuſpended to the conductor by the ring, and a chain or wire is to be fixed to the hook *d*, at the bottom.

Fig. 119, Pl. V. repreſents the bottle director which is hollow and coated like a common bottle, acting in all reſpects like one, but is convenient from its ſhape and ſome other circumſtances in giving ſmall ſhocks.

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.

Fig. 87 repreſents an univerſal diſcharger upon

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 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

as to occaſion the wires to touch the table, paſs a ſmall glaſs tube over them, which will prevent a diſſipation of the fire.

ELECTRICITY MAY BE APPLIED MEDICALLY IN THE FOLLOWING DIFFERENT MODES.

Firſt, By merely placing the patient in an inſulated chair, and connecting him with the prime conductor; when the machine is in action, he will be filled with the electric fluid, which will be continually diſſipated from the points and edges of his cloaths: and though the effects of this are probably too ſlow to be rendered very advantageous, yet, a ſedentary perſon might perhaps derive ſome benefit from ſitting in an inſulated chair, having before him an inſulated table; the chair to be connected with the ball of a large charged jar or battery, by which means a ſmall quantity of the fluid will be continually paſſing through thoſe innumerable capillary veſſels, on the right ſtate of which our health ſo much depends.

2. BY THROWING THE FLUID UPON, OR EXTRACTING IT FROM A PATIENT, BY MEANS OF A WOODEN POINT.

This may be effected in a twofold manner: 1ſt, By inſulating the patient and connecting him either with the cuſhion or the poſitive prime

prime conductor, the operator presenting the point. 2nd, Let the patient stand upon the ground, and the wire of the director be connected either with the positive or negative parts of the machine. The sensation produced by the fluid when acting in this manner, is mild and pleasing, resembling the soft breezes of a gentle wind; generating a genial warmth, and promoting the secretion and dissipation of tumors, inflammations, &c.

### 3. BY THE ELECTRIC FRICTION.

Cover the part to be rubbed with woollen cloth or flannel. The patient may be seated in an insulated chair, and rubbed with the ball of a director that is in contact with the conductor: or he may be connected with the conductor, and rubbed with a brass ball which communicates with the ground. The friction thus produced is evidently more penetrating, more active, and more powerful than that which is communicated by the flesh brush; and there is, I apprehend, very little fear of being thought too sanguine, if I assert, that this, when used but for a few minutes, will be found more efficacious than the other, after several hours application.—Electricity applies here with peculiar

culiar propriety to ſpaſm, pleuriſy and ſome ſtages of the palſy, and in every caſe anſwers the end of bliſtering where the diſcharge is not wanted, being the moſt ſafe and powerful ſtimulant we know.

### 4. BY TAKING STRONG SPARKS FROM THE PATIENT.

Here, as in every other caſe, the operator may connect the ball of the director with the poſitive or negative conductor, or he may connect the patient with either of theſe and the ball with the ground; now it is clear from what has been already laid down, that if the director be connected with the poſitive conductor, the fluid is thrown upon the patient, if with the cuſhion, the fluid is extracted from him. Let the patient be inſulated, and the action is in ſome meaſure reverſed; if he is joined to the negative conductor or cuſhion, he will receive a ſpark from a perſon ſtanding on the floor, but if he communicates with the poſitive conductor he will give the ſpark to the perſon on the ground.

5. BY CAUSING A CURRENT OF THE ELECTRIC FLUID TO PASS FROM ONE PART OF THE BODY, AND THUS CONFINING AND CONCENTRATING ITS OPERATION WITHOUT COMMUNICATING THE SHOCK.

Place the patient in an inſulated chair, and touch one part of the body with a director, joined to a poſitive conductor; then with a braſs ball communicating with the ground, touch another part, and when the machine is in action the fluid will paſs through the required part, from the conductor to the ball; the force of the ſtream will be different according to the ſtrength of the machine, &c. Or connect one director with the cuſhion and the other with the poſitive conductor, and apply theſe to the part through which the fluid is to paſs, and when the machine is in action the electricity will paſs from one ball to the other. It is not neceſſary to inſulate the patient in this caſe.

6. BY THE SHOCK.

Which may be given to any part of the human body, by introducing that part of the body into the circuit which is made between the outſide and

and inſide of the bottle. This is conveniently effected, by connecting one director by a piece of wire with the electrometer, and the other with the outſide of the bottle; then hold the directors by their glaſs handles, and apply the balls of them to the extremity of the parts through which the ſhocks are to be paſſed. The force of the ſhock, as we have already obſerved, is augmented or diminiſhed by increaſing or leſſening the diſtance between the two balls, which muſt be regulated by the operator to the ſtrength and ſenſibility of the patient. When the little bottle with the glaſs tube is uſed as a common bottle both wires are to be left there, and the ſhock is communicated by two directors, one connected with the bottom, the other with the top by means of the electrometer. (See the plate facing the title-page of this eſſay). The operator will often find himſelf embarraſſed in giving ſmall ſhocks, the fluid paſſing from the conductor to the ball of the electrometer, inſtead of going through the circuits he deſires: when this happens, which may be known by the chattering noiſe of the ſpark in paſſing to the electrometer, the reſiſtance formed to the diſcharge is ſo great that the fluid cannot force its way through the circuit; to remedy this, and leſſen the reſiſtance, paſs two metallic pins through the clothing, ſo that they may be in contact with the ſkin, which will leſſen the reſiſtance and conduct the fluid.

7. BY A SENSATION BETWEEN A SHOCK AND THE SPARK, WHICH DOES NOT COMMUNICATE THAT DISAGREEABLE FEELING ATTENDING THE COMMON SHOCK.

This is effected by taking out the long wire from the ſmall medical, and leaving the ſhorter one which is connected with the tube in its place, the directors to be connected and uſed as before. In leſſening this vibratory ſhock the electrometer may be drawn to a much greater diſtance; for the rapidity with which the charge of the bottle ſends forward the charge of the tube is ſufficient to overcome the reſiſtance of a large body of air. The effect of this ſpecies of ſhock, if it may be called one, is to produce a great vibration in the muſcular fibres, without inducing that pungent ſenſation which the ſhock effects. It is therefore applicable to ſome ſtages of palſy and rheumatiſm; it may alſo ſerve as an artificial means of exerciſe.

8. BY

### 8. BY THE BOTTLE DIRECTOR.

Insulate the patient, and place the ball *g* in contact with him, by which means this director is charged. Now if a wire is conveyed from the bottom of this to the top of another director, the bottle director Fig. 119, Pl. V. will be discharged whenever the ball *h* is brought in contact with the patient, so that by bringing it down with rapidity any number of sparks may be procured in a minute. Or connect the insulated patient with the top or inside of a large charged jar, and then this apparatus used in the foregoing manner will discharge, from the large jar at each spark, its own contents, and by repetition discharge the whole jar; thus a number of shocks may be given without continually turning the machine or employing an assistant.

### 9. BY PASSING THE WHOLE FLUID CONTAINED IN THE LEYDEN PHIAL THROUGH A DISEASED PART WITHOUT GIVING THE SHOCK.

Connect a director by means of a wire, with the ball of a Leyden jar; charge the jar either completely or partially, and then apply the ball or point of the conductor to the part intended to be electrified, and the fluid which was 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. Or inſulate the patient, connect him with the top of a jar, charge this, and then apply a metal wire or piece of wood to the part through which you mean to make the fluid paſs. It is obvious, that in this caſe the circuit between the inſide and the outſide of the jar is not completed, therefore the ſhock will not be felt. The condenſed fluid paſſes in a denſe ſlow ſtream through the required part, while the outſide acquires a ſufficient quantity from ſubſtances near it to reſtore the equilibrium.

It is in all caſes moſt adviſable to begin with the more gentle operations, and proceed gradually to increaſe the force, as the ſtrength and conſtitution of the patient, or the nature of the diſorder requires. The ſtream from a wooden point, a wooden ball, or braſs point, may be firſt uſed; ſparks, if neceſſary, may then be taken, or ſmall ſhocks given.

In rheumatic cafes, the electric friction is generally ufed. If the pains are local, fmall fhocks may be given. To relieve the tooth-ach, very fmall fhocks may be paffed through the tooth; or, cover the part affected with flannel, and rub it with a director, communicating with the machine.

In inflammations, and other diforders of the eyes, the fluid fhould be thrown from a wooden point: the fenfation here produced is that of a gentle cooling wind; but, at the fame time, it generates a genial warmth in the part affected.

In palfies, the electric friction and fmall fhocks are adminiftered. Streams of the fluid fhould always be made to pafs through the affected part.

The only treatife we have yet had from the Faculty, on the fubject of Medical Electricity, 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 intitled to the attention of practitioners; but we have reason to expect much more from it, since the prejudices of the Faculty seem removed, and the practice is becoming more general every day.

## CHAP. 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

with common gun-powder 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 gun-powder the moment it was applied; at others, it would require half a minute or more before it took effect. This difference in time was 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 CCXIV.

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 the phial, and the gun-powder will be fired by the paſſage of the electric ſtream through the

the cartridge. Tinder, or touch-wood, placed in a metal cup, may be lighted by paſſing the ſtream from the inſide of the jar through them, as in the foregoing experiment, without completing the circuit.

As it therefore appears, that the electric fluid, when it moves through bodies, either with great rapidity, or in great quantities, will ſet them on fire, it is ſcarce diſputable, that this fluid is the ſame with the element of fire.

### EXPERIMENT CCXV.

To fire the ſmall electrical cannon, charge it with gun-powder in the uſual manner, then fill the ivory touch-hole with gun-powder, ram it well down, and puſh the braſs pin down, ſo that the end of it may be near the bottom of the hole; make a communication between the outſide of a large charged jar or battery and the body of the cannon, by placing one end of the diſcharging rod on the pin which paſſes down the touch-hole, and bring the other end to the knob of the jar, and the diſcharge will fire the powder.

### EXPERIMENT CCXVI.

Fig. 89 is a perſpective view of the powder-houſe; the ſide of the roof next the eye being omitted

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 CCXVII.

Fix the ladle I, fig. 33, into a hole at the end of the conductor. Place a broad piece of camphor in the ladle, ſet the upper ſurface of the camphor on fire, let it burn ſome time, then extinguiſh it, and put the machine in action; the upper ſurface of the camphor will throw out a variety of ſmall ſhoots, and have the appearance of an imperfect vegetation, which is ſoon diſperſed in the air if the machine is continued in action, but will laſt ſome time if the electrization is ſtopped as ſoon as the ſhooting of the camphor has taken place.

EXPERIMENT CCXVIII.

Wrap ſome looſe cotton, which has been previouſly rolled in fine powder of yellow reſin, round one of the balls of a diſcharging rod, and hold the other end to the 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

contain the inflammable air, B a glaſs baſon, or reſervoir, to hold water; D is a cock, which is to form occaſionally a communication between the reſervoir of water B, and that of air A; the water paſſes into the latter through the metal pipe *g g*, which is fixed to the upper part of the reſervoir A: at *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 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

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 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 electrophorus, 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 42 of this Eſſay.

EXPERIMENT CCXIX.

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 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, rarified 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 CCXX.

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 CCXXI.

Charge a Leyden phial, (the top of which is cemented into the bottle) place it upon an inſulated ſtand, and then take hold of it by the ball, and preſent the coated ſurface towards the condenſing ball of a prime conductor while the

* Cavallo on Medical Electricity, p. 117.

cylinder

cylinder is charging, and a large bruſh and ſpark will paſs between the coating of the bottle and the ball of the conductor, from four to twelve inches and upwards in length.

EXPERIMENT CCXXII.

Take ſome of the powder of Canton's phoſphorus, and by means of a little ſpirit of wine, ſtick it all over the inſide of a clean glaſs phial, then ſtop the bottle, and keep it from the light. To illuminate this phoſphorus, draw ſeveral ſtrong ſparks from the conductor, keeping the phial about two or three inches from the ſparks, ſo that it may be expoſed to their light; the phial will afterwards appear luminous, and remain ſo for a conſiderable time.

EXPERIMENT CCXXIII.

Cut out in paſteboard or ſoft wood, the figure of a creſcent or any of the planets; cover this equally with the white of an egg beat up till it is quite ſmooth, over which ſift the phoſphorus through a fine lawn ſieve, then let it dry, and blow off all that is not fixed by the egg. To make the experiment, place the

the object in the communication between two directors, and difcharge the jar, when the whole will become beautifully luminous, care muft however be taken to hold the directors at a little diftance above the phofphorus, for if it paffes through it, the whole of the powder in the track of the fluid will be torn off.

Place a fmall key on the phofphorus, and difcharge a Leyden phial over the phofphorus, 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 feen.

As the experiments on phofphorus are in themfelves exceedingly curious, and appear to me to be intimately connected with the nature of electricity, I hope I fhall not be thought to have deviated too far from the fubject of this effay by introducing fome experiments of Mr. Wilfon on this fubject; the more fo, as the producing the prifmatic colours is by no means difficult, as little more is required than a few oyfter-fhells, and a good fire of any kind. For, if thofe fhells are thrown carelefsly into the middle of the fire, and continued there for aproper time, (which may be from ten minutes, a quarter, half, or three quarters of an hour, according to the thicknefs and compactnefs of the fhells, and the degree of fire they are expofed to) they will exhibit lively prifmatic colours, after they are removed from the fun into the dark fuddenly, and the eyes have been previoufly prepared a little to receive them. Mr. Wilfon excited alfo the light of thefe fhells with electricity in the following manner.

EXPERIMENT CCXXIV.

He placed upon a metal ftand, which was rounded at top, and about half an inch in diameter, a prepared fhell, that would exhibit the prifmatic colours very lively on the upper furface of this fhell, 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 difcharge the fluid. In this circuit there was left, defignedly, an interval of about three inches, unoccupied by metal, and next one fide of the glafs; the difcharge was made by compleating the circuit with metal where the interval was left. The fhell, at that inftant, was lighted up to an exceeding great advantage, fo that all the colours appeared perfectly diftinct, and in their refpective places, anfwering to their different

colour-

colour-making parts. Thefe colours continued vifible feveral minutes, and when they ceafed to appear, a white purplifh light occupied their places, which lafted for a confiderable time. And notwithftanding this experiment was repeated with the fame and other fhells, the colours continued in their refpective places, and nearly of the fame degree of brilliancy; excepting, that in or near thofe parts where the explofion took place a few fcales were driven off.

## EXPERIMENT CCXXV.

Which proves, that bodies of the fame nature, but of different volumes and different maffes, are charged with electrical matter only in proportion to their furface, without any influence or concurrence of their maffes in this cafe.

The following experiment, which we fhall give in Mr. Achard's own words, feems to decide this queftion, on which philofophers have entertained very different opinions.

I electrified (fays he) a cylindrical, hollow brafs conductor, feven inches long, and one and a half in diameter: when it had acquired forty degrees of electricity, I drew from it a

 fpark,

ſpark, with a conductor of hollow braſs, of ſeven inches long, and one and a half in diameter, which weighed eight ounces, and was carefully inſulated. The firſt conductor loſt fifteen degrees of 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, 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,

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

EXPERIMENT CCXXVI.

Take out the upper cork and wire; pour ſome ſallad oil into this tube, and then fit in the cork, and puſh down the wire, ſo that the end of it may be near or rather below the ſurface of the oil; preſent the ball towards a prime conductor, holding the finger or any other non-conductor oppoſite the bent end of the wire, and when a ſpark paſſes from the conductor to the braſs ball, another will paſs from the end of the wire, and perforate the glaſs; the oil will be curiouſly agitated.

This experiment appears more beautiful when it is made in the dark. After the firſt hole is made, turn the end of the wire round towards another part of the glaſs tube, and a ſecond hole may be made in the ſame manner. This experiment was communicated to me by the Rev. Mr. Morgan, of Norwich, who has carried it much farther, by filling ſmall bottles with cement, and then paſſing the ſhock in a ſimilar mode through them. The perforation may be made with water in the tube inſtead of oil.

Mr. Lullen produces very conſiderable effects by paſſing the ſhock through wires that were inſerted in tubes filled with oil. The ſpark appears larger in its paſſage through oil, than when it paſſes through water.

Mr. Vilette filled a diſh of metal with oil, and when he had electrified the diſh, he plunged a needle into the oil, and received a very ſtrong ſpark as ſoon as the point of it came within a ſmall diſtance of the diſh. A ſmall cork ball being made to ſwim in this oil, upon the approach of the thick end of the ſtalk of a lime, it plunged to the bottom, and immediately roſe up again.

Analogous to this experiment of Mr. Morgan are ſome obſervations of Dr. Prieſtley, who conſtantly found, that whenever he had covered the fractured place of a jar with any kind of cement or varniſh, it always broke at the place where the cement terminated; there the glaſs was perforated, and a new fracture was made, which had no communication with the former. The jar always broke at the firſt charge, generally before it had received half its charge. Struck with this phenomenon, the Doctor proceeded to try the experiment on a

jar

jar which was not broken, and whofe ftrength he had previoufly afcertained by repeated difcharges: he took off a little of the outfide coating, and put on the glafs a patch of cement, about an inch in diameter, then drawing the coating over it, he charged the jar, but before it had received half its charge, it burft by a fpontaneous explofion, not indeed at the termination, but at the middle of the patch of cement, where the glafs was thinneft. He covered another entirely with cement, and it broke near the bottom, where the glafs is generally thickeft. A jar that was covered entirely both infide and outfide with cement, and then coated with tin-foil, burft at the very firft attempt to charge it.

