

An introduction to electricity. In six sections ... : illustrated with copper plates / by James Ferguson.

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Ferguson, James, 1710-1776.
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Publication/Creation

London : Printed for W. Strahan and T. Cadell, (successor to Mr. Millar) ...,
1775.

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AN
INTRODUCTION
TO
ELECTRICITY.
IN SIX SECTIONS.

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|---|---|
| I. Of Electricity in general. | chine be in good Order |
| II. A Description of the Electrical Machine. | for performing the Experiment, and how to put it |
| | in Order if it be not. |
| III. A Description of the Apparatus (belonging to the Machine) for making Electrical Experiments. | V. How to make the Electrical Experiments, and to |
| | preserve Buildings from |
| | Damage by Lightning. |
| IV. How to know if the Ma- | VI. Medical Electricity. |

THE SECOND EDITION.

Illustrated with Copper-plates.

By JAMES FERGUSON, F. R. S.

L O N D O N :

Printed for W. STRAHAN, and T. CADELL,
(Successor to Mr. MILLAR,) in the Strand.

MDCCLXXV.



ADVERTISEMENT.

*H*AVING lately added to my Electrical Apparatus, Models of all the Machines represented in the second and third plates, which I have reason to believe were never made for the like purpose before, and having observed that the Experiments made by these Models seemed to please those who have seen them, I now publish an account of them; hoping that others may copy them for their own amusement and that of their friends.

If any one who is already acquainted with the various operations of Electricity condescends to read this small treatise, he will see that it is written chiefly for those who scarce know how to make the common Electrical Experiments, or even know how to keep a Machine in good order for that purpose.— And if the following directions, and explanation of the Causes why the results of the operations are such as we find them, be kindly received by such persons, my design will be fully answered.

J. F.

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A N
I N T R O D U C T I O N
T O
E L E C T R I C I T Y.

S E C T I O N I.

Of Electricity in general.

1. **T**HE term ELECTRICITY is derived from *ηλεκτρον*, the Greek name for amber, which Theophrastus, about 300 years before Christ's birth, found to attract light bodies, such as chaff and bits of straws; but now it is extended to signify the like power in all other bodies wherein that power resides.

B

2. All

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

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

tracted from the humidity of the air, or from people's breath.

4. The quantity of electric fire which every body has lying dormant in it, is called its natural quantity; and this would always remain motionless and invifible, if nothing difturbed it.----- But when any more is forced into it, as, fuppofe at one end, the whole is infantly put into motion thereby, and begins to be driven out at the other, if it can find a paffage *; as if a long narrow tube, open at both ends, be filled with water, and laid down on level ground, the water will remain at reft in the tube; but, if a fyringe be filled with water, and fixed to either end of the tube, and then the piston of the fyringe be pushed inward, to force more water into the tube, the whole water in it is thereby infantly put into motion, and begins to run out at the other end.

* In conductors of electric fire, fharp points are as free paffages as the open ends of tubes are for water.

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5. The earth is the grand source of electric fire, and no additional quantity can be forced into any body but from the earth. If the body be a free conductor, and has a communication with the earth by means of any other conducting substance, as metal, or by a table, to the floor and walls of a room, and from thence to the earth, the electric fire will run as fast from the conductor to the earth, as it is by any means driven into the conductor. But if the communication between the earth and the conducting body be cut off by means of any non-conductor, some of the electric fire may be forced into the conductor, by which means it will have more than its natural quantity; and the earth, from which that additional quantity comes, will have so much the less: which could never be, if the electric fluid were not of an elastic nature, or could not be compressed.

6. When any body has more than its natural quantity of this fire or fluid, it is said to be electrified positively, or *plus*; and when it has less than its natural quantity, it is said to be electrified negatively, or *minus*.----- And the machine may be made so, as to electrify either of these ways.

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

8. If one body, as suppose a piece of metal, be kept for some time in an electrified state, by means of the machine, and an un-electrified light body, as suppose the down of a feather, be brought near the metal, the feather will be attracted to the metal, and electrified thereby: on which it

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will be immediately repelled therefrom, and will not return to the metal again, till after it has touched some unelectrified body that is of the conducting kind, and deposited its fire thereon ; and then, if the distance be but small, as about two or three inches, it will return to the electrified metal as before, and be repelled from it again.

9. If a fine linen thread be tied to the down of a feather, and allowed to hang downward from it, so as almost to touch the table or floor, and the feather be brought near the electrified metal, it will be attracted by the metal, and cling thereto, as long as the metal is kept in an electrified state. For then, as fast as the feather receives the electric fire, that fire will run off by the thread to the table or floor, so that the feather can retain no more fire than what is equal to its natural quantity. But, if the thread be cut off close by the feather with a pair
of

of scissars, the feather will then be immediately electrified *plus*, and repelled from the metal.

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

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

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attracts, and be seen going off in the form of a cone from the other point.

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

SECTION II.

A Description of the Electrical Machine.

13. **T**HE electrical machine, mostly now in use, and as it is made in the greatest perfection by Mr. *Edward Nairne*, Optician in Cornhill, London, is represented by Fig. 1. of Plate 1. in which *A* is a glass globe, *B* the handle or winch that turns it, by means of some wheel-work within the brass box *C*; and *D* is a cushion, covered with red basil leather, for rubbing gently against the globe. The cushion is supported by a brass spring *E*, and may be made to press more or less against the globe, by turning the screw *F* forward or backward; *GH* is the prime conductor, which is a brass tube with a round hollow ball at each end. The brass piece *I* is stuck into a hole in the ball *G*, and has several small forks of brass or steel, with sharp points,

points, which almost touch the globe. The barrel of the conductor is put into the brass socket *a*, (which may be done after taking off the ball *G*), and to this socket is joined the brass socket *K*, in which the upper end of the glass tube *L* is fixed with cement, and the lower end is cemented into the wooden foot *M*.—The glass tube, being a non-conductor, insulates (as it were) the prime conductor *GH*, by cutting off all conducting communication between it and the earth. For, as the electric fire comes from the earth to the machine, and is put into motion and action by the rubbing of the glass globe against the cushion, and this fire goes round with the globe to the points *I*, which attract it and carry it to the prime conductor; if the conductor were not insulated in this manner, or hung by silk lines, the fire would run as fast from it to the ground, as it received the fire from the globe; and then the whole machine would be good for nothing.

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

15. The

15. The holes in the prime conductor, for receiving the ends of the wires *N*, *c*, *d*, and the feather *b*, should be well rounded off, and made smooth about their edges. For, if the edges are left sharp, they will be of the same nature as points, in throwing off the electric fire; and this would spoil the experiments.—I shall next describe the different parts of the apparatus belonging to my electrical machine, of which those in Plate 2. are entirely new; at least they are so to me.

S E C.

SECTION III.

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

PLATE I. FIG. I.

16. *O* and *P* are two little balls, made of pith of elder, to which the ends of a fine linen thread (about 7 or 8 inches long) are fixed.—When they are used, they are hung by the middle of the thread upon a wire *N*, close by a round ball of metal, which is fixed upon one end of the wire; and the other end is then stuck into a hole in the end *G* of the prime conductor *GH*.

17. *cd* is a crooked wire (which must be roundish, not sharp at the bended parts) to be stuck into a hole
in

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

18. *Q* is a brass hook fixed to a cross bar of brass, from which hang three bells *R, S, T*, with their clappers *U* and *V*, which are small brass balls.—The bells *R* and *T* are hung by metal chains; the middle bell *S* by a
filk

filk line, and the clappers by filk threads.—A metal chain *W* hangs from the middle bell, the lower part of this chain lies on the table (to which the electrical machine is fixed) and a piece of filk cord *w* is tied to the lower end of the chain.

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

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be placed, if the other plate be hung directly over it.

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

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

22. In Fig. 6. ABC is a bended wire, the end A being made blunt, and of such a size as to fit either of the round holes in the prime conductor, instead
of

of either the straight wire N , or the crooked wire cd ; and the end c must be a sharp point.

23. In Fig. 2. *A* is a glass jar, coated on the outside, and lined on the inside with tinfoil to about two inches short of its top, which is stopp'd with a thin cork, first dipt all over in melted wax. A straight brass wire is put down through the middle of the cork, quite to the lining which covers the inside of the bottom of the jar; and a smooth ball *a* is fixed on the top of the wire, which must be of such a height as to touch the ball of the prime conductor when the jar is set near enough to it on the table.—*B* is the discharger, which is made of strong brass wire, bent into the form of part of a circle; and has two brass balls *c* and *d* fixed on its ends. The brass balls on the tops of all the wires belonging to the several jars ought to be of equal height when they are set upon a table. The thinner these

C

jars

jars are, they are so much the better for electrical experiments. The coating and lining are generally fixed to them with thick starch, or book-binder's paste; but I find that thick varnish, such as is used by coachmakers, does better for that purpose; and dries immediately, which the other does not.