## EXPERIMENT CCXXVII.

The magic picture is a COATED pane of glafs, proper to anfwer the purpofe of the Leyden experiment; over the coating on one fide is pafted a picture, on the other fide a piece of white paper is pafted, fo as to cover the whole glafs; it is then put into a frame, with the picture uppermoft, and a communication is formed from the tin-foil of the under fide to the bottom

rail

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 CCXXVIII.

Put a quantity of braſs duſt into a coated jar, and when it is charged invert it, and throw ſome of the duſt out, which will be ſpread in an equable and uniform manner on any flat ſurface, and fall juſt like rain or ſnow. May it not be queſtioned, ſays an ingenious writer, whether water, falling from the higheſt region of the clouded atmoſphere, would not meet the earth in much larger drops, or in cataracts, if the coaleſcing power of the drops was not counteracted by their electric atmoſpheres?

## EXPERIMENT CCXXIX.

Place a piece of ſmoking wax-taper on the prime conductor; turn the cylinder; the volume of ſmoke will become more contracted, and 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 CCXXX.

Take a round board, well varniſhed, and lay on it a chain in a ſpiral form; let the interior end of the chain paſs through the board, and connect it with the coating of a large jar; fix the exterior end to a diſcharging rod, and then diſcharge the jar; a beautiful ſpark will be ſeen at every link of the chain. The illuminations to be produced by a chain are capable of an infinite variety of modifications.

EXPERI-

EXPERIMENT CCXXXI.

Place ſpots of tin-foil, at equal diſtances from each other, on a piece of bent glaſs, and let the ends of the glaſs be furniſhed with braſs balls, and a glaſs handle be fixed to the middle of the bent glaſs. The inſtrument will ſerve as a diſcharger, and at the ſame time exhibit, at each ſeparation of the tin-foil, the electric light.

I made ſeveral of theſe luminous diſcharging rods, many years ſince, in order to ſhew, that the electric fluid iſſues from the negative and poſitive coating of each diſcharge, agreeable to the idea conveyed by Mr. Atwood's experiments; ſee Exp. CXX, CXXI, CXXII, of this Eſſay. But I ſoon found, that the circuit of a diſcharging rod was not ſufficiently extenſive for the purpoſe.

EXPERIMENT CCXXXII.

Fig. 98 repreſents ſeveral ſpiral tubes, placed round a board; a glaſs pillar is fixed to the board, and on this pillar is cemented a metal cap, carrying a ſmall ſteel point; a braſs wire, furniſhed

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 CCXXXIII.

Suſpend a light cork ball, which is covered over with tin-foil or gold-leaf, by a pretty long ſilk thread, ſo as juſt to touch the knob of a charged jar placed on a table; it will be firſt attracted and then repelled to ſome 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

of the phial, the cork will inftantly be agitated, and, after fome irregular motions, will defcribe a curve round the knob of the phial, and this it will continue to do for fome time.

Fig. 96 and 97 reprefent an electrometer, nearly fimilar to that contrived by Mr. Brooke. The two inftruments are fometimes combined in one, or ufed feparately, as in thefe figures. The arms F H f k, fig. 97, when in ufe, are to be placed as much as poffible out of the atmofphere of a jar, battery, prime conductor, &c. The arm F H and the ball K are made of copper, and as light as poffible. The divifions on the arm F H are each of them exactly a grain. They are afcertained at firft by placing grain weights on a brafs ball which is within the ball L, (this ball is an exact counterbalance to the arm F H and the ball K when the fmall flide r is at the firft divifion) and then removing the flide r till it, together with the ball K, counterbalances the ball L and the weight laid on it.

A, fig. 69, is a dial-plate, divided into 90 equal parts. The index of this plate is carried once round, when the arm B C has moved through 90 degrees, or a quarter of a circle. That motion is given to the index by the repul-

five

five power of the charge acting between the ball D and the ball B *.

The arm B C being repelled, shews when the charge is increasing, and the arm F H shews what this repulsive power is between two balls of this size in grains, according to the number the weight rests at when lifted up by the repulsive power of the charge: at the same time the arm B C points out the number of degrees to which the ball B is repelled; so that by repeated trials, the number of degrees, answering to a given number of grains, may be ascertained, and a table formed from these experiments, by which means the electrometer, fig. 96, may be used without that of fig. 97.

Mr. Brooke thinks that no glass, charged (as we call it) with electricity, will bear a greater force, than that whose repulsive power, between two balls of the size he used, is equal to sixty grains: that in very few instances it will stand sixty grains weight; and he thinks it hazardous to go more than forty-five grains.

Hence, by knowing the quantity of coated surface, and the diameter of the balls, we may be enabled to say, so much coated surface, with a repulsion between balls of so many grains,

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

will

will melt a wire of ſuch a ſize, or kill ſuch an animal, &c.

Mr. Brooke thinks, that he is not acquainted with all the advantages of this electrometer; but that it is clear, it ſpeaks a language which may be univerſally underſtood, which no other will do; for though other electrometers will ſhew whether a charge is greater or leſs, by an index being repelled to greater or ſmaller diſtances, or by the charge exploding at different diſtances, yet the power of the charge is by no means aſcertained: but this electrometer ſhews the force of the repulſive power in grains; and the accuracy of the inſtrument is eaſily proved, by placing the weights on the internal ball, and ſeeing that they coincide with the diviſions on the arm F H, when the ſlide is removed to them.

Mr. Achard has ſhewn clearly, that if the ſcale of an electrometer is divided into equal parts (degrees for example) the angle at which the index is held ſuſpended by the electric repulſion will not be a true meaſure of the repulſive force; to eſtimate which truly, he demonſtrates that the arc of the electrometer ſhould be divided according to a ſcale of arcs, the tangents of which are in arithmetical progreſſion.

## OBSERVATIONS AND EXPERIMENTS MADE BY DR. PRIESTLEY ON THE EFFECTS OF ELECTRICITY ON DIFFERENT ELASTIC FLUIDS.

### EXPERIMENT CCXXXIV.

To change the blue colour of liquors, tinged with vegetable juices, red. The apparatus for this purpoſe is ſeen in fig. 94. AB 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 diſcompoſed 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

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. 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

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 concuſſion given to it by the exploſion; and that, if it be the calx of the metal which ſupplied the phlogiſton, it is not to be diſtinguiſhed from what metal, or indeed from what ſubſtance of any kind, the air had been extracted.

Dr.

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 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 explofions of a common jar, each of which might be produced in lefs than a quarter of a minute with the fame machine in the fame ftate, the whole of the infide of the tube was compleatly covered with the black matter. Now had the electric matter formed any union with the air, and this black matter had been the refult of that combination, all the difference that would have arifen from the fimple fpark or the explofion, could only have been a more gradual, or a more fudden formation of that matter.

A large phial, about an inch and a half wide, being filled with this air, the explofion of a very large jar, containing more than two feet of coated furface, had no effect upon it; from which it fhould feem, that in thefe cafes, the force of the fhock was not able to give the quantity of air fuch a concuffion as was neceffary to decompofe any part of it.

He had generally made ufe of copper, but afterwards he procured this air from almoft every fubftance from which it could be obtained; the electric explofion taken in it produced the fame effect. But, as fome of the experiments were attended with peculiar circumftances, he briefly mentions them, as follows.

When

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 ſomething that had adhered to the ſhot. However, in the air ſo produced, he took the electric exploſion; and in the firſt quantity he tried, a whitiſh matter was produced, almoſt covering the inſide of the tube; but in the ſucceeding experiments, with air produced from the ſame ſhot, or from ſomething adhering to it, there was leſs of the whitiſh matter; and at laſt, nothing but black matter was produced, as in all the other experiments. Water being admitted to this air, there remained a conſiderable reſiduum, which was very ſlightly inflammable.

Vitriolic acid air is eaſily procured from ſpirit of wine, the mixture becoming black before any air is yielded. The electric exploſion taken in this air alſo produced the black matter.

The experiments made with ether ſeem to throw moſt light upon this ſubject, as this air is as eafily procured from ether as any other fubftance, containing phlogifton. In the air procured by ether the electric explofion tinged the glafs very black, more fo than in any other experiment of the kind; and, when water had abforbed what it could of this air, there was a refiduum in which a candle burned with a lambent blue flame. But what was moft remarkable in this experiment was, that befides the oil of vitriol becoming very black during the procefs, a black fubftance, and of a thick confiftence, was formed, which fwam on the furface of the acid.

It is very poffible, that the analyfis of this fubftance may be a means of throwing light upon the nature of the black matter, formed by electric explofions, in vitriolic acid air, as they feem to refemble one another very much.

The electric fpark or explofion, taken in common air, confined by quickfilver in a glafs tube, covers the infide of the tube with a black matter, which, when heated, appears to be pure quickfilver. This, therefore, may be the cafe with the black matter into which he fuppofed the vitriolic acid air to be converted by the fame procefs, though the effect was much more remarkable than in the common air. The 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 CCXXXV.

This curious experiment was made by Mr. Marsham, originally with a view to melt wires with a small Leyden bottle. The effects are curious, and seem to open a new field for investigating the force and direction of the electric fluid. He fixed a small piece of wax upon the outside coating of the Leyden bottle; the head of a small needle was stuck in the wax, so as to be at right angles to the coating; opposite to the point of this needle, and at half an inch distance, another needle was fixed, by being forced through the bottom of a chip box; this was connected with the discharging rod by a wire. On discharging the bottle, the needle

needle with the wax was driven from the coating of the bottle, and fixed into the box opposed to it. The distance between the needles was then increased to two inches and a half, which was the greatest striking distance. The head of the needle, which was fixed to the bottle, was evidently melted in two or three places. If the charge was strong, and the wax was not stuck fast to the coating of the bottle, both the wax and the needle would be driven some inches from the bottle. On placing a ball of wax on the point of each needle, and passing the discharge through them, the ball was thrown from that connected with the bottle full two feet. Repeating this again, he could not produce the same effect.

Mr. Marsham now fixed the needle, opposed to that on the bottle, with wax on a brass plate. On passing the charge through them, when the needles were half an inch distance from each other, the needle was thrown six inches from the brass plate, while the other remained in its situation. On increasing the distance, the effects were the same, till it came to one inch and a half, when neither were thrown off. In many instances, both were thrown off, leaving the wax behind them.

The needles in all these experiments passed through

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.

## EXPERIMENT CCXXXVI.

Cut a piece of India or thin paper, into the ſhape of an iſoſceles triangle, whoſe ſides are about two inches long, breadth two tenths of an inch; then erect a braſs ball of two or three inches diameter, on a braſs wire one ſixth of an inch diameter, and two feet ſix inches long, on the prime conductor; electrify the conductor, and then bring the obtuſe end of the pieces of paper within the atmoſphere of the ball, and let

it

it go, and the paper will revolve round the ball and often round its own axis. This pleaſing and exceeding curious experiment was communicated to me by the ingenious Mr. J. Gamble of Pembroke-Hall, Cambridge.

### EXPERIMENT CCXXXVII.

Electrify two pieces of ſwans down, one negatively, and the other poſitively; they will then float in the air, and may be eaſily driven about by bottles charged with contrary electricity; when brought near together, they will attract each other, meet with rapidity, their fibres will collapſe, and they will then fall to the ground, repreſenting in miniature what may be ſuppoſed often to happen in the higher regions of the atmoſphere.

### EXPERIMENT CCXXXVIII.

Inſulate a Leyden phial, and connect a ſet of electrical bells with the inſide of the phial, and another ſet with the outſide; charge the phial, and then touch the ſet of bells connected with the inſide; theſe will ceaſe ringing, and the other ſet will begin to ring: now touch theſe, and then the ſet connected with the inſide will

ring:

ring: and ſo on alternately till the bottle is diſcharged. Thus illuſtrating in a pleaſing manner the received theory of the Leyden phial.

A diſtinct apparatus is often fitted up for the performing of this experiment: or it may be ſhewn by means of the apparatus repreſented Fig. 49. Pl. III. which can eaſily be applied to a great variety of purpoſes, and is ſufficient for explaining moſt part of the phenomena relative to the Leyden phial, beſides being very convenient for ſeveral pleaſing experiments.

## ON THE ANALOGY BETWEEN THE PRODUCTION AND EFFECTS OF ELECTRICITY AND HEAT, AND ALSO BETWEEN THE POWER BY WHICH BODIES CONDUCT ELECTRICITY AND RECEIVE HEAT; WITH THE DESCRIPTION OF AN INSTRUMENT TO MEASURE THE QUANTITY OF THE ELECTRICAL FLUID, WHICH BODIES OF A DIFFERENT NATURE WILL CONDUCT, WHEN PLACED IN THE SAME CIRCUMSTANCES. BY MR. ACHARD *.

The production of heat is ſimilar to that of electricity.

Every kind of friction produces heat and

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

electricity.

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 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,

ticity, 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 increafe of the difference between the conducting power of thofe bodies.

2. That where two bodies are equally adapted to receive and tranfmit the electric fluid, they give no fign of electricity; not becaufe they cannot become electrified by friction, but becaufe the electricity, which is difturbed by the friction, is at the fame time reftored, on account of the facility with which it penetrates each fubftance. For a reafon nearly fimilar, electrics, when rubbed together, do not appear electrified.

It feems therefore, that we may conclude from this theory, which is founded on fact, that in all cafes, and whatever is the nature of the fubftance, the friction always produces electricity; and when the effect is not fenfible, it is only becaufe electricity is loft as foon as produced.

That there are no fubftances, that are rubbed againft a body, which tranfmit the electric fluid with greater or lefs difficulty, but what give figns of electricity: that metals are as electrical by themfelves as glafs and wax.

That

That as friction always, and in all cafes, 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 fhews its dilating power alfo; and if we do not generally perceive it, it is becaufe the force with which bodies cohere together exceeds the dilating power of electricity.

Heat promotes and accelerates vegetation as well as germination: Electricity, whether pofitive or negative, does the fame.

Electricity, as well as heat, accelerates evaporation.

Heat and electricity accelerate the motion of the blood *. Leaft fear, conftraint, or the attention to the experiment, might accelerate the pulfe and thus be attributed to electricity, Mr. Achard made the experiment on a dog when afleep, and always found, that the number

* This pofition has been much controverted, and it feems clear, from modern experiment, that fimple electricity does not accelerate the pulfe.

of

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 equal 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 of a certain time, the ſame degree of heat. There is a conſiderable difference, however, in the ſpace of time in which they acquire the temperature of the medium, ex. gr. metals take leſs time than glaſs, to acquire or loſe an equal degree of heat.

On an attentive examination of the bodies which receive and loſe their heat ſooneſt, when they are placed in mediums of different temperature, they will be found to be the ſame which receive and loſe their electricity with the greateſt facility. Metals which become warm or grow cool the quickeſt, are the ſubſtances which receive and part with their electricity ſooneſt. Wood, which requires more time to be heated or cooled, receives and loſes electricity ſlower than metals. Laſtly, glaſs and reſinous ſubſtances, which receive and loſe ſlowly the electric fluid, acquire with difficulty the temperature of the medium which ſurrounds them.

If one extremity of an iron rod is heated red-hot, the other extremity, though the bar is ſeveral feet long, will become ſo warm in a little time that the hand cannot hold it; becauſe the iron conducts heat readily; though a tube of glaſs, only a few inches long, may be held in the hand, even while the other end is melting. The electric fluid, in the ſame manner, paſſes with great velocity from one end of a rod of iron to the other; but it is a conſiderable time before a tube of glaſs, at one end of which an excited electric is held, will give electric ſigns at the other.

Theſe

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 faculty with which the body that touches it receives the electric fluid. Beſides the figure and volume of this ſubſtance, the time the two bodies remain in contact will alter the quantity taken from the electrified ſubſtance; ſo that all other circumſtances being the ſame, the property of bodies to deprive other bodies of their electricity, or, in other words, to conduct the electric fluid, is in the inverſe ratio of the time neceſſary to make them loſe an equal degree of electricity.

The inſtrument which is repreſented fig. 95 is conſtructed on theſe principles, and with it the quantity of electricity that one body loſes in a given time, when touched by another, may be accurately aſcertained. A B is a very ſenfible balance; at the extremity of each arm two very light balls of copper are affixed; C F D a divided femicircle, which is faftened to the cock which fupports 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 brafs cap, which is cemented on the glafs pillar G G, which is fixed to the board Q R S T; this pillar fhould be at leaft 18 inches high. U is a Leyden bottle; to the wire Z Z, which communicates with its infide coating, three horizontal wires, V Z, X Z, and Z Y, are fixed; the ends of thefe wires are furnifhed with hollow brafs balls; the bottle U is fo fixed to the board, that when the beam is horizontal, the ball B touches exactly the ball X, as is reprefented in the figure.

K N is a metal lever, which turns upon an axis at I, fo as to move freely in a vertical plane, which fhould coincide with the bar V X; the lever K N is fupported 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 fcrew, to hold the fubftance on which the experiment is to be made; the upper end of this fubftance fhould be turned into a convex form. A thread N O is tied to the end N of the lever; at O is a fmall hook, on which a ball I is to be fufpended.