24. In Fig. 3. *A* is just such a jar as the one above described; only it has an additional wire *B*, bent into the form of a ring, so as to fit the outside, and remain on any part of the coating over which it is placed; with a brass ball *D* on its top, of equal height from the table with the ball *C*.—*E* is a bit of cork, cut into the form of a spider, with legs of linen thread, fixed into it by drawing them through with a small needle, and then they are cut with scissors to a proper length. It is hung by a fine silk thread to the ceiling of the room, and at such a height above the table that its legs may touch
the

the balls *C* and *D*, if it be made to swing between them.—Before the legs are put to it, it must be put upon the point of a wire, and turned round and round in the flame of a candle, to burn off the roughness and sharp edges which the knife had left on its surface; and then the burnt parts must be rubbed off between a wet finger and thumb, to smooth it.

25. In Fig. 4. *A a* is a thin glass, blown into the shape of a Florence flask, left open at the small end *a*. A cork, through which a small hole has been made by a red-hot iron wire, is cemented into this glass at the mouth *a*; and a narrow slip of thin bladder, that had been moistened before, is tied over the hole, by way of a valve. The glass is then put under a receiver on the air-pump, and exhausted of air; then taken out, and a brass cap *a*, in which some hot sealing-wax has been poured, is put on, over the valve, to prevent any air from getting afterward

into the glass. The inside of this glass must be perfectly clean and dry: for, if there be any dust or damp within it, it will be of no use for an experiment.

26. Fig. 5. is the artificial *thunder-house*, with its appurtenances. *A* is a mahogany board, half an inch thick, and shaped like the gable-end of a house, which is all that is necessary of the house for an experiment. It is fixed upright on the horizontal board or stand *B*, in which is also fixed the lower end of an upright glass tube *CD*; in the upper end of which, the end *D* of a crooked brass wire *DEwF* is cemented; and on the other end of the wire is fixed the smooth brass ball *F*; above which some downy feathers *H* are hung around the wire by linen threads, which are tied round the wire by a thread of the same sort. —One end of a metal chain *IK* is hung by a hook on this wire, and the other end is hung by a hook to the farthest

farthest end *L* of the prime conductor of the electrical machine; and the coated jar *M* is so placed, in making the experiment, that the ball *m* on the top of its wire may touch that end of the conductor.—A square hole *a b c d*, a full quarter of an inch deep and three quarters wide, is made in the gable-board *A*, and filled with a square piece of wood *N* just as thick as the hole is deep; but it must go so easily into the hole, that it would drop out if *A* were turned over toward *B*. A wire *a N c* is put into this board, very fast, in a diagonal channel just as deep as the wire is thick, so as never to be taken out again. And, in the same manner, the wires *g d* and *b b* are fixed in the gable-board, the lower end of the former being at the corner *d* of the square hole, and the upper end of the latter at the opposite corner *b*. The wire *g d* has a brass ball *G* on its top, directly below the ball *F*, and about half an inch from it: the wire *b b* is turned up at the lower end, in the

form of a hook, on which one end of a metal chain $i k$ is hooked, and the other end of the chain is put round the bottom of the coated jar M .—When the square board N is put into the hole $a b c d$ in the way represented in the figure, its diagonal wire $a N c$ has no connection with the wires $g d$ and $b b$: but, if it be taken out, and turned a quarter round, and then put in again, the wire $a N c$ will be in the position $d N b$; and then its ends will touch the nearest ends of both the other wires at d and b , and the whole will seem as if it were only one continued wire, bent at the opposite corners b and d .—This was contrived by Dr. James Lind of Edinburgh, for verifying Dr. FRANKLIN's method of preserving houses by means of metal rods, from damage by lightning, when it breaks upon them; the rods collecting the whole of the lightning into themselves, and conducting it harmlessly down into the ground.

27. The magical picture, contrived by Mr. Kinnerfley *, is made thus :
 “ Having a large mezzotinto with a
 “ frame and glafs suppose of the
 “ KING, (God preserve him), take
 “ out the print, and cut a pannel out
 “ of it, near two inches diftant from
 “ the frame all around. With thin
 “ pafte, or gum-water, fix the border
 “ that is cut off on the infide of the
 “ glafs, preffing it fmooth and clofe ;
 “ then fill up the vacancy by gilding
 “ the glafs with leaf-gold or brafs.
 “ Gild likewise the inner edge of the
 “ back of the frame all round, except
 “ the top part, and form a communi-
 “ cation between that gilding and the
 “ gilding behind the glafs ; then put
 “ in the board, and that fide is finifh-
 “ ed. Turn up the glafs, and gild the
 “ forefide exactly over the back-gild-
 “ ing, and when it is dry, cover it,
 “ by pafting on the pannel of the

* Franklin's Letters, page 29. printed in the year 1769.

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“ picture that had been cut out, ob-
“ serving to bring the correspondent
“ parts of the border and picture to-
“ gether, by which the picture will
“ appear of a piece, as at first, only
“ part is behind the glass, and part
“ before.”

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

29. I shall now describe the figures on Plate 2^d and 3^d, which are representations of some models of machines
that

that I have lately made; and, for the amusement of those who attend my lectures, I set these models in motion by a stream of electric fire. It must be confessed, they do not properly belong to the class of electrical experiments, because they might be put into motion by water, wind, or weights. Yet, as it is not unpleasing to see them move by electricity, perhaps some gentlemen who have a mechanical turn, and are provided with electrical machines, may like to copy these models, both for their own amusement and that of their friends.

— All the wheels and trundle-heads are made of card-paper, the axles of common knitting wires, the trundle-staves of wood, the frames (in which the ends of the axles turn round) of thick brass-wire, and the supporting foot of wood.— The biggest wheel, which resembles the water-wheel of a common breast-mill, is five inches in diameter; and all the rest of the wheels much in the same proportion thereto,

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thereto, as the figures represent them. The whole work is made so free, easy, and light, that a force equal to one grain weight, acting on the great wheel, will put all the rest into motion.

30. Fig. 1. of Plate 2. is a clock for shewing the apparent diurnal motions of the sun and moon, with the moon's age and phases. — *A* is the back of the dial plate (the face of which is shewn by Fig. 2.) *B* the horizontal board or foot that supports the whole; and *C* is the great wheel which is turned by the electric stream, according to the order of the letters *a b c*. On the axis of the great wheel is a trundle *D*, turning the contrate wheel *E*, on whose axis is the trundle *F*, turning two wheels *G* and *H*; *G* having 59 teeth, and *H* 57; and these are the only two wheels in which the numbers of teeth need be regarded, for all the use of the rest is only to put these two in motion. The axis of the wheel *H* is

is a short hollow socket, and the wire-axis of *G* turns within it: the former of these carries a sun round the dial-plate, and the latter carries a moon round the same. If the sun's motion round the dial-plate be accounted 24 hours, the moon will not go round it in less than 24 hours 50 minutes 32 seconds: for as 57 teeth are to 24 hours, so are 59 teeth to 24 hours 50 minutes 32 seconds; which is very near the truth: for the moon in the heavens is 50 minutes 28 seconds later in coming to the meridian every day, than she was in the day before.

The face of the dial-plate (Fig. 2.) has all the 24 hours upon it; and a point from the sun *S* serves for the index or hour-hand. In the middle are two round plates, equal in size, one directly over the other, so that the lowest is hid from sight by the uppermost, in a front view. The sun *S* is a part of the lowest plate, and the moon *M* a part of the uppermost; so that, if these

these plates be turned round, they carry the sun and moon round with them.—The sun's plate has a circular space all around, divided into $29\frac{1}{2}$ equal parts, which shew the days of the moon's age from change to change, and appear successively through an opening *a b* in the upper plate; and between that opening and the center is a round hole, through which the moon's different phases are seen on the under plate, according to all the different days of her age. — The undermost plate, which carries the sun, is fixed on the hollow axis of the wheel *H* (Fig. 1.) and the uppermost plate, which carries the moon, is fixed on the axis of the wheel *G*: so that the revolutions of these plates will be just as different as the revolutions of their two wheels are; *viz.* in the time the wheel that carries the sun makes $29\frac{1}{2}$ revolutions, the wheel that carries the moon will make only $28\frac{1}{2}$. And this will carry the moon so much slower round than the sun, that she will
be

be 50 minutes 32 seconds later in coming to the meridian, or uppermost XII, every day, than she was on the day before; accounting each complete revolution of the sun to be 24 hours, which includes both the day and the night: So that the moon, by going gradually off, will go round from the sun to the sun again in $29\frac{1}{2}$ days and nights, which is the time between change and change. In each revolution of the sun a different day of the moon's age will be seen through the opening *a b*; and a different phase of the moon will appear through the round hole.—I need not inform any clockmaker how easy it would be for him to have such an apparent diurnal motion of the sun and moon in a real clock.

31. Fig. 3. of Plate 2. is a kind of Orrery, for shewing the earth's motion round its axis in 24 hours, the age of the moon from change to change, and all her various phases during that time. *A* is the horizontal

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board or stand of this machine, and *B* is the great wheel, with 18 floats or wings for the electric stream to act upon, and turn the wheel according to the order of the letters *a b c d*. On the axis of this wheel is a trundle *C*, of 8 flaves, for turning the wheel *F*, of 32 teeth, on whose axis is a trundle *G*, of 8 flaves, for turning the wheel *H*, of 59 teeth, which will go once round in the time the great wheel *A* goes $29\frac{1}{2}$ times round. A light hollow globe *D*, representing the earth, with its meridians, equator, tropics, polar circles and poles, is put upon the top of the axis of the great wheel *A*, and on the same axis is an index *E*, which goes round a small dial-plate *e* of 24 hours in the time that the earth *D* turns round. And an ivory ball *I* is placed on the top of the axis of the wheel *H*, half black half white, to represent the moon; below which, on the same axis, is an index *K*, which goes round a small plate *k* divided into $29\frac{1}{2}$ equal parts, for the days of the moon's

moon's age from change to change. —So that, in the time the great wheel *A*, the earth *D*, and hour-index *E*, make $29\frac{1}{2}$ revolutions, the moon *I* and her index *K* make only 1; and in that time, by shewing herself all round to the observers, they see all her different phases or appearances, like those of the real moon in the heavens.