The

The diſtance of the pillar I H from the bottle is to be ſo adjuſted, that when the end N is lowered, the body L may touch in one point the ball V; the proportion between the weight of the arms of the lever, the weight I and the body L, and the length of the pillar I H to the thread N O, is to be ſuch, that when the ſubſtance L         the ball V, at the ſame moment the ball P will touch the board Q R S T, and be diſengaged from the thread N O; the ſubſtance L will alſo at the ſame inſtant quit the ball V.

To uſe this inſtrument, connect the bottle U with the prime conductor by the ball Y, and form a communication by a wire from Y to the cap G; charge the bottle, and the ball X will 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 V, 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, only ſubſtituting ſome other ſubſtance in the place of the body L; ſuppoſe that with this ſubſtance the diminution of the angle is 8 degrees, then is the conducting power of these two substances in the proportion of five to eight.

Fig. 106 represents an apparatus, to set a wire on fire by the electric explosion in dephlogisticated air. I am obliged to defer the description and use of it to some future opportunity, as I have not had any time to try its success.

AN

AN

# ESSAY

ON

# MAGNETISM.

# ADVERTISEMENT.

THIS small Essay is published to illustrate and exemplify some uses of a Magnetical Apparatus, constructed in order to exhibit the general phænomena of Magnetism. It is extracted from a larger work, which is laid aside for the present, as it is probable the public will soon be favoured with a treatise on this subject by Mr. CAVALLO.

# AN ESSAY ON MAGNETISM.

THOUGH the phænomena of the magnet have, for many ages, engaged the attention of natural philosophers, not only by their singularity and importance, but also by the obscurity in which they are involved; yet very few additions have been made to the discoveries of the first 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 phænomena of the universe. Though it is certain that both natural and artificial electricity will give polarity to needles, and even reverse; from whence it would appear, that there is a considerable affinity between the electric and magnetic fluid, but how it acts when producing magnetism, is entirely unknown.

It is known by the works of Plato * and Aristotle, that the antients were acquainted with the attractive and repulsive powers of the magnet; but it does not 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 ad-

* "A power resembling that, which acts in the stone, "called by Euripides the magnet. For this stone does "not only attract iron rings, but impart to those rings the "power of doing that very thing which itself does, ena-"bling them to attract other rings of iron; so that sometimes "may be seen a very long series of iron rings, depending "as in a chain one from another. But from that stone "at the head of them is derived the virtue, which ope-"rates in them all." See Sydenham's translation of the IO of Plato.

vantage

vantage 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, LEADING STONE, OR NATURAL MAGNET, is an iron ore or ferruginous ſtone, found in the bowels of the earth, generally in iron mines; of all forms and ſizes, and of various colours. It is endowed with the property of attracting iron; and of both pointing itſelf, and alſo enabling a needle, touched upon it, and duly poiſed, to point towards the poles of the world.

Loadſtones are in general very hard and brittle, and for the moſt part more vigorous in proportion to their degree of hardneſs. Conſiderable portions of iron may be extracted from them. Newman ſays, that they are almoſt totally ſoluble in ſpirit of nitre, and partially in the vitriolic and marine acids.

Mr. Kirwan ſays, "That the magnet ſeems to contain a ſmall quantity of ſulphur, is often contaminated with a mixture of quartz and argill; it is poſſible, it may contain nickell, for this, when purified to a certain degree, acquires the

the properties of a magnet, but its conftitution has not as yet been properly examined *.

Artificial magnets, which are made of fteel, are now generally ufed in preference to the natural magnet; not only as they may be procured with greater eafe, but becaufe they are far fuperior to the natural magnet in ftrength, and communicate the magnetic virtue more powerfully, and may be varied in their form more eafily, fo that the natural magnet is now very little efteemed, except as a curiofity.

The power of attracting iron, &c. poffeffed by the loadftone, which is alfo communicable to iron and fteel, is called MAGNETISM. It has been fuppofed that iron and the loadftone were the only two bodies which could be rendered magnetical; but it now appears that nickel, when purified from iron, becomes more inftead of lefs magnetic, and acquires, what iron does not, the properties of a magnet †.

A rod or bar, of iron or fteel, to which a permanent polarity has been communicated, is called a MAGNET.

The points in a magnet which feem to poffefs the greateft power, or in which the virtue

* Kirwan's Elements of Mineralogy, p. 271.

† Ibid. p. 369.

feems

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, 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 wonder-

* Lettres à une Princeſſe d'Allemagne.

ful

ful properties of a magnet are, firſt, a particular ſtructure of the internal pores of the magnets, 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. 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,

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

A SECOND

A SECOND HYPOTHESIS*.

1. That the earth is a large magnet.

2. That there is a ſubtil fluid, called the magnetic fluid, which exiſts in every kind of iron; is equally attracted by all its parts, and equally diſſeminated throughout its ſubſtance, unleſs it is forced into an inequality by a power ſuperior to the attraction of the iron.

3. That the natural quantity of magnetic fluid contained in a piece of iron, may be put in motion ſo as to be more rarified in one part, and more condenſed in another; but it cannot be ſo taken away by any known force, as to leave the whole maſs in a negative ſtate with reſpect to its natural quantity; neither can any additional quantity be introduced ſo as to put it in a poſitive ſtate.

4. A piece of ſoft iron permits the magnetic fluid which is contained in its ſubſtance to be put in motion by a ſmall force, ſo that, being placed in the direction of the magnetic meridian, it acquires immediately the properties of a magnet, its magnetic fluid being drawn or puſhed from one extremity to the other, and continuing ſo while it remains in the ſame po-

* Oeuvres de Franklin. Tom. 1. p. 277.

ſitions.

ſition, one of the ends becoming poſitively, the other negatively magnetic. This tranſient magnet loſes its properties when it is laid in an eaſt and weſt ſituation, the magnet returning to its original ſituation.

If the iron is hard as ſteel, it is more difficult to put the magnetic fluid in motion, it requires a ſtronger force than is exerted by the magnetiſm of the earth to move it, and when moved from one end to the other, it cannot eaſily return, and thus a ſteel bar requires a permanent magnetiſm.

6. A great heat opens the ſubſtance and ſeparates the parts of the bar, and thus gives a free paſſage for the magnetic fluid, which deſtroys its magnetic properties.

7. A ſteel bar not magnetical, placed in the direction of the magnetic meridian and dip, and firſt heated and then ſuddenly cooled, while in this poſture, acquires a permanent magnetiſm; for while the bar was warm, the magnetic fluid contained in it was eaſily forced from one end to the other, by the magnetiſm of the earth, and was retained there by the contraction of the bar from cold.

8. Violent concuſſions of the ſteel bar placed as in the foregoing article, ſo ſeparate its parts during the vibrations, as to ſuffer the magnetic fluid to be

 forced

forced from its ſituation by the magnetiſm of the earth, and is retained in its altered ſituation by the cloſing of the pores when the vibration ceaſe.

9. An electric ſhock dilating a needle for a moment, gives it, for the foregoing reaſon, a magnetic virtue.

I. THERE IS A TENDENCY IN IRON AND A MAGNET TO APPROACH EACH OTHER, AND ATTACH THEMSELVES TOGETHER, AND THAT WITH SUCH FORCE, AS OFTEN TO REQUIRE A CONSIDERABLE WEIGHT TO SEPARATE THEM.

This curious property of the magnet was that by which it was firſt diſcovered, and by which it engaged the attention of the curious. Every ſubſtance which contains iron is more or leſs attracted by the magnet, with one exception, as Henckel, Gellert, and Brand aſſert, that the ſmalleſt quantity of antimony mixed with iron prevents its being attracted by the magnet. Mr. Burgman uſed the following method to diſcover the ſubſtances which are attracted by the magnet, he placed the bodies which he intended to examine on pure water or very pure mercury,

mercury, either directly on the ſurface, or on a piece of paper, when on the approach of a ſtrong magnet, they will be ſenſibly attracted, although the attraction could be diſcovered by no other method; in this way he found martial ſalts ſtrongly attracted by the magnet. Howbeit, in general, iron when involved in a coating of ſaline matter is attracted leſs ſtrongly in proportion as it is more intimately united to the ſalts. The attraction of iron is ſtrongeſt when it is moſt deprived of oily, ſulphureous, and ſaline particles. Spirit of nitre poured on iron which is acting on a magnetic needle, will diminiſh its action.

### EXPERIMENT I.

Place a piece of iron on a cork, and put the cork into water, the piece of iron will be attracted by, and follow a magnet, in a pleaſing manner. The tendency between the magnet and the iron is reciprocal; for if the magnet be put on the cork, it will follow the iron, in the ſame manner as this followed the magnet.

On this principle many ingenious and entertaining pieces of mechaniſm have been contrived. Small ſwans ſwiming in the water have been made to point out the time of the day, &c.

EXPERIMENT II.

Place a magnet upon one of the braſs ſtands, and preſent one end of a ſmall needle towards it, holding the other end by a piece of thread, to prevent the needle fixing itſelf to the bar, and the needle will be pleaſingly ſuſpended in the air; the needle will remain ſuſpended, although a piece of paper, glaſs, braſs, &c. be introduced between the magnet and the needle.

EXPERIMENT III.

Suſpend a magnet under the ſcale of a balance, and counterpoiſe it by weights in the other ſcale, then preſent a piece of iron towards the magnet, it will immediately deſcend, and, if the iron is not placed at too great a diſtance, will adhere to it: now ſuſpend the iron under the ſcale inſtead of the magnet, then bring the latter towards it, and the iron will deſcend and adhere to the magnet.

### EXPERIMENT IV.

Hold one end of the magnet at about half an inch from ſome ſteel filings, and theſe will fly to the magnet and form a kind of beard about the end of the magnet.

II. THERE ARE CERTAIN POINTS IN A MAGNET IN WHICH ITS VIRTUES SEEM AS IT WERE CONCENTRATED, WHICH ARE CALLED ITS POLES.

### EXPERIMENT V.

Let a magnet be placed on one of the braſs ſtands contained in the apparatus; and then try what number of iron balls it will ſuſtain at different parts; it will be found to ſupport moſt near the ends, evincing that the magnetic power is exerted there with the greateſt force.

Take out the ſteel needle from the facturer, the two pillars *ab*, fig. 117, and place in its ſtead the needle, one half of which is made of ſteel, the other half of braſs, the ſteel part of this needle is to be touched; on preſenting the ſouth end of a magnet to the end of the arch, this will repel

repel the end of the needle to a certain degree, but on moving the magnet progreſſively forwards, the needle will gradually fall down till it comes to Zero. If the magnet is moved further the needle will be attracted.

### TO FIND THE POLES OF A MAGNET.

### EXPERIMENT VI.

Let a magnet be placed under one of thoſe panes of glaſs which are contained in the bottom of the box; ſift ſome ſteel filings on this glaſs, and then ſtrike it gently with a key, in order to throw the glaſs into a vibratory motion; this will diſengage the filings, and they will ſoon be arranged in a pleaſing manner: thoſe parts of the magnet from which the curves ſeem to take their riſe, and over which the filings ſeem to be almoſt erect, are the poles of the magnet: or roll the magnet or loadſtone in ſteel filings, which will adhere in a greater quantity, and more ſtrongly to thoſe parts, that are near the poles; and thoſe particles which are over the poles will be perpendicular to the bar, the other particles will incline towards the poles. If a ſmall needle be placed

in

in a glaſs ball and carried over the magnetic bar, it will ſtand perpendicular to the bar when it is over either of the poles, the various inclinations of a piece of ſteel, and at different parts of a magnet, may be pleaſingly obſerved by this little apparatus.

In this, as well as many other magnetical experiments, a mechanical force is evidently exerted, detaching the particles of iron from one ſituation, removing them to another, and then retaining them there with conſiderable force.

EXPERIMENT VII.

The poles of a magnet may be aſcertained with greater accuracy by means of the ſmall dipping needle, fig. 117, place this on a magnet, and move it backwards and forwards till the needle is perpendicular to the magnet, it will then point directly to one of the poles. When it is between the north and ſouth poles, ſo that their mutual actions 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.

EXPERIMENT VIII.

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.

III. THE CONTRARY POLES OF TWO MAGNETS ATTRACT EACH OTHER.

THE NORTH POLES OF TWO MAGNETS, WHEN BROUGHT CONTIGUOUS, REPEL EACH OTHER. THE SOUTH POLES ALSO, WHEN BROUGHT NEAR, REPEL EACH OTHER.

Theſe phænomena are eaſily illuſtrated by a variety of pleaſing experiments.

## EXPERIMENT IX.

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.

## EXPERIMENT X.

Strew a few fteel filings upon a pane of glafs, put either the north or fouth pole of one of the bars under the pane; the filings will rife upon the glafs as the magnet approaches. Bring the fame pole of the other bar directly over that under the glafs, and when it is at a proper diftance, the fteel filings will drop flat on the pane.

## EXPERIMENT XI.

Fix two needles horizontally in two pieces of cork, and put them in water; if the poles of the fame name are placed together, they will mutually repel each other. If the poles of a contrary denomination are turned towards each other, they will be attracted and join.

### EXPERIMENT XII.

Dip the north or ſouth ends of two magnets in ſteel filings, which will hang in cluſters from the end of the bars; bring the ends of the bars towards each other, and the ſteel filings on one bar, will recede from thoſe on the other. Dip the ſouth pole of one magnet, and the north pole of the other, into ſteel filings, then let the ends be brought near to each other, and the tufts of filings will unite, forming ſmall circular arches.

## IV. THE POWERS OR PROPERTIES OF A MAGNET MAY BE COMMUNICATED TO IRON OR STEEL.

To give a detail of the various proceſſes which have been ſuggeſted, for the touching or communicating the properties of the magnet to iron or ſteel, would alone fill a volume, I ſhall therefore only give an account of two general and good methods which I preſume will be found adequate to every common purpoſe.

1. Place two magnetic bars AB, fig. 100, in a line, with the north or marked end of one, oppoſed

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, remove D and C a foot or two from the bar when they are off the ends, then bring the north and ſouth poles of theſe magnets together, and apply them again to the middle of the bar C as before; repeat the ſame proceſs five or ſix times, then turn the bar, and touch the oppoſite ſurface in the ſame manner, and afterwards the two remaining ſurfaces, and by this means the bar will acquire a ſtrong fixed magnetiſm.

2. Place the two bars which are to be touched parallel to each other, and then unite the ends by two pieces of ſoft iron called ſupporters, in order to preſerve, during the operation, the circulation of the magnetic matter; the bars are to be placed ſo that the marked end D, fig. 101, may be oppoſite the unmarked end B, then place the two attracting poles G and I

on the middle of one of the bars to be touched, raising the ends so that the bars may form an obtuse angle of 100 or 120 degrees; the ends G and I of the bars are to be separated two or three tenths of an inch from each other. Keeping the bars in this position, move them slowly over the bar A B, from one end to the other, going from end to end about fifteen times. Having done this, change the poles of the bars *, and repeat the same operation on the bar C D, and then on the opposite faces of the bars; the touch, thus communicated, may be farther increased, by rubbing the different faces of the bars with sets of magnetic bars disposed as in fig. 102.

It seems, that in order to render steel magnetical, we must so dispose the pores that they may form contiguous tubes parallel to each other, capable of receiving the magnetic fluid, and then propagating and perpetuating 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

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

should

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 perfect magnetiſm than ſoft ſteel, though it does not appear that they differ from each other in any thing but the arrangement of the parts; perhaps the ſoft ſteel contains phlogiſton in 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 ſe-

ſeparated

parated from the ore, they are expofed to a moft intenfe degree of heat, and moft of the changes to which they are afterwards fubmitted, are effected in a red hot ftate. A piece of fpring-tempered fteel will not retain as much magnetifm as hard fteel, foft fteel ftill lefs, and iron fcarce retains any. From fome experiments of Mr. Muffchenbroek, it appears, that when iron is united with an acid, it will not become magnetical; but if the acid is feparated, and the phlogifton reftored, it will become as magnetical as ever.

The dimenfions and fhape of a magnet will make a difference in its force, therefore the bars to be touched, fhould neither be too long nor too fhort, but in proportion to the thicknefs; if they are too long, the paffage of the magnetic matter coming out of one pole, and proceeding round the magnet to enter the other, will be impeded, and its velocity leffened. If they are too fhort, 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 ftream fufficiently ftrong to refift the

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

It is moſt advantageous to turn the bar that is quitted, while the touching magnets are placed on the other; by this means, the ſtream that is to be excited will diſpoſe the channels of the firſt, and thus render the operation more efficacious; beſides, by only turning one bar at a time, the touching bars need never be totally removed during the whole operation, a circumſtance which will contribute to the ſtrength of the magnet.

The touching bars ſhould never be ſeparated but at the equator of the magnet; and their motion over the others ſhould be ſlow and regular.

The magnetic power of touching needles has been increaſed 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 a ſmall magnetic needle on the point of one of the ſmall ſtands, and put it between two mag-

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 fluids find 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

iron is ſoft, the magnetiſm remains very little longer than while the heat continues. Lightening is the ſtrongeſt power yet known in producing a ſtream of magnetiſm; it will, in an inſtant, render hardened ſteel ſtrongly magnetical, and invert the poles of a magnetic needle.