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

fo

so that this model has all the working parts of a double water-mill, turning two millstones.

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

g and *b* must be hooked to the other ends of the wires. The method of using it will be shewn in the 31st experiment.

34. The figure on Plate III. is taken from a model of a horizontal windmill that works three pumps for raising water.—It was invented by an American farmer, and sent by him to Dr. FRANKLIN, now in London, who gave me leave to copy it, as doing so could not any way injure the inventor, who has contrived his horizontal wheel in such a manner that it will turn equally well by the wind, blowing from any point of the compass. But, as such a wheel would not have answered so well for my electrical machine, I have, instead thereof, made one like that of a common mill.

A is the horizontal wheel, and *B B* its axis, on which is a crank *C*.— As
D
this

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this crank is turned round by the motion of the wheel, it moves the wires *D*, *E*, and *F*, backward and forward, which being hooked to the tops of the wires *G*, *H*, and *I*, gives them a like motion; and they move the wires *K*, *L*, and *M*, up and down alternately, and with them the pump rods which move the pistons in the pumps *N*, *O*, and *P*.

By this ingenious method, one single crank works three pumps in the same manner as is generally done by three cranks on an axis.—The invention is quite new, and seems to me to have a great deal of merit.

SECTION IV.

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

35. **T**AKE away both the cushion and prime conductor from the glass globe, then wipe the globe quite dry and clean with an old soft linen cloth that has been just warmed by the fire; and then put on the cushion, making it press gently against the globe by means of the adjusting screw *F*. (Fig. 1. of Plate I.) This done, turn the globe by the winch, and hold a knuckle of any finger near the side of the globe. Then, if you hear the fire hissing from the globe, and feel it like a gentle wind blowing through a pipe against your knuckle, the machine is in good order. But, if you neither

hear nor feel any fire, take off the cushion, put a little candle-tallow upon it, and then rub on a little amalgama* by means of a piece of brown paper between your hand and the cushion: this done, put on the cushion again, and the machine will work much stronger; as you will find by turning the globe, and presenting your knuckle as before, or by placing the conductor so as the points *I* may be about an eighth part of an inch from the globe, and holding your knuckle near any part of the conductor whilst you turn the globe: for then bright sparks of electric fire will snap from the conductor to your knuckle, which will give a disagreeable but not a painful sensation.

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

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

37. When any of the amalgama sticks to the globe, it must be picked off.—When the working of the globe has made the amalgama smooth and glossy, the cushion must be taken off, and rubbed with a piece of rough brown paper, to take off the polish.—And when amalgama has been put on three or four times, at different times of using the machine, it will form into a hard crust on the cushion, and there will be no occasion to use any more afterwards: only, when the globe has made the surface smooth and glossy again, take

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off the cushion, and rub it to a rough surface by brown paper.

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

39. One day, last summer, when the weather had continued long dry and
warm,

warm, I could not make my electrical machine work at all, either by rubbing the cushion, moistening its leather, or putting more amalgama thereon. For both the earth and floor of the room were so dry, that no electric fire could come to the cushion. I then dipt a hempen cord in water, tied one end of it to the brass spring that supports the cushion, and put the cord out at the window to the ground, under a large water-tub, which by constantly dripping had well moistened that part of the ground; and then the machine did very well.—I afterward told this circumstance to Dr. FRANKLIN, and he informed me that he had often, at Philadelphia, when the weather and ground were very dry, been obliged to put one end of a long wire down into his pump, and hook the other end to the cushion; and then he had fire enough to his electrical machine.

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

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

SECTION V.

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

EXPERIMENT I.

Electric Attraction.

42. **T**IE one end of a fine linen thread to a small downy feather, and let the other end hang down to the table. Then turn the globe of the machine by the winch; and, holding the feather near the ball *G* of the prime conductor, the feather will fly to the ball, and adhere to it as long as you keep working the machine*.

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

As fast as the feather receives the electric fire from the prime conductor, the fire runs off from the feather by the thread to the table, or to the hand that holds the thread. So that, although the feather is still receiving new fire, it parts with it as fast; and therefore there is no increase of its natural quantity: if there were, the feather would then be repelled from the prime conductor. See Sect. I. § 5, 6, and 9.

EXPERIMENT II.

Electric Attraction.

43. Make a ring of wire, at least a foot larger in diameter than the glass globe of the machine, and tie pieces of fine linen threads to it, each about five inches long, and about two inches from each other. Then, having taken away the conductor *G H*, hold the ring in a horizontal position round

the globe, and turn the globe by the winch. As soon as the globe begins to turn round, all the threads will be attracted toward it, and point toward its center, standing horizontally inward, and resembling the radii or spokes of a wheel.

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

EXPERIMENT III.

Electric Repulsion.

44. Stick the wire *N* into the ball *G* of the prime conductor
(Fig.

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

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

natural state; and so they repel each other, according to § 6 and 7.

EXPERIMENT IV.

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

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

N. B. These balls are very good for trying the strength of the electrical machine, which may be done as follows:

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

EXPERIMENT V.

The Electrical Fly.

46. The prime conductor being set properly to the globe, (as in Fig. I.) and every thing at a proper distance from it *, put the blunt end of the

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

crooked

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

To account for this motion of the fly, suppose its arms to be straight hollow tubes, open throughout. Then, if water were forced into them from the center, it would run out at the the open ends, farthest from the center. In this case, the pressure of the water against the inside surfaces of the tubes, being equal all around, could excite no
 motion

motion in the fly. But if the tubes are all bent one way, near their outermost ends, there will be a pressure against the insides of the bended parts, and no pressure opposite to them at the open ends where the water spouts out: and therefore, the pressure against the insides of the bendings will cause the fly to turn round that way.

The electric fluid (like water in tubes) runs from the wire *c d* into the substance of the metal arms of the fly, and goes off freely from their points. If these arms were straight, the fly would not move: but being bent, it must turn round, as a fly of bended tubes would do if water were forced into them at the center.

EXPERIMENT VI.

The ringing of bells.

47. Hang the hook *Q* upon the prime conductor, and the lower part of the chain *W* that hangs from the middle bell *S* (§ 18) will lie upon the table.

table. Then turn the globe by the winch, and the clappers *U* and *V* will fly from bell to bell with a very quick motion; and all the three bells, *R*, *S*, and *T*, will continue to ring as long as you keep turning the globe. In a darkened room, sparks of electric fire will be seen between the clappers and bells.

The two bells *R* and *T*, being hung by metal chains, are electrified from the prime conductor; but the middle bell *S*, and the two clappers *U* and *V*, being hung by silk lines, cannot be electrified thereby (§ 3), because the silk transmits no fire from the conductor to them. The outside bells, being electrified, attract the unelectrified clappers, and deposit part of their fire upon them. The clappers, being then electrified as well as the bells, are repelled from them to the unelectrified middle bell, which takes the fire from them the moment they touch it; and that fire immediately runs off from the middle bell, by the chain *W*,

E

to

to the table. The clappers being then unelectrified (as well as the middle bell), they are attracted back again to the two electrified bells *R* and *T*, and being then again electrified, they are repelled from these bells (as before) toward the middle bell. And thus the ringing must continue as long as the outside bells are kept in an electrified state by the machine.

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

additional quantity, unless that quantity be allowed to run off.

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

EXPERIMENT VII.

Drawing off Streams of Electric Fire.

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

the edge of the plate, the fire will follow your hand, and come to it.

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

EXPERIMENT VIII.

Dancing of Electrified Bran, Images, &c.

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

Or, put some little images, of cut paper, between the plates; and when you turn the globe, the images will
dance

dance, between the plates, in such antick postures as will probably make a whole company laugh, that had never seen the experiment before.

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

EXPERIMENT IX.

Dancing of electrified Cotton.

50. Turn the globe by the winch with one hand, and hold the other about three or four inches from the end G of the prime conductor. While you are doing this, desire any person to let a small lock of cotton drop from his hand upon yours which is near

the conductor; and the cotton will jump from your hand to the conductor, and back to your hand again, with a quick motion, stretching itself out into a longish form both ways, and moving so quick that you will not well be able to perceive its form, and can only see its colour.

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

EXPERIMENT X.

The Electrified Feather.

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

bend about, and follow the moving body.

The first part of this experiment shews electric repulsion; and the last part, electric attraction, as in the 3^d, 1st, and 2^d experiments.

EXPERIMENT XI.

Water Electrified in a Cup.

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

of the unelectrified finger; which shews that an unelectrified body, if it be of the conducting kind, will attract an electrified one.—In a dark room, a stream of fire will be seen issuing from the water to the finger; which shews that water is a conductor of electric fire. See § 3.

EXPERIMENT XII.