To make a magnetical bar with ſeveral poles, place magnets at thoſe parts where the poles are intended to be, the poles to be of a contrary name to thoſe required, and if a ſouth pole is fixed on one part, the two next places muſt have north poles ſet againſt them; conſider each piece between the ſupporters as a ſeparate magnet, and touch it accordingly.

### EXPERIMENT XIII.

Take a piece of iron wire and bend it into the form of a ſtaple, then touch the middle of the wire ſtaple with only one of the poles of a magnet; without moving it backwards or forwards, the place where the magnet touches the wire will be one pole, and the two ends the other pole.

### EXPERIMET XIV.

Take any number of ſmall ſteel bars, lay them end to end, and touch them while in this poſi-

tion;

tion; when you ſeparate them there will be a north and a ſouth pole at every ſeparation. See a ſimilar experiment in the eſſay on electricity.

## EXPERIMENT XV.

Touch a piece of iron wire, and then twiſt it about a large glaſs tube or any other cylindrical body, and the magnetic virtue will be ſo diſturbed that in ſome parts it will attract, and in others repell the ſame pole of a magnetic needle.

## TO TOUCH HORSESHOE MAGNETS.

As theſe magnets from their form are capable of ſuſtaining great weights, and maintaining the circulation of the magnetic fluid, I ſhall deſcribe a convenient mode of touching them.

Place a pair of magnetic bars againſt the ends of the horſeſhoe magnet, with the ſouth end of the bar againſt that end of the horſeſhoe, which is intended to be the north; and the north end of the other bar to that which is to be the ſouth. The contact or lifter of ſoft iron to be placed at the other end of the bars. In this ſituation the magnetic fluid which circulates through the

 bars

bars will endeavour to force a paſſage through the horſeſhoe magnet, and thus facilitate the further communication of the magnetic virtue to the horſeſhoe magnet: to this end, rub the ſurfaces of the horſeſhoe with a pair of bars placed in the form of a compaſs turning the poles properly towards the poles of the horſeſhoe-magnet, being careful that theſe bars never touch the ends of the ſtrait bars, as this would diſturb the current of the magnetic fluid, and injure the operation. If the bars are ſeparated ſuddenly from the horſeſhoe-magnet, its force will be conſiderably diminiſhed; to prevent this, ſlip on the lifter or ſupport to the end of the horſeſhoe-magnet, but in ſuch a manner, however, that it may not touch the bars, the bars may then be taken away, the ſupport ſlid to its place, and left there to ſtrengthen the circulation of the fluid.

## TO MAKE AN ARTIFICIAL LOADSTONE.

The late Dr. Gowin Knight poſſeſſed a ſurpriſing ſkill in magnetiſm, being able to commucate an extraordinary degree of attractive and repulſive power, and to alter or reverſe the pole at pleaſure, but as he refuſed to diſcover his methods

methods, theſe curious and valuable ſecrets died with him. In the LXIXth volume of the Philoſophical Tranſactions, however, Mr. Benjamin Wilſon has given a proceſs, which diſcovers one of the leading principles of Dr. Knight's art; namely his method of making artificial loadſtones.—To this end Dr. Knight provided himſelf with a ſufficient quantity of clean iron filings, he put them into a large tub more than one third filled with water, he then with great labour worked the tub to and fro for many hours together, that the friction between the grains of iron by this treatment, might break off ſuch ſmaller parts as would remain ſuſpended in the water for a time. The obtaining theſe very ſmall particles in ſufficient quantity, ſeemed to him to be one of the principal deſiderata in the experiment. The water being by this means rendered muddy, he poured the ſame into a clean iron veſſel, leaving the filings behind, and when the water had ſtood long enough to become clear, he poured it out carefully, without diſturbing ſuch of the ſediment as ſtill remained, which now appeared reduced almoſt to an impalpable powder. This powder was afterwards removed into another veſſel in order to dry it, but as he could not obtain a proper quantity thereof by this one proceſs, he was obliged to repeat the proceſs many times. Having at laſt procured a ſufficient quantity of this fine powder, the next thing was to make a paſte of it; and that with ſome vehicle that ſhould contain a ſufficient quantity of the phlogiſtic principle, for this purpoſe he uſed linſeed oil, and with thoſe two ingredients he made a puff paſte, and took particular care to kneed it well before he moulded it into convenient ſhapes. This paſte was then put on wood or tiles at about a foot diſtance from a moderate fire, a great degree of heat frequently cracked the compoſition. The time for breaking or drying this paſte was generally five or ſix hours, at which time they had generally attained a ſufficient degree of hardneſs; when this was done, he gave them the magnetic virtue in any direction he pleaſed by placing them for a few ſeconds between his large magazine of artificial magnets, where they acquired ſuch force, that when any of their pieces were held between two of his beſt ten guinea bars, with its poles purpoſely inverted, it immediately turned itſelf about to recover its natural direction, which the force of thoſe very powerful bars were not able to counteract.

Ruſt of iron and common ſtone cemented together by any fat ſubſtance will alſo form an artificial loadſtone.

## OF ARMED MAGNETS.

In a ſtrait loadſtone or magnet, the ſtream is carried back on all ſides in curved lines, but applying plates of ſoft iron to the poles of the magnet the direction of the fluid is changed, and it is conducted, united and condenſed at the feet to the armour, ſo that if the feet are connected by another piece of iron which is called the lifter, the ſtream proceeding from one pole will be carried by the lifter to the other, which cauſes it to adhere with conſiderable force.

The armour ſhould be made of ſoft homogenious iron, well fitted to the ends of the magnets, it ſhould alſo be thicker in proportion as the diſtance of the poles from each other increaſes.

## EXPERIMENT XVI.

Place an armed magnet under a glaſs plane which has been ſtrewed over with ſteel filings, and theſe will arrange themſelves in curves from one foot of the armour to the other.

Gaſſendi invented a peculiar kind of armour, which was formed by piercing a magnet in the direction of the axis, and placing a cylinder of iron in the hole, which augmented considerably the force of the magnet.

EXPERIMENT XVII.

Mr. Van Swinden applied to an artificial magnet B. fig. 106, which supported four ounces by its north pole, another magnet B, so that its north pole was almost half an inch from the pole which supported the weight, and this pole immediately supported seven ounces. Du Hamel, Le Maire, &c. have also made many curious experiments on this head.

EXPERIMENT XVIII.

Apply a bar of iron M N, fig. 107, to one foot of an armed magnet, and it is supported, approach the iron lifter of the magnet so that it may touch this bar and the armour; and the bar will fall.

EXPERIMENT XIX.

Apply to the pole B, fig. 108, a small piece of iron, nearly as much as that foot of the armour

armour will ſuſtain; let this piece of iron reach a little beyond the foot of the armour, then apply the lifter to the foot A, ſo that it may touch the piece of iron M; and the magnet will then ſupport a conſiderable addition of weight.

### EXPERIMENT XX.

If one end of the armour of a magnet only juſt ſuſtains an iron ball, it will ſupport two or three balls, if the contrary pole of a magnet is brought near it.

### EXPERIMENT XXI.

Place an armed magnet at the magnetic equator and ſome diſtance from a magnetic needle, and mark how much it makes it deviate from its ſituation. Apply the contrary pole of another magnet to the end of the armed one, and the needle will be more ſtrongly attracted.

V. LET 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

VIRTUE TO THIS ROD, AND ONE EXTREMITY WILL BE ALWAYS DIRECTED TOWARDS THE NORTH.

## EXPERIMENT XXII.

Place any of the untouched needles in the apparatus on a point, and it may be fixed, or will remain in any required ſituation; communicate the magnetic virtue to it, and it will no longer be indifferent as to its ſituation; but will fix upon one, in preference to any other, one end pointing towards the north, the other towards the ſouth.

## EXPERIMENT XXIII.

Float a magnet on water by means of cork, and it will place itſelf in the direction of the magnetic meridian. A terella floated on quickſilver will do the ſame, the magnetic axis conforming itſelf to the direction of the meridian.

It is not improbable, that in ſome future period, it may be diſcovered, that moſt bodies are poſſeſſed of a polarity, and will aſſume directions relative to the various affinities of the elements of which they are compounded.

The directive power of a touched needle is of the greatest importance to mankind, as it enables the mariner to traverse the ocean, and thus unite the arts, manufactures, and knowledge of distant countries, together. The surveyor, the miner, and the astronomer, derive many advantages from this wonderful property.

The mariner's compass consists of three parts, the box, the card or fly, and the needle.

The card is a circle of stiff paper representing the horizon, with the points of the compass marked on it; the magnetical needle is fixed to the under side of this card; the center of the needle is perforated, and a cap, with a conical agate at its top, is fixed in this perforation; this cap is hung on a steel pin, which is fixed to the bottom of the box, so that the card hanging on the pin turns freely round its centre; one of the points being from the property of the needle always directed towards the north pole. The box which contains the card and needle, is a circular brass box hung within a square wooden one, by two concentric rings called jimbals, so fixed by cross centres to the two boxes, that the inner one shall retain an horrizontal position in all motions of the ship. The top of the inner

box

box has a cover of glaſs to prevent the card from being diſturbed by the wind.*

It has been already obſerved, that the antients, do not ſeem to have been acquainted with the directive power of the magnet. The only thing that ſeems capable of being miſtook for ſome ſuch knowledge, is what Jamblichus tells us in his life of Pythagoras, *That Pythagoras took from Abaris, the Hyperborean, his golden dart, without which it was impoſſible for him to find his road.* But the authority of the writer, as well as the obſcurity of the paſſage, prevents any concluſion being drawn from it.

Paul the Venetian, is ſaid to have introduced the uſe of the compaſs in 1260, but this is ſaid not to have been his own invention, but borrowed from the Chineſe. P. Gaubil ſays, the directive power of the needle was known to the Chineſe as early as the year A. D. 223, under the Dynaſty of Haz. But the Abbi Renaudot in his Diſſertation on the Stone, when the Mahomedans went firſt to China, has adduced

* Before the compaſs was invented, the navigating of ſhips was a tedious and precarious operation, and ſeldom performed out of ſight of land; but this inſtrument enables the mariner to travel over the ſeas almoſt in as direct and true a tract as the land carrier directs his carriage in a well beaten road.

ſtrong

ſtrong reaſons to prove that the Chineſe knew nothing of the mariners compaſs, till it was introduced there by the Europeans. Vertomanus affirms that A. D. 1500 he ſaw an Eaſt Indian pilot, direct his courſe by a compaſs framed, and faſtened like thoſe uſed in Europe; but this muſt be received with ſome caution, as Mr. Barlow in 1597, ſays that in a perſonal conference with two Eaſt Indians he was told by them that inſtead of our compaſs they made uſe of a magnetical needle of ſix inches or longer, ſet upon a pin in a diſh of white China earth filled with water; that in the bottom of the diſh they had two croſs lines, to mark the four principal winds, and that the reſt of the diviſions were left to the ſkill of the pilot. But to return to Europe, Mr. Perrault in his parallel between the antients and the moderns has cited ſome verſes of Guyot de Provins, who wrote in 1180, which ſhew diſtinctly that the mariners compaſs was known in the South of France at that time.

"There is," ſays he,

"A ſtar that never moves,
"And an art that ne'er deceives,
"By virtue of the compaſs,
"An ugly black ſtone
"Which always attracts iron."

Though by moſt writers the invention of the

com-

compaſs is aſcribed to Flavio Goia of Analſi in Campanee, who lived about the year 1300. He is ſaid to be the firſt that applied it to navigation in the Mediterranean.

Mr. de Lalande informs us that in "Le trèſor de Brunet," a manuſcript in the French king's library, there is a paſſage which proves that the compaſs was made uſe of about the year 1260.

VI. THE NEEDLE OF THE MARINER'S COMPASS, DOES NOT POINT EXACTLY TO THE NORTH, BUT IS OBSERVED TO CHANGE ITS AZIMUTH, POINTING SOMETIMES TOWARDS THE EAST, AND SOMETIMES TO THE WEST OF THE MERIDIAN.

Fig. 109, N S, repreſents the true merridian line; and E S, the eaſt and weſt line which is perpendicular to it; now the magnetic needle A B, does not direct itſelf ſo as to coincide with the meridian line N S, but ſeparates itſelf ſo as to form an angle N C B, at preſent of about 22 degrees.

This deviation from the meridian is called the variation of the needle, and is different at different parts of the world, being weſt at ſome places, eaſt at others. and in parts where the

variation

variation is of the ſame name, 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.

From ſucceſſive obſervations made afterwards, it appears that this deviation was not a conſtant quantity, but that it gradually diminiſhed, and at laſt about 1660 it was found that the needle pointed due north at London, and has ever ſince been

been increafing to the weftward of the north. So that in any one place the variations have a kind of libratory motion, traverfing through the north to unknown limits eaftward and weftward.

Dr. Halley in the laft century publifhed a theory of the variation of the compafs. In this work, he fuppofes that there are four magnetic poles in the earth; two of which are fixed, and two moveable, by which he explains the different variation of the compafs at different times in the fame place. But it is impoffible to apply exact calculations to fo complicated an hypothefis.

Mr. Euler has fhewn that two magnetic poles placed on the furface of the earth will fufficiently account for the fingular figure affumed by the lines which pafs through all the points of equal variation in the chart of Dr. Halley.

Mr. Euler firft examines the cafe wherein the two magnetic poles are directly oppofite; fecondly, he places them in two oppofite meridians but at unequal diftances from the poles of the world; thirdly, he places them in the fame meridian. Finally he confiders them fituated on two different meridians. Thefe four cafes may become equally important; becaufe, if it is determined that there are only two magnetic poles, and that thefe poles change their fituation,

it

it may hereafter be discovered that they pass through all the different positions.

Mr. Euler after having examined the different cases, finds that they also express the earth's magnetism, as represented in the chart published by Messrs. Mountaire and Dodson in 1744, particularly throughout Europe and North America, if the following principals are established.

Between the arctic pole and the magnetic pole 14° 53. Between the antarctic and the other magnetic pole 29° 23, 53° 18 the angle at the north pole formed by the meridian's passing through the two magnetic poles, 250° the longitude of the meridian, which passes over the northern magnetic meridian.

I shall now give a short description of a *variation compass*; an instrument which is used to observe with accuracy, the deviation of the needle from the meridian. To this end it should possess the following properties.

1. That it may be easily and accurately placed in the meridian.

2. It should indicate small variations of the needle.

3. That the nonius which marks the small variation of the needle may be moved without disturbing it.

4. That the needle may be easily taken off and inverted

inverted to diſcover whether the line marked on the needle coincides with the direction of magnetiſm in the needle.

Fig. 110 repreſents a variation compaſs which it is preſumed will anſwer the foregoing purpoſes. It has a glaſs cover which is made to ſlide on or to be taken off occaſionally, two graduated arches are fixed at each end of the box with a moveable nonius to each arch, the nonius are both moved by means of the milled nut A. without diſturbing the ſituation of the needle.

The inſtrument is placed in the meridian by a teleſcope, whoſe line of collimation is parallel to the zero line of the inſtrument. The teleſcope is to be placed in two forks, in the manner adviſed by Mr. Magellan in his Collection de differens Taites ſur des inſtrumens D'Aſtronomie, &c. p. 227," where the reader will find ſome obſervations on the adjuſtments, which are too long to be introduced in this eſſay. When the inſtrument is placed in the meridian, the method of obſerving is to move the northern nonius till the middle diviſion coincides with the line on that end of the needle; and the nonius will then ſhew the angle that end of the needle makes with the meridian. If the line on the ſouthern end of the needle coincides with the middle diviſion of its nonius, the foregoing obſervation

ſervation is ſufficient; if not, the ſouthern nonius muſt be moved till it coincides with this end of the needle, and the mean between the two numbers thus found will be the true angle.

The needle is ſo conſtructed, that it may be readily taken off the cap and inverted, in order to obſerve with the under face of the needle uppermoſt, to diſcover whether the line on the needle is parallel to the direction of the magnetiſm in the needle, and hence diſcover whether this line gives the true angle which the direction of magnetiſm makes with the meridian. Having made the obſervation as before with both ends of the needle, invert and obſerve what is now ſhewn by the inverted ends of the needle, and if the line is parallel to the dreċtion of the magnetiſm in the needle, the mean of the obſervation with the inverted ends, will agree with the foregoing; on the other hand, if it is not parallel to the direction of magnetiſm, but makes it appear too much when the needle is upright, it will appear as much leſs when inverted, ſo that the mean of the foregoing means is the true angle which the needle makes with the zero line of the compaſs.

About the year 1722 and 1723, Mr. George Graham made a great number of obſervations on the diurnal variations of the magnetic needle.

In the year 1750, Mr. Wargentin took notice of the regular diurnal variation of the needle; and alſo of 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 eight or nine o'clock in the morning, till about one or two in the afternoon, when the needle became ſtationary for ſome time; after that the variation weſtward was decreaſing, and the needle came back again to its former ſituation in the night, or by the next morning.

THE DIURNAL VARIATION IS IRREGULAR WHEN THE NEEDLE MOVES SLOWLY EATSWARD, IN THE LATTER PART OF THE MORNING, OR WESTWARD IN THE LATTER PART OF THE AFTERNOON; ALSO WHEN IT MOVES MUCH EITHER WAY AFTER NIGHT, OR SUDDENLY BOTH WAYS IN A SHORT TIME.

Theſe irregularities ſeldom happen more than once

once or twice in a month, and are always accompanied with an aurora borealis.

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

### EXPERIMENT XXIV.

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 magnet being covered by a braſs weight of ſixteen ounces, about two ounces of boiling water was poured into it, by which means the magnet was gradually heating for ſeven or eight minutes; and during that time, the needle moved about three quarters of a degree weſtward, and became ſtationary 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 ſome hours before it gained its former ſituation, and ſtood at 45°.

EXPERIMENT XXV.

On each ſide of the compaſs, and parallel to the magnetic meridian, he placed a ſtrong magnet, of the ſize above-mentioned; ſo that the ſouth 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, ſo as to ſtand at 45 degrees. The magnets were both covered with braſs weights of ſixteen ounces each. Into the eaſtern weight about two ounces of boiling water was poured; and the needle in one minute moved half a degree, and continued moving weſtward for about ſeven minutes, when it arrived at $2^{\circ}\frac{3}{4}$. It was then ſtationary for ſome time; but, in twenty four minutes from the beginning, it came back to $2^{\circ}\frac{1}{2}$, and in fifty minutes to $2^{\circ}\frac{1}{4}$. He then 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 mag-

netic

netic 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 increaſing equally, the needle will be ſtationary, and the abſolute variation will then be greateſt; but, when the weſtern magnetic parts are either heating faſter, or cooling ſlower than the eaſtern, the needle will move eaſtward, or the abſolute variation will decreaſe; and when the eaſtern and weſtern magnetic parts are cooling equally faſt, the needle will again be ſtationary, and the abſolute variation will then be leaſt. This may be ſtill further illuſtrated, by placing the compaſs and two magnets, as in the laſt experiment, behind a ſcreen near the middle of the day in ſummer; then, if the ſcreen be ſo moved, that the ſun may ſhine only on the eaſtern magnet, the needle will ſenſibly vary in 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 contray way. By this theory, the diurnal variation in the ſummer ought to exceed that in the winter; and we accordingly find by obſervation, that the diurnal variation in the months of June and July, is almoſt double that of December and January.

The irregular diurnal variation muſt ariſe from ſome other cauſe than that of heat communicated by the ſun; and here we muſt have recourſe to ſubterranean heat, which is generated without any regularity as to time, and which will, when it happens in the north, affect the attractive power of the magnetic parts of the earth on the north end of the needle. The Reverend Dr. Hales has a good obſervation on this head, in the Appendix to the ſecond volume of his Statical Eſſays, which I ſhall here tranſcribe. "That the warmth of the "earth, at ſome depth under ground, has an "influence in promoting a thaw, as well as "the change of the weather from a freezing to "a thawing ſtate, is manifeſt from this 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 ſnow continued to lie, whether thoſe "drains were full of water, or dry; as alſo "where

"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 ſe-

vere

vere cold weather; and that the curious in thefe matters are now acquainted with a fubftance, that will, without friction, both emit and abforb the electrical fluid, only by the encrafe or diminution of its heat: for if the Tourmalin be placed on a plane piece of heated glafs, or metal, fo that each fide of it, by being perpendicular to the furface of the heating body, may be equally heated, it will, while heating, have the electricitty of one of its fides pofitive, and that of the other negative; this will likewife be the cafe when it is taken out of boiling water, and fuffered to cool; but the fide that was pofitive while it was heating, will be negative while it is cooling, and the fide that was negative, will be pofitive.

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 IS CALLED THE DIP OF THE NEEDLE.

Fig. 111. HO reprefents an horizontal line placed in the magnetic meridian *d e*, a line at right

right angles to it, *b a* the fituation a needle would take at London with refpect to the horizon, making with the horizontal line an angle of 72 with the vertical line.

This property was difcovered by Robert Norman, about the year 1576. We fhall give the account of the difcovery in his own words.

"Having, fays he, made many and divers compaffes, and ufing always to finifh and end them before I touched the needle, I found continually that after I had touched the yrons with the ftone that prefently the north point thereof would bend or decline downwards under the horizon in fome quantity; infomuch, that to the flie of the compafs, which before was made equal, I was ftill conftrained to put fome fmall piece of wax in the fouth part thereof, to counterpoife this declining, and to make it equal again.

"Which effect having many times paffed my hands without any great regard thereunto, as ignorant of any fuch property in the ftone, and not before having heard nor read of any fuch matter: it chanced at length that there came to my hands an inftrument to be made, with a needle of fix inches long, which needle after I had polifhed, cut off at juft length, and made to ftand level upon the pin, fo that nothing refted but only the touching of it with the ftone: when I had

touched

touched the ſame, preſently the north part thereof declined down in ſuch ſort, that being conſtrained to cut away ſome of that part to make it equal again, in the end I cut it too ſhort, and ſo ſpoiled the needle wherein I had taken ſo much pains.

"Hereby being ſtroken into ſome choler, I applied myſelf to ſeek further into this effect, and making certain learned and expert men (my friends) acquainted in this matter, they adviſed me to frame ſome inſtrument, to make ſome exact trial, how much the needle touched with the ſtone would decline, or what greateſt angle it would make with the plain of the horizon. Thus far Mr. Norman."

The dipping needle, repreſented fig. 112 was conſtructed by Dr. Lorimer, and is deſcribed in the Philoſophical Tranſactions, vol. lxv. part 1, page 81. It appears to me better calculated for the ſea ſervice than any other I have ſeen; it is leſs liable to be affected by the motion of the ſhip, than thoſe which are ſuſpended by gimbols fixed to the upper part of the inſtrument, beſides other advantages which are derived from the double motion of the needle. The needle *a b* plays vertically upon its own axis, which has two conical points, which are inverted into the oppoſite ſides of the upright parallelogram *c d*, into this parallel-

parallelogram, and at right angles to it, a ſlender braſs circle *f g h* is fixed; this circle is ſilvered and graduated to every half degree upon which the needle ſhews the dip: this, for the ſake of diſtinction, is called the circle of the magnetic inclination. The braſs parallelogram, and conſequently the circle of inclination alſo, turns horizontally upon two other points, the one above and the other below, in correſponding ſockets in the parallelogram; theſe points are fixed in a vertical circle *l i* which is of ſuch a diameter as to allow the circle of inclination and parallelogram to move within it. This ſecond circle may be called a general meridian; it is not graduated, but has a ſmall braſs weight fixed to the lower part of it, to keep it upright; and the circle itſelf is ſcrewed at right angles, into another circle of equal external diameter which is ſilvered and graduated on the upper ſide to every half degree. It repreſents the horizon, as it ſwings freely upon gimbols, and is always nearly parallel to it.

The uſe of this inſtrument is very plain, as the inclination or dip is at any time apparent from inſpection, and alſo the variation; if the frame is turned round till the great vertical lines meet exactly in the plane of the true meridian: for the circle of inclination being always in the needle's vertical

vertical plane, the edge of it will evidently point out upon the horizon the variation E or W. But at ſea, when there is not too much motion, you turn the frame round, till the vertical circle is in the plane of the ſun's rays; that is till the ſhadow of one ſide of it juſt covers the other, and the edge of the circle will then give the magnetic amplitude, if the ſun is riſing or ſetting; but the azimuth at all times of the day; and the true amplitude or azimuth being found in the uſual way, the difference is the variation. If the motion is conſiderable, obſerve the extremes of vibration, and take the mean for your magnetic amplitude or azimuth. This inſtrument has a conſtant power in itſelf, not only of ſetting itſelf in the proper poſition, but alſo of keeping itſelf ſo; or of reſtoring itſelf to the ſame ſituation, if at any time it has loſt it; and it is curious to ſee how, by its double motion, it counteracts as it were, the rolling motion of the veſſel. The degrees ſhewn by each end of the needle ſhould be attended to, and the medium taken for the true dip or variation: alſo apply a good artificial magnet in ſuch manner as to turn the parallelogram and circle of inclination half way round horizontally, ſo that the end of the axis of the needle which before pointed to weſt, ſhall now point to the eaſt; and obſerve

where

where the needle ſtands, and if it differs from the preceding obſervation, take the mean which will be found as near the truth as it is poſſible for any inſtrument to give.

DESCRIPTION OF A TERELLA AND OF THE MAGNETISM OF THE EARTH.

If a touched needle is placed near a magnet, its direction to the magnetic needle is ſuſpended, and it aſſumes a direction relative to its ſituation and diſtance from the poles of the magnet.

EXPERIMENT XXVI.

Place a ſmall needle on the pointed end of the braſs ſtands, and then bring it near the magnet, and the needle will direct itſelf differently, according to the diſtance from the poles of a magnet; or,

Move the ſmall dipping needle over a magnet, and by its varied ſituations it will illuſtrate the foregoing obſervation; or,

Theſe relative ſituations and tendencies may be pleaſingly obſerved by placing ſeveral touched needles round a magnet at the ſame time.

Fig. 113, A B repreſents a magnet B the north pole,

pole, A the ſouth *ba*, *ba*, *ba*, &c. ſeveral ſmall magnetic needles placed round the ſouth pole of the magnetic *ab*, *ab*, *ab*, ſimilar needles placed round the north end: *a* the north pole of theſe needles, *b* the ſouth pole, *c* the center on which they turn. From this experiment may be derived others accurately inveſtigating the nature of the magnetic curves.

Now, if the earth is a great magnet, or if a large magnet is placed within it, we ſee from the foregoing experiment, that magnetic needles placed on its ſurface would have different directions in different places, which is conformable to experience; and the apparent irregularities in the variation of the needle muſt be occaſioned by the ſituation of the magnetic poles of the earth.

If the magnetic poles agreed with thoſe of the earth there would be no variation, and the magnetic needle would point to the true north and ſouth. If the axis of the magnetic poles paſſed through the center of the earth, it would be eaſy to aſſign the quantity of the variation at every place; but as this is not the caſe, to account regularly for the variation, it would be neceſſary to know the exact ſituation of the magnetic poles of the earth, their number, force, and diſtance from the real poles, whether they ſhift their place, and if they move, the quantity of motion every year.

Dr.

Dr. Haller ſuppoſed the earth to be an hollow ſphere, with an internal nucleus in the cavity, he looked upon each part (the external and internal) to be a ſeparate magnet endowed with two poles, and whoſe magnetical axis were not coincident. A compaſs needle on the ſurface of the globe would be acted upon in the ſame manner as it would be by a magnet with four poles, and thus explains the variation. But as the variation changes in proceſs of time, he ſuppoſed that the poles do not keep the ſame poſition with reſpect to the ſurface of the earth and one another, and accounted for this motion, by ſuppoſing that the diurnal motion of the earth was impreſſed from without, and that the velocity of the internal part was leſs than the external. Therefore the nucleus would ſeem to turn ſlowly towards the weſt, and its poles deſcribe ſmaller circles round the poles of the earth. And as the relative poſition of the four magnetical poles to each other, and to the poles of the earth is changed, ſo muſt the direction of the needle be varied.

Mr. Euler, who has conſidered the ſubject in every point of view, and treated it with greater perſpicuity than any other writer, ſees no reaſon for adopting ſo laborious and complicated an hypotheſis. He thinks that every thing may be accounted for by two magnetic poles which are

 not

not directly oppoſite to each other, or whoſe magnetic axis does not paſs through the axis of the earth, whereby he avoids many difficulties with which the other theory is incumbered.

In order to inveſtigate the phenomena of the variation and the dip of the needle, Gilbert, who ſuppoſed the earth to be a magnet, ground a loadſtone into a round figure, like a globe, which he called a terella or little earth, as it exhibited in ſome degree the ſame phenomena which take place on the different parts of the ſurface of the earth. But little progreſs, however, was made with this inſtrument, as it did not ſufficiently correſpond with the nature of the earth's magnetiſm. It has ſince received ſeveral improvements from Mr. Magellan, but ſtill remained very defective. The following improvement by Dr. Lorimer will, I hope, prove of eſſential ſervice, in diſcovering the laws by which the myſterious properties of the magnet are directed.

This terella conſiſts of a twelve inch terreſtrial globe, ſo contrived that the two hemiſpheres may be ſeparated or united at pleaſure. Two ſtrong artificial magnets are placed within the globe, in correſponding ſockets at the center of each hemiſphere, but ſo filled that while they act as

one

one magnet, their extremities or ends may be placed in various poſitions, and moveable to any latitude within 30° degrees of the pole, and are likewiſe moveable round the axis to any degree of latitude at pleaſure.

Mr. Savery has adduced ſeveral inſtances to ſhew the force and action of the earth's magnetiſm; among others, that it will ſupport ſmall pieces of iron. He hung up a bar of iron, about five feet long, by a loop of ſmall cord, at the upper end, and then carefully wiped the lower end, and the point of a nail, that there might be no duſt or moiſture to prevent a good contact; then holding the nail under the bar, with 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.

EXPERIMENT XXVII.

The upper end A of a long iron rod, which has no fixed polarity, will attract the north end of a magnetic needle; the under end B repels the north end of the needle; invert the iron bar, and the end B, which is now the upper one, 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. Mr. Canton proposed to make artificial magnets without the assistance of natural ones; but in this he was mistaken, for his poker and tongs were natural magnets, and had their verticity fixed by being heated and cooled in a vertical position, and an iron or steel bar, though without a verticity, while it remains in that position exerts a polarity, and is able to communicate a fixed verticity to the small bar, and is therefore for the time a natural magnet. And further, every iron bar, from the largest size to a sixpenny nail will exert this power when treated as above mentioned, ed. But how this power is raiſed ſo ſoon to a degree greatly exceeding that which communicated it we do not know; nor is it more eaſy to account for the facility with which the magnetic power is withdrawn by a friction contrary to that which gave it.

THE MAGNETIC MATTER MOVES IN A STREAM FROM ONE POLE TO THE OTHER, INTERNALLY, AND IS THEN CARRIED BACK IN CURVED LINES, EXTERNALLY, TILL IT ARRIVES AGAIN AT THE POLE, WHERE IT FIRST ENTERED, TO BE AGAIN ADMITTED.

EXPERIMENT XXVIII.

Put one of the glaſs panes over a magnetical bar, ſift ſteel filings on the glaſs, then ſtrike the glaſs gently, and the filings will diſpoſe themſelves in ſuch a manner as to repreſent, with great exactneſs, the courſe of the magnetic matter. The curves by which it returns back to the pole, where it firſt entered, are alſo accurately expreſſed by the arrangement of the filings. The largeſt curves riſe from one polar ſurface, and extend to the other; they are larger in proportion as they riſe nearer the axis or center of the polar ſurface; the curves which ariſe from the ſides of a magnetical body, are interior to thoſe which ariſe from the polar ſurfaces, and are ſmaller and ſmaller in proportion to their diſtance from the ends. That the magnetic matter does move back, in a direction contrary to that with which it paſſes through the magnetical body, is confirmed by 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.

### EXPERIMENT XXIX.

Let two magnets be placed at ſome diſtance from each other, the ſouth pole of one oppoſed to the north pole of the other, lay a pane of glaſs over them, and ſprinkle it with ſteel filings, then ſtrike the pane gently with a key, and the filings will arrange themſelves in the direction of the

the magnetic virtue. The filings which lay between the two polar ſurfaces, and near the common axis, are diſpoſed in ſtrait lines going from the north pole of one, to the ſouth pole of the other: the pores being now in the ſame direction, ſo that the fluid which paſſes through A B, fig. 104, finds the pores at the pole *a* open to receive them, it will therefore paſs through this, and coming out at *b* will turn towards A, to continue 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.

EXPERIMENT XXX.

While the magnets remain in the foregoing position, place a ſmall untouched bar or needle in the ſtream of the magnetic virtue; this will paſs through it, and give it a polarity in the direction of the ſtream.

EXPERIMENT XXXI.

On the ſame principal, a large key, or other untouched piece of iron, will attract and ſupport a ſmall piece of iron, while it is within the ſphere of action of the pole of a magnet, but will let them fall when it is out of the magnetic ſtream.

EXPERIMENT XXXII.

A ball of ſoft iron in contact with a magnet, will attract a ſecond ball, and that a third, till the ſtream becomes too weak to ſupport a greater weight.

EXPERIMENT XXXIII.

Place two magnets parallel to the horizon with two poles of the ſame name oppoſed to each other, and their diſtance in proportion to the ſtrength of the magnets; ſuſpend a needle nicely balanced on a thread between them, and either pole will attract the needle notwithſtanding their mutual repulſion.

EXPERIMENT XXXIV.

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

EXPERIMENT XXXV.

Place a magnet upon each of the braſs ſtands, with their poles of contrary names oppoſed to each other, and a pleaſing chain of iron balls may be be ſuſpended between them. Preſent either pole of another magnet towards them, and they will fall down.

EXPERIMENT XXXVI.