The Electrified Water-jet.

53. Hang the leg *A* of a small glass syphon, (Fig. 6. of Plate 2.) into the water in the cup, the other end *B* of the syphon having been turned a little upward, and drawn out into a small capillary bore. Put your mouth to the end *B*, and draw the air out of the syphon, and then the water will follow, and fall from the syphon in drops.—But, turn the globe by the winch, to electrify the water, and it will fly to a good distance from the end *B* of the syphon,

syphon, in one continued jet, which will have the appearance of fire if the room be darkened. If an unelectrified person puts his finger, or any piece of metal, upon the prime conductor, the fire will immediately cease, and the jet will stop; but when the finger or metal is taken away from the conductor, the fire will appear again, and the jet will fly out as before.

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

EXPERIMENT XIII.

A Clock put in Motion by Electricity.

54. Put the end *A* of the crooked wire *ABC* (Fig. 6. of Plate I.) into the hole next above *G* (Fig. 1.), in the end of the prime conductor; and place the wire so, as that its sharp point *C* may be just as high from the table as the great wheel of the clock (Fig. 1. of Plate 2.) is. Then place the clock so on the table as that the point of the wire may be about an inch from the wings of the wheel; and in such a direction, that if the wire were hollow, and wind were blown through it, the wind might turn the wheel according to the order of the letters *a b c*. Then turn the globe of the electrical machine by the winch, and the clock will be put into motion by the small force of the electric stream thrown off by the point of the wire against the wings of the wheel;

wheel ; and the sun and moon will be carried round the dial-plate (the face of which is represented by Fig. 2.) so as to shew their apparent diurnal motions, the different ages and phases of the moon (as described in § 30.), and the time of her coming to the meridian every day of her age, accounted from any change to the next change after it.

EXPERIMENT XIV.

A simple Orrery put into Motion by Electricity.

55. Having set the orrery (§ 31.—Fig. 2. of Plate 2.) properly, near the prime conductor, and placed the above-mentioned crooked wire so as its point may be even with the great wheel *B*, and tend to turn it in the direction *a b c d* ; turn the glass globe of the electrical machine by the winch, and a stream of fire will issue from the wire to the wheel, and turn the whole
of

of the moveable work: by which means, the earth *D* will be turned round its axis, from west, by south, to east; and, in each turn of the earth, the index *E* will go round all the 24 hours on the dial-plate *e* *.——In the time the earth and index turns $29\frac{1}{2}$ times round, the moon *I* will turn once round her axis, shewing all her various phases; and the index *K* will go over all the $29\frac{1}{2}$ days of the moon's age on the plate *k*.

EXPERIMENT XV.

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

56. Set the mill (§ 32.—Fig. 3. of Plate 2.) properly, near the prime conductor, and place the crooked wire so as its point may be directed toward the uppermost side of the great wheel *A*.

* By a mistake in the engraving, the hours are numbered the wrong way round this plate.

Then

Then turn the glass globe by the winch, and the stream of fire that issues from the point of the wire will turn the wheel; and, consequently, all the other working parts of the mill.

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

EXPERIMENT XVI.

A Model of a triple Pump-mill (for raising Water by the Force of the Wind) put into Motion by Electricity.

57. Set the mill (Plate 3.) described in § 34. properly, near the prime conductor, and place the crooked wire so therein as its point may be directed toward

toward the wings of the wheel *A*. Then turn the glass globe by the winch, and the stream of electric fire that issues from the point will turn the wheel; and consequently, the pump-rods will be alternately moved up and down in the pumps *N*, *O*, and *P*.

EXPERIMENT XVII.

The luminous Glass, or Aurora Borealis,

58. This is one of the finest of all electrical experiments, and owes its invention to Mr. JOHN CANTON.—Take the glass *A a* (Fig. 4. of Plate I.) by either of its ends, and hold the other end to the prime conductor. Then make the room quite dark, and turn the globe of the machine by the winch. On doing this, the glass will be full of electric fire, which will stream and flash, exactly resembling the *Aurora Borealis*, or northern lights
in

in the heavens ; and the flashing will continue for some time after the glass is removed from the conductor. When the flashing ceases, and you continue to hold the glass by either end in one hand, apply the palm of the other hand to the other end of the glass, and the fire will appear within it again.—— The method of preparing this glass is shewn in § 25.

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

trical machine, or by rubbing ; which shews that air acts against the electrical fire, and keeps it the longer from flying off, at the surfaces of bodies.

EXPERIMENT XVIII.

Electric Sparks taken from the Prime Conductor.