Place two bars in a line with the north end of one to the ſouth end of the other, and about one third the length of the bar diſtance from each other, to which diſtance the power ſeems to be ſeparated in moſt bars; place the glaſs panes on theſe bars, and then ſift the filings over them, and they will range themſelves between the bars, in the ſame manner they are ranged about the middle of each bar; ſhewing that when the powers are ſeparated to this diſtance they act much in the ſame manner as when they are ſeparated in the ſame bar.

MAGNETIC REPULSION ARISES FROM THE ACCUMULATION OF THE MAGNETIC FLUID, AND THE RESISTANCE FORMED TO ITS ENTRANCE IN THE MAGNET.

EXPERIMENT XXXVII.

If the two poles of the ſame name of two magnets,

nets 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.

## EXPERIMENT XXXVIII.

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.

EXPE-

EXPERIMENT XXXIX.

Dip one 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 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 *.

EXPERIMENT XL.

Place two magnets cloſe to each other, with the north and ſouth poles conjoined together, in this ſituation the magnetic power is ſo far counteracted or condenſed as to have very little effect

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

on

on iron, hardly ſuſtaining the ſmalleſt piece, ſeparate the magnets half an inch, and they will ſupport a piece of iron, cloſe them, and they will let it drop.

### EXPERIMENT XLI.

Suſpend two ſewing needles from the pole of a magnet, and the needles will diverge, the repulſion will be augmented by the addition of another magnet, it is alſo increaſed by applying a bar of iron to the oppoſite pole of the magnet and diminiſhed by applying it to the ſame.

### EXPERIMNT XLII.

Bring a bar of iron towards the extremity of the needles, and their repulſion will be augmented.

### EXPERIMENT XLIII.

Suſpend by a thread the light cylindrical bar G D, fig. 114, which has a round head at each end, and place it at a little diſtance from the magnet

net M, then bring an iron wire E E, near the lower head D, and the cylinder will be repelled, but will be attracted by the same wire if it is brought near the upper head.

### EXPERIMENT XLIV.

Hang a number of balls to each other, by applying the first to the north pole of a magnet; present the south pole of another magnet to one of the middle balls, and all those below it will thereby be deprived of the magnetic stream, and fall asunder; the ball to which the magnet was applied will be attracted by it, and all the others will remain suspended. If the north end of the magnet be presented, then the ball, to which it is applied, will also drop.

A singular fact is related by some ancient writers on magnetism. That if two loadstones, a stronger and a weaker, have their repellent poles brought together, the weaker will have 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 the polar surface, the unaltered power, in the remaining part of the stone, is able, by its contra-

ry

ry 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 *.

Though many experiments have been made to diſcover, whether the forcc 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, *cæteris 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

* The magnetic effects of the contrary pole muſt be alſo conſidered in eſtimating the forces of magnetic attraction and repulſion.

in

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 two poles of the ſame name, but its force is overpowered by the attraction of the ſtronger.

EXPERIMENT XLV.

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

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.

### EXPERIMENT XLVI.

Fill a ſmall dry glaſs tube with iron filings, preſs them in rather cloſe, and then touch the tube as if it was a ſteel bar, and the tube will attract a light needle, &c. ſhake the tube ſo that the ſituation of the filings may be diſturbed, and the magnetic virtue will vaniſh.

### EXPERIMENT XLVII.

But though a violent percuſſion will deſtroy a fixed magneniſm, 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,

bar, and then the other, while it is held in a vertical ſituation, the poles may be changed. Twiſt a long piece of iron wire backwards and forwards ſeveral times, then break it off at the twiſted part, and the broken end will be magnetical.

EXPERIMENT XLVIII.

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

EXPERIMENT XLIX.

If a magnet is divided by a ſection perpendicular to the axis, the parts which were joined before will have acquired contrary poles, one north, the other ſouth, thus generating a new magnet at every ſection.

From theſe, and ſimilar experiments, Mr. Eeles infers, that magnetiſm conſiſts of two different diſtinct powers, which in their natural ſtate are conjoined, and exert but little ſenſible action, and ſtrongly attract each other at all times; but when they are ſeparated by force,

 they

they act like those of electricity; for if magnetism is excited in two different pieces of steel by the south pole of a magnet, the ends repel each other; but if one piece be excited by the north pole, and another by the south, they will attract each other. He further supposes, that a magnet attracts, and is attracted, not entirely according to its own strength, but according to the quantity of iron to be attracted; and that magnetism is a quality inherent in all iron, and of which it cannot be divested; for fire, which will destroy a fixed magnetism, does not deprive it of its natural quantity; on the contrary, it will give it a polarity, or fixed magnetism, according to the manner of heating or cooling of the iron.

The powers of magnetism, like those of electricity, are excited and separated by friction. This effect is wonderful in both, but more so in magnetism, where two powers, naturally attracting each other, remain separated in the same steel bar for many years, and yet they may be reduced to their natural state by the friction of two other magnets, acting in a contrary order to that by which the poles were originally separated.

Magnetism and electricity act strongest at corners, edges and points.

Magnetism may be communicated to a small steel needle, by passing the discharge of a large battery through it.

The

The dischage of a battery through a small magnetic needle will sometimes destroy the magnetism, and at other times invert the poles of the magnet, which has also been frequently effected by lightening.

EXPERIMENT L.

Place a magnet M, fig. 115, at a given distance from the needle A B, fig. 115, that it makes the needle deviate from the meridian N C to C B, forming an angle N C B of 40 degrees. Now apply a bar of iron I to the magnet M, so that it may be perpendicular to it, but only covering half the breadth of the magnet, and the needle will go back to 30 degrees.

EXPERIMENT LI.

Place on the other side a bar Y, exactly similar to the bar I, and situated in the same manner; the needle will be very little affected, nay, by altering a little the situation of the bar the needle will not be at all affected by it.

Remove the bar Y from the magnet by a parallel motion, and the needle will approach

* See Essay on Electricity, p. 154.

ſtill nearer the meridian, or, in other words, the action of the magnet will be weaker.

EXPERIMENT LII.

Place a magnet M, fig. 116, at ſome diſtance from the needle A B, and parallel to the magnetic meridian N S, the needle will deviate from its ſituation; now approach ſlowly towards the needle with a bar of iron, moving it in the equator of the needle, and the attraction of the needle to the magnet will be diminiſhed, till a ſmall part of *g* of the iron bar gets beyond the magnet; when its action will be conſiderably increaſed, and the needle more ſtrongly attracted.

EXPERIMENT LIII.

Place a magnet ſo that it may attract a needle by its ſouth pole, place one end of a bar of iron on the north pole of the magnet, and it will immediately attract the needle with more force.

EXPERIMENT LIV.

Place a ſtrong magnet at ſome diſtance from a magnetic needle, ſo that it may either not act on the

the needle or elſe make it deviate only a certain quantity from the meridian; apply a bar of iron to the magnet, placing the bar between it and the needle, and the needle is immediately agitated.

EXPERIMENT LV.

Let the magnet be placed ſo near to the needle as to produce a ſenſible effect on it, then place the bar of iron on the pole of the magnet, deſcribe a circle with the bar of iron, and the action of the magnet appears to be weakened, and the needle returns to the ſituation it had before the magnet was placed near it.

EXPERIMENT LVI.

Place a bar of iron between a magnet and the needle, ſo that it may be perpendicular to the magnet; and the needle endeavours to recover its true ſituation, and even returns to it, if the bar be thick enough, or if two or three more are interpoſed *.

* Van Swinden, Memoire ſur l'Electricité et le Magnetiſme.

# MAGNETICAL RECREATIONS.

## BOX OF METALS.

THIS box contains five metallic tablets, of the ſame ſhape and ſize, that they may be placed indiſcriminately into ſimilar holes made in the bottom of a box. One of the tablets is gilt to repreſent gold, the ſecond is ſilvered to repreſent ſilver, the third is of copper, the fourth of tin, and the fifth of lead. A ſmall magnetic bar is incloſed in each of theſe pieces of metal, but is placed in a different ſituation in each piece. Another part of the apparatus is a ſmall magnetic perſpective, furniſhed at bottom with a magnetic needle, ſimilar to thoſe in ſmall compaſſes; a piece of paper is paſted at the bottom of the perſpective on the inſide, on which is marked the initials of the different metals; theſe initials are ſo placed as to correſpond with the magnets which are incloſed in the metals. If this perſpective be placed over any of the tablets, ſo that the north and ſouth line is perpendicular to the front of the box, the needle will point to the initial letter of the metal over which it is placed. Preſent the box to any one to diſpoſe of the

the tablets as he pleaſes, then to ſhut the box, and to return it you; when by means of the perſpective you will be enabled to tell him how he has placed them.

## COMMUNICATIVE MIRROR.

This apparatus conſiſts of the perſpective and ſtand repreſented N O L M K, fig. 118, four tablets as R, and a ſmall box A B with a drawer to hold one of the tablets.

A ſmall circular card with a touched needle, and on which are placed four pictures at right angles to each other, plays on a pivot in the foot M K of the perſpective. Over part of this card is a hole, the center of which coincides with the center of the tube L N. An inclined mirror is fixed in the perſpective N O, ſo as to be directly over the above-mentioned hole. There are alſo four tablets, on each of which a ſmall picture is paſted ſimilar to thoſe on the card, and a magnetic bar incloſed in each. If one of theſe is placed in the drawer of the box A B, and the perſpective over that as in fig. 118, and the fore part is then preſſed down to diſengage a ſpring which is within the foot, then will the card place itſelf ſo as to correſpond with the tablet in the drawer, and a ſimilar figure will be ſeen by looking in at at the eye end of the perſpective. Conſequently if you preſent the four tablets to any perſon, deſiring him to place any one of them in the drawer and conceal the others, then ſhut the drawer and return it. Now place the perſpective in a box, and preſſing the part T as abovementioned, and you may ſhew him the figure on the tablet he placed in the drawer, in the eye end of the perſpective.

Theſe, and many other recreations of this kind will be found in "Hooper's Rational Recreations," the greater part of which I have executed with improvements.

## OF THE ACTION OF THE MAGNETIC ATMOSPHERE.

The pole of a magnet produces on the part of a bar to which it is applied, the pole of a contrary name: therefore, if two bars fully touched have the poles of the ſame name joined together, they tend to produce on each other a force of a contrary name to that with which they are endowed; and this effect will diminiſh the polar force of each bar; conſequently the magnetic force of each longitudinal element of an artificial magnet diminiſhes as its bulk is increaſed, and the total force

force of two magnets fully touched, and of the ſame length but unequal in bulk, will be in a leſs ratio than that of their maſs.

If the magnet does not touch the bar, but is held at ſome diſtance from it, the phenomena will be the ſame; but the bar will acquire leſs magnetiſm than when it was in contact with the magnet.

Each point of a magnet may be looked on as the pole of a ſmaller magnet, tending to produce on the points of the magnet a force contrary to its own. The effect of this tendency will be greater, in proportion to the force of the point, and its nearneſs to thoſe points on which it acts; and the force of a magnet will depend on the reciprocal action of theſe points on each other.

The action of a magnetic point is increaſed according as the intenſity of the other points on it increaſes, as their number is greater, and their diſtance from it is leſs. The more the magnetic points are (from the figure of the magnet) brought together, and the ſtronger their action on each other in order to deſtroy their reciprocal forces, the weaker is the force of each point.

Hence in two bars of the ſame weight and length the broadeſt will be the moſt powerful, becauſe its longitudinal fibres are more inſulated.

If

If a bar is divided into two parts, each will receive a greater degree of magnetiſm than when they were united.

From the ſame analogy we may infer, that the exterior points and edges of a magnet will have more power than the interior ones of the ſame bar, as they are alſo more inſulated.

A bar is ſaid to be ſaturated with magnetiſm, if when ſuſpended freely in an horizontal poſition it continues to make the ſame number of oſcillations in the ſame time, though continued to be rubbed with a magnet. As each point of a magnet tends to deſtroy the magnetiſm of the neighbouring parts, the bar appears to be in a forced or unnatural ſtate, and the magnetic fluid endeavours to ſpread itſelf over the bar in an uniform manner, and conſequently to weaken and deſtroy its powers. The greater part of what has been ſaid on the action of the particles of magnetiſm on each other will be found equally applicable to electricity.

F I N I S.

# INDEX.

A

Bottle

D



E

F

## I



## K



## L

## P

## Q



## R



## S

## V



## W



A CATA-

A

# CATALOGUE

OF

## MATHEMATICAL and PHILOSOPHICAL INSTRUMENTS,

MADE AND SOLD BY

## GEORGE ADAMS,

Mathematical Inſtrument-Maker to His MAJESTY,
No. 60, Fleet-Street, London.

### Optical Inſtruments.

| | £. | s. | d. |
|---|---|---|---|
| THE beſt double jointed ſilver ſpectacles with glaſſes — | 1 | 1 | 0 |
| The beſt ditto with Brazil pebbles — | 1 | 16 | 0 |
| Single joint ſilver ſpectacles with glaſſes | 0 | 15 | 0 |
| Ditto with Brazil pebbles — | 1 | 10 | 0 |
| Double joint ſteel ſpectacles with glaſſes | 0 | 10 | 6 |
| Another ſort of ditto — | 0 | 7 | 6 |
| Beſt ſingle joint ſpectacles — | 0 | 5 | 0 |
| Ditto inferior frames —— | 0 | 3 | 6 |
| Noſe ſpectacles mounted in ſilver | 0 | 7 | 0 |
| Ditto in tortoiſeſhell and ſilver | 0 | 4 | 0 |
| Ditto in horn and ſteel — | 0 | 1 | 0 |
| Spectacles for couched eyes | | | |
| Spectacles with ſhades | | | |
| Concave glaſſes in horn boxes for ſhort ſighted eyes | | | |

Ditto

| | £. | s. | d. |
|---|---|---|---|
| Ditto mounted in tortoiseſhell and ſilver, pearl and ſilver, in various manners, and at different prices | | | |
| Reading glaſſes, from 2s. 6d. to | 2 | 2 | 0 |
| Opera glaſſes, from 10s. 6d. to | 2 | 2 | 0 |
| Ditto of an improved conſtruction | 1 | 1 | 0 |
| Concave and convex mirrors in frames, from 7s. 6d. to — — | 18 | 18 | 0 |
| Teleſcopes of various lengths, ſizes and prices | | | |
| Teleſcopes to uſe at ſea by night | 1 | 11 | 6 |
| Acromatic proſpects, from 15s. to | 2 | 12 | 6 |
| Acromatic teleſcopes, with braſs drawers, which may be drawn out at once, and that ſhut up, conveniently for the pocket, from 2l. 12s. 6d. to — | 13 | 13 | 0 |
| An optical vade mecum, or portable acromatic teleſcope and microſcope, &c. for tranſparent and opake objects, &c. from 3l, 13s. 6d. to —— | 4 | 14 | 6 |
| A thirty inch acromatic teleſcope, with different eye pieces for terreſtrial and celeſtial objects, from 8l. 8s. to | 11 | 11 | 0 |
| Ditto with rack work | | | |
| An acromatic teleſcope, about three feet and an half long, with different eye pieces | 18 | 18 | 0 |
| Reflecting teleſcopes of all the various ſizes | | | |
| A three foot reflecting teleſcope with four magnifying powers | | | |
| A ditto with rack work —— | 36 | 15 | 0 |
| A two foot reflecting teleſcope, with rack work and four magnifying powers | 21 | 0 | 0 |
| A two foot reflecting teleſcope, with two magnifying powers —— | 12 | 12 | 0 |
| An eighteen inch ditto —— | 8 | 8 | 0 |
| A twelve inch ditto —— | 5 | 5 | 0 |
| Double reflecting microſcopes, from 3l. 13s. 6d. to - - - - - | 21 | 0 | 0 |
| Ellis's aquatic microſcope - - | 2 | 2 | 0 |

Wilſon's

| | £. | s. | d. |
|---|---|---|---|
| Wilſon's microſcope, improved - | 2 | 12 | 6 |
| Adams's lucernal microſcope for opake and tranſparent objects, being the moſt perfect inſtrument of the kind hitherto contrived, affording more entertainment and inſtruction than any other inſtrument - | 21 | 0 | 0 |
| Solar microſcopes - - - | 5 | 5 | 0 |
| Ditto for opake objects - - | 16 | 16 | 0 |
| Ditto - - - | 21 | 0 | 0 |
| Camera obſcuras, from 12s. to - | 7 | 7 | 0 |
| Glaſs priſms, from 7s. 6d. to - | 2 | 2 | 0 |
| Magic lanthorns - - | 1 | 5 | 0 |

## Geographical and Aſtronomical Inſtruments.

| | | | |
|---|---|---|---|
| Adams' new eighteen inch globes mounted in the moſt approved form, from 9l. 9s. to | 27 | 0 | 0 |
| Ditto in the Ptolemaic or common manner | 6 | 6 | 0 |
| Ditto, twelve inches in diameter, mounted in the beſt manner, from 5l. 5s. to | 6 | 16 | 6 |
| Ditto in the common manner - | 3 | 3 | 0 |
| An armillary dialling ſphere - - | 40 | 0 | 0 |
| Manual orreries, from 1l. 1s. to | 3 | 13 | 6 |
| Planetarium, tellurian, and lunarium | 31 | 10 | 0 |
| Adams's improved equatorial dial, or portable obſervatory, from 7l. 17s. 6d. to | 31 | 10 | 0 |
| Horizontal ſun dials, from 5s. to - | 12 | 12 | 0 |
| Univerſal ring dials, from 7s. 6d. to | 3 | 3 | 0 |
| Tranſit inſtruments | | | |
| Aſtronomical quadrants, from 50l. to | 800 | 0 | 0 |

## Mathematical and Surveying Inſtruments.

| | | | |
|---|---|---|---|
| Caſes of drawing inſtruments, from 7s. 6d. to | 35 | 0 | 0 |
| Neat magazine caſes of inſtruments - | 11 | 11 | 0 |
| Eliptical compaſſes - - | 4 | 4 | 0 |
| Beam compaſſes with diviſions, &c. | | | |
| Triangular compaſſes of a new conſtruction | | | |

Adams'

| | £. | s. | d. |
|---|---|---|---|
| Adams's sectoral elliptical and callipper compasses in one instrument, from 4l. 14s. 6d. to | 9 | 9 | 0 |
| Adams's protracting parallel rules, and universal plotting scale | | | |
| Protractors, sectors, scales, parallel rules, &c. | | | |
| A new instrument for taking perspective views, &c. - - - | 12 | 12 | 0 |
| A ditto for ascertaining points - | 2 | 12 | 6 |
| Another instrument for taking views | 5 | 5 | 0 |
| Pantographer, from 2l. 2s. to - - | 6 | 6 | 0 |
| Plain tables, from 3l. 13s. 6d. to - | 14 | 14 | 0 |
| Theodolites, from 4l. 4s. to - - | 31 | 10 | 0 |
| A neat portable theodolite - - | 8 | 18 | 6 |
| Adams's improved double theodolite, exceeding, for accuracy and utility, every former kind, from 12l. 12s. to | 31 | 10 | 0 |
| Measuring wheels, from 6l. 6s. to | 10 | 10 | 0 |
| Circumferenter, from 2l. 2s. to - | 15 | 15 | 0 |

## Philosophical Instruments.

| | | | |
|---|---|---|---|
| Improved electrical machines, from 3l. 13s. 6d. to - - - - | 40 | 0 | 0 |
| Electrical machine and apparatus, in a box, from 6l. 16s. 6d to - - | 12 | 12 | 0 |
| Medical apparatus - - | 2 | 2 | 0 |
| Electrical machines, with a selected apparatus, in a box, from 7l. 7s. 0d. to | 31 | 10 | 0 |
| Batteries, and all other parts of an electrical apparatus | | | |
| Small single barrelled air pump | | | |
| Small double ditto | 4 | 14 | 6 |
| A large ditto | 6 | 16 | 6 |
| Table air pump | 10 | 10 | 0 |
| An improved air pump, superior to Smeaton's construction of the pump | | | |
| Apparatus to an air pump, from 4l. 4s. to | 30 | 0 | 0 |

Barometers

| | | | |
|---|---|---|---|
| Barometers - - - | 2 | 2 | 0 |
| Ditto - - - | 2 | 12 | 6 |
| Barometers, Thermometers, from 3l. 3s. to | 5 | 5 | 0 |
| Marine barometers | | | |
| Thermometers, in mahogany boxes, from 1l. 1s. to - - - | 1 | 11 | 6 |
| Ditto with Reaumur and Farrenheit's ſcales, Botanic thermometers - - | 0 | 18 | 0 |
| Thermometers for brewers, from 12s. to | 2 | 2 | 0 |
| Hygrometers, from 10s. 6d. to - | 3 | 13 | 6 |
| The mechanic powers, compriſed in a ſmall neat form - - - - | 21 | 0 | 0 |
| Ditto, fitted up on a larger ſcale, with improvements - | | | |
| An apparatus for making experiments on accelerated, retarded, and rotatary motion | | | |
| A mechanic apparatus fitted up for the purpoſe of inſtructing young people, &c. | | | |
| A pneumatic apparatus, fitted up for the ſame purpoſe - - | 15 | 15 | 0 |
| An electrical apparatus, fitted up on the ſame plan - - - - | 7 | 7 | 0 |
| A magnetical apparatus, from 2l. 12s. 6d. to | 10 | 10 | 0 |
| Conductors for ſhips to preſerve them from lightning - - - | 5 | 5 | 0 |

Fig. 1.

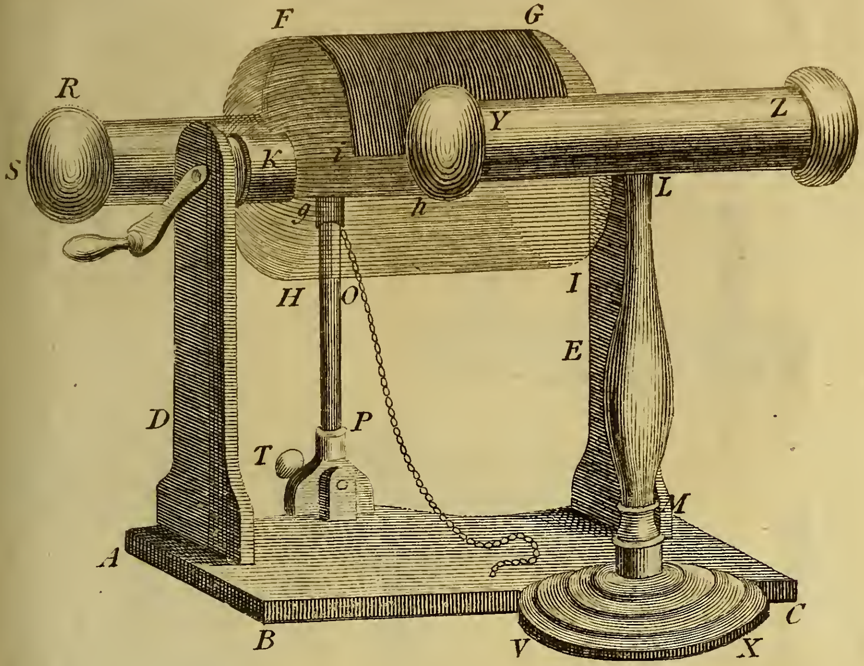
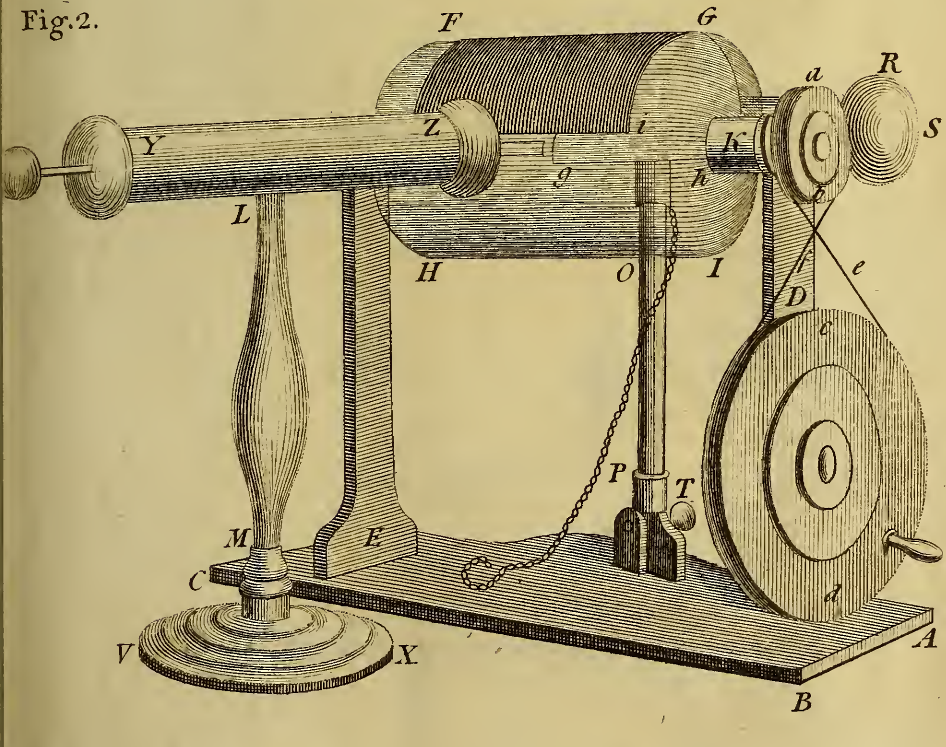



Fig. 2.




J. Lodge sculp.

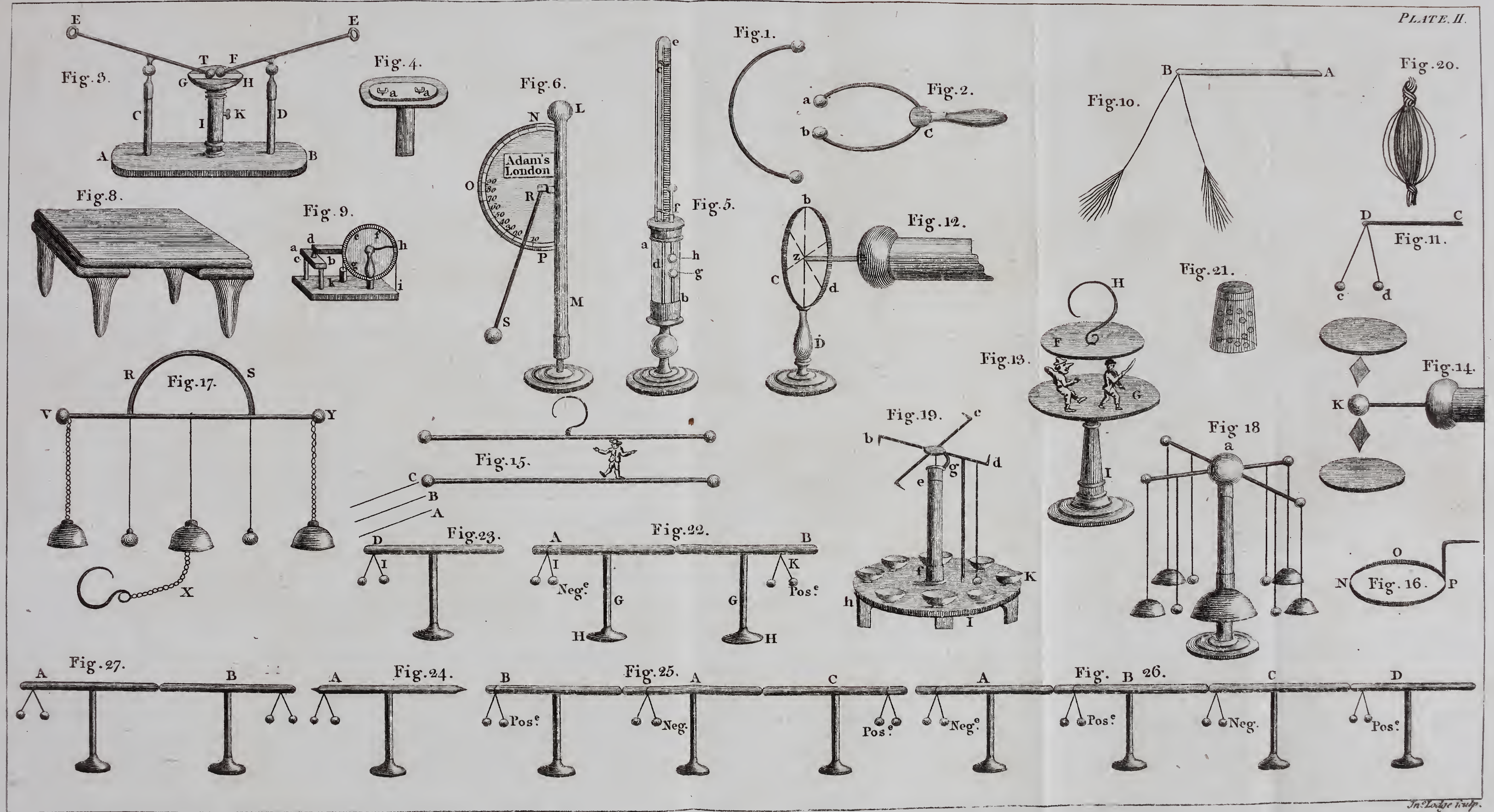
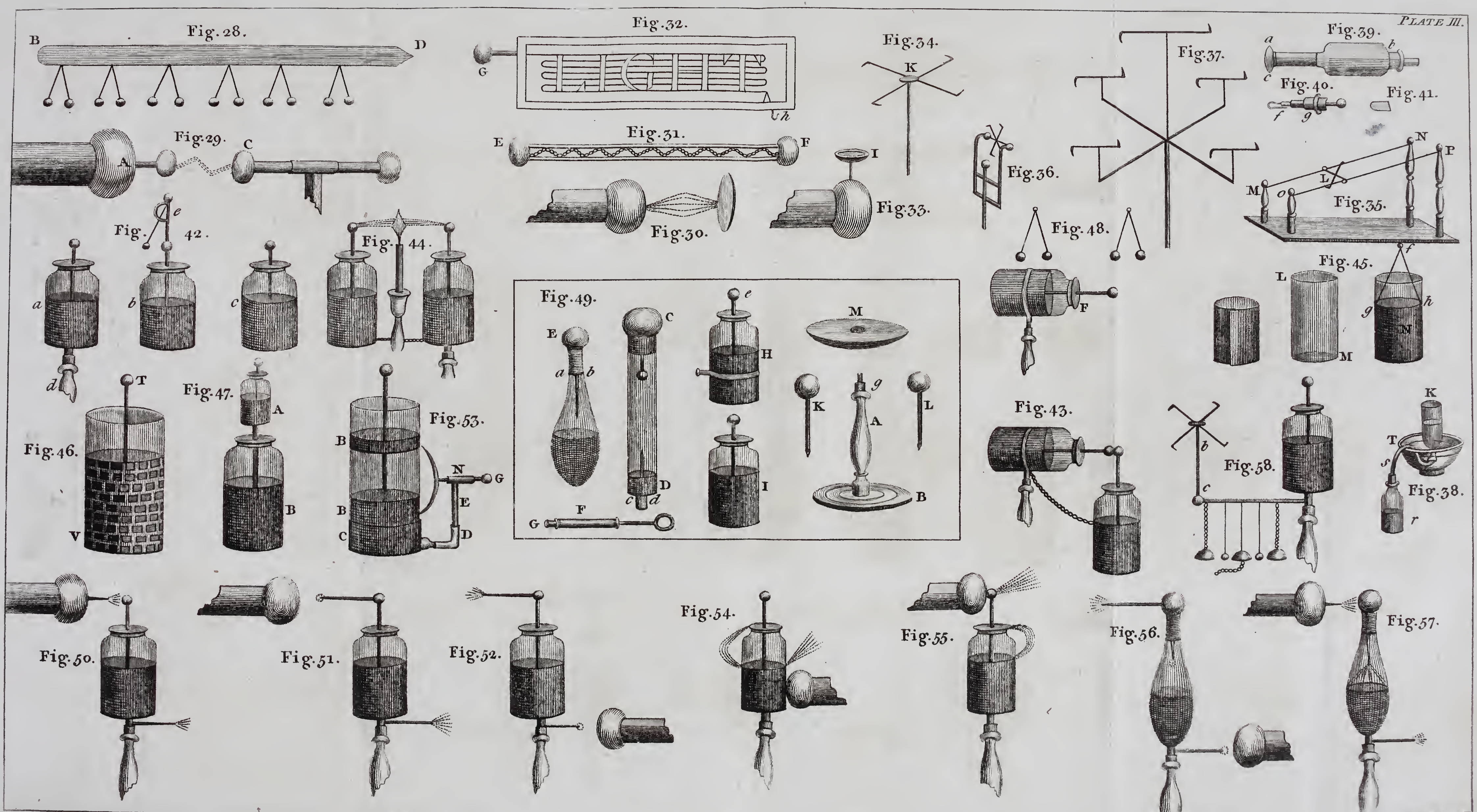


PLATE. II.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Adam's London
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig 18
Fig. 19.
Fig. 20.
Fig. 21.
Fig. 22.
Fig. 23.
Fig. 24.
Fig. 25.
Fig. 26.
Fig. 27.
Neg.e
Pos.e
Neg.
Jn.o Lodge sculp.

PLATE III.




Jn. Lodge sculp.

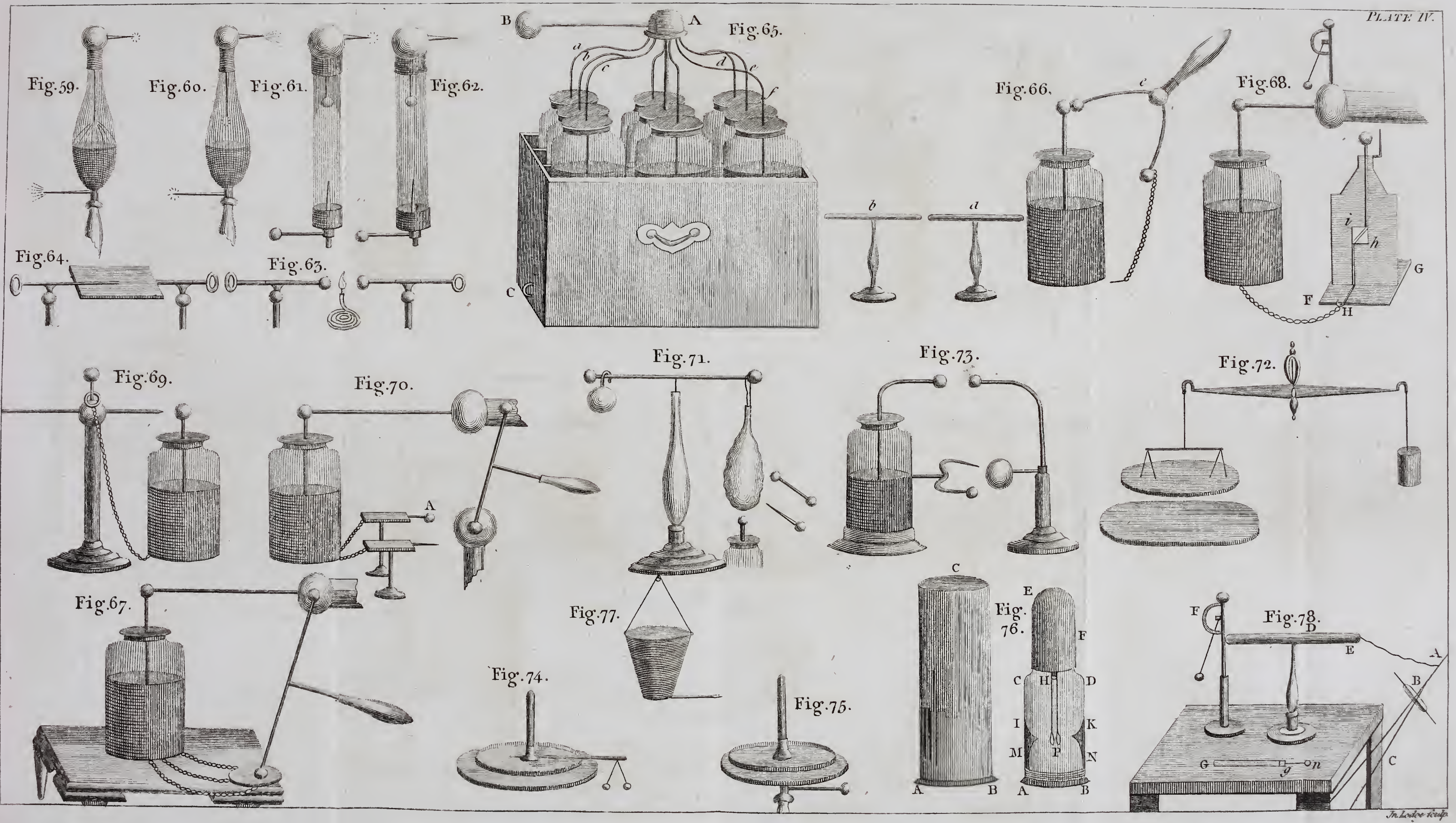


PLATE IV.
Fig. 59.
Fig. 60.
Fig. 61.
Fig. 62.
Fig. 63.
Fig. 64.
Fig. 65.
Fig. 66.
Fig. 67.
Fig. 68.
Fig. 69.
Fig. 70.
Fig. 71.
Fig. 72.
Fig. 73.
Fig. 74.
Fig. 75.
Fig. 76.
Fig. 77.
Fig. 78.
Jn. Lodge sculp.

PLATE V.

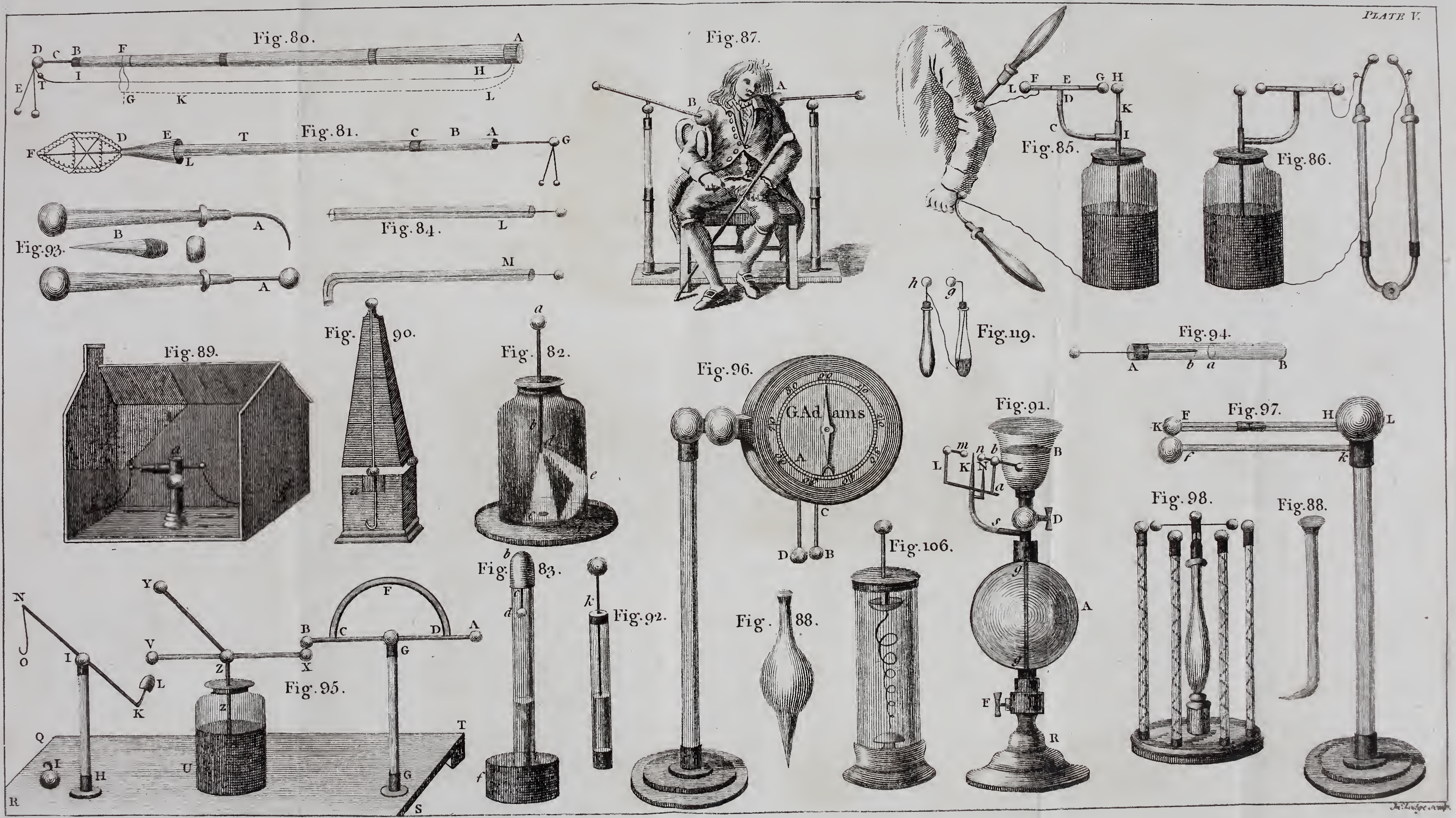


Fig. 80.
Fig. 81.
Fig. 82.
Fig. 83.
Fig. 84.
Fig. 85.
Fig. 86.
Fig. 87.
Fig. 88.
Fig. 88.
Fig. 89.
Fig. 90.
Fig. 91.
Fig. 92.
Fig. 93.
Fig. 94.
Fig. 95.
Fig. 96.
G. Adams
Fig. 97.
Fig. 98.
Fig. 106.
Fig. 119.

Fig. 99.

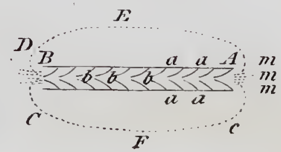



Fig. 100.

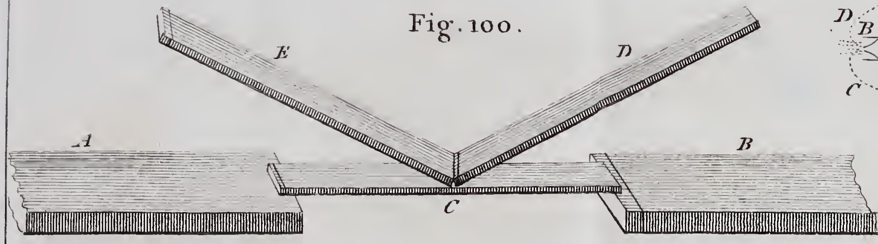



Fig. 101.

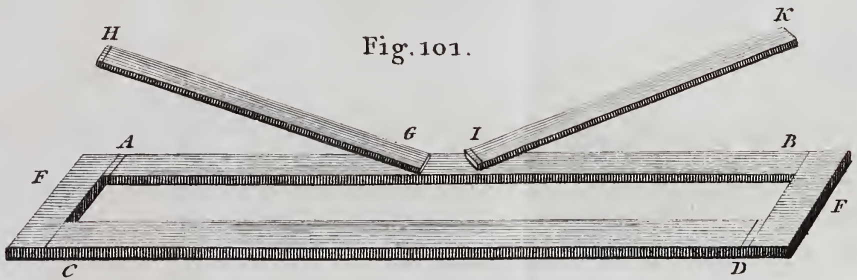



Fig. 102.

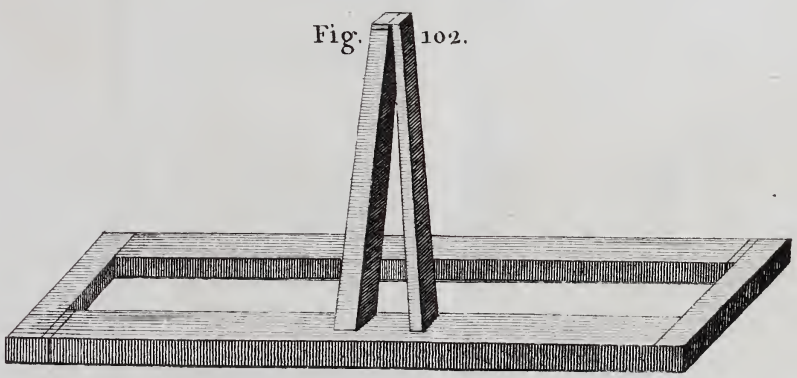


Fig. 103.

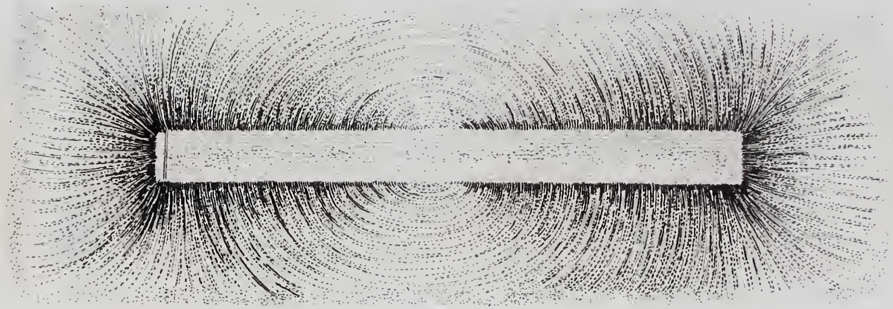


Fig. 104.

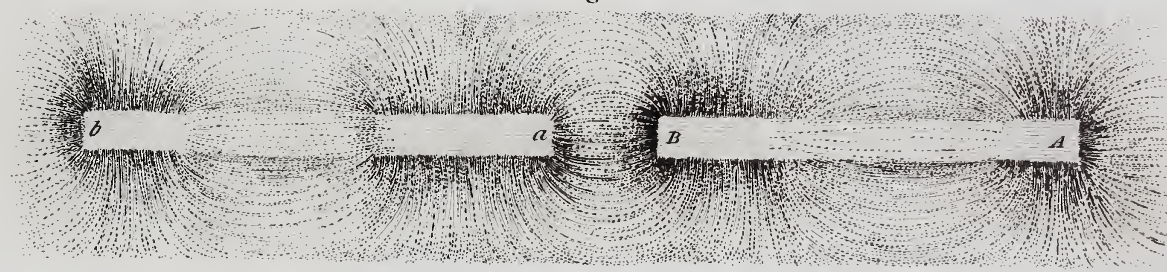
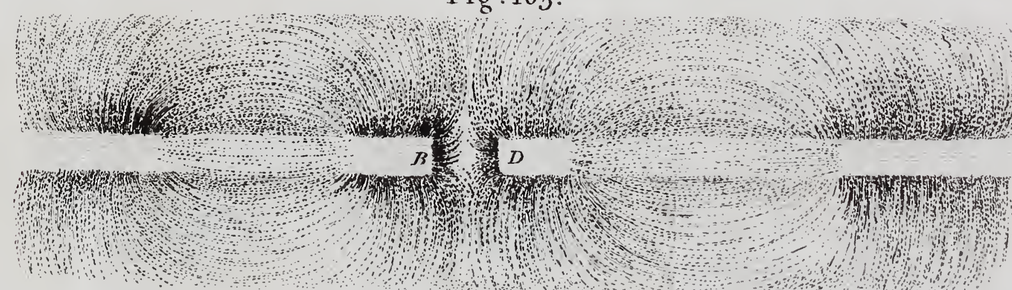
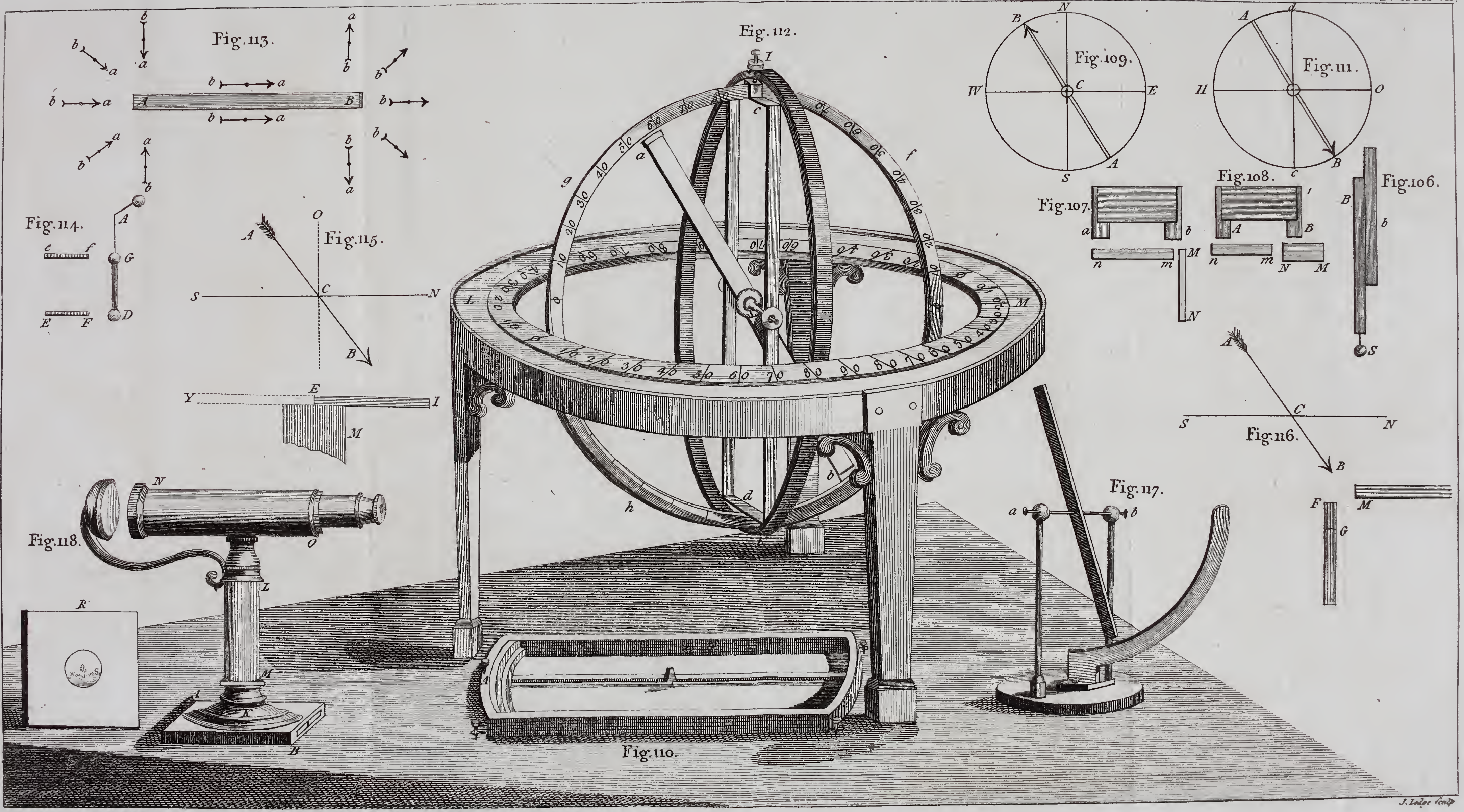



Fig. 105.




Jn.o Lodge sc.




J. Lodge sculp.