59. While the globe is turned by the winch, the points *I* (Fig. 1. of Plate I.) attract the fire from the globe to the prime conductor, wherein the fire becomes accumulated and condensed, when there is no other conductor therefrom to carry the fire to the ground. But if any person, standing on the floor, holds a knuckle of any finger near the conductor, as suppose about an inch from it, the condensed fire will snap from the conductor in large sparks to his knuckle ; and give him rather a disagreeable than painful sensation :

fation: and as fast as the fire flies to his knuckle, it runs off by his arms and body to the ground. If he holds his knuckle very near the conductor, he will not feel the fire so sharp, because he has it more gradually, and in a constant small stream: and if he puts his finger upon the conductor, he will not feel the fire in the least, although he receives it just as fast from the conductor as it is given thereto by the globe.

EXPERIMENT XIX.

Electric Sparks taken from the human Body.

60. Having warmed the glass-footed stool (§ 28.) a little by the fire, and wiped it all over to clear it of dust, set it upon the floor, and let any person stand upon it, holding one end of a chain (or rather of a wire), the other end of which is hooked to the prime conductor; the chain or wire being held

held up at some distance from the table, and no chair, table, or person in the room being within a foot of the person who stands on the stool. Then turn the glass globe of the machine by the winch, and all the fire that the prime conductor receives from the globe will be conducted from it by the chain or wire to the person on the stool, and he will be strongly electrified, without feeling any thing from the fire he receives, unless some person who stands on the floor touches him any where with the finger; and if he does, all the fire will snap against his finger from the electrified person, and both these persons will feel it smartly, but it will do no harm to either of them.—By this method, all the electric fire, which a person receives while he stands on the stool, may be drawn off from any part of his body that is touched by a person standing on the ground. But the person who touches, should present

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

In this experiment, the person on the stool may be considered as part of the prime conductor; for he is connected with it by means of a wire or chain, and the glass feet of the stool cuts off all electric communication between him and the ground; so that he retains the fire till it be drawn off from any part of his body, as it was drawn off from the prime conductor itself in the 17th experiment. And the glass tube *L*, on which the prime conductor is supported, cuts off all electric communication between it and the table. If it were supported by any substance (§ 3.) that conducts the electric virtue, no sparks could be taken from it, nor could any thing be electrified by it, for all the electric matter would run from it by the conducting substance to the table and ground, as
fast

fast as it received that matter or virtue from the globe.

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

EXPERIMENT XX.

The Electrical Kiss.

61. Suppose the two above-mentioned persons to be a gentleman and a lady. Let either of them be electrified on the glass-footed stool, whilst the other stands at a little distance on the floor, so that the clothes of the one may not touch the clothes of the

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

EXPERIMENT XXI.

Setting Spirits of Wine on Fire.

62. Let one person be electrified, as in the last experiment, while another stands at some distance on the floor. If either of them holds a silver spoon
with

with some rectified spirits of wine in it, and warms the spirits a little, by holding the spoon over the flame of a candle, and the other person then presents the tip of his finger briskly toward the spirits, a snap of electric fire will ensue, which will set the spirits all in a flame directly.—The person who presents his finger must withdraw it immediately, lest the flame should hurt him.

EXPERIMENT XXII.

The diverging Electrical Flame.

63. Let the person electrified on the stool hold a sword in his hand, or any other pointed piece of metal that is well polished. Then, if the room be darkened, a bluish flame will be seen to issue, in a diverging state, from the point; and continue as long as the globe of the machine is turned by the

F 4 winch,

winch, unless some person standing on the floor touches him who holds the sword; and if this be done, the flame will immediately disappear, because the person who touches, draws off all the electric virtue from him who holds the sword. The same will happen, if a person standing on the floor put his finger upon the prime conductor; but the moment he withdraws his finger the flame will appear again.

EXPERIMENT XXIII.

The Diadem of Beatification.

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

come from the hoop to the fingers, and be felt like a gentle cool breeze of wind.

EXPERIMENT XXIV.

Giving a Shock to the Teeth.

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

EXPERIMENT XXV.

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

66. Let the fly *efg h i k* (*Exp. V.*) be hung upon the sharp point of the

crooked wire *c d* (Fig. 1. of Plate I.), and a person electrified on the glass stool hold the wire by the other end in his hand. Then, as long as the glass globe is turned by the winch, the fly will turn round with as quick a motion as it did when the wire was stuck into the prime conductor, in the 5th experiment.

EXPERIMENT XXVI.

Charging and discharging coated Glass Jars.

67. Place the jar *A* (§ 23.—Fig. 2. of Plate I.) so on the table, that the ball *a*, on the top of its wire, may be about the eighth part of an inch from the ball *G* (Fig. 1.) of the prime conductor. Then turn the glass globe of the machine by the winch, and all the electric fire, which the points *I* take from the globe to the conductor, will fly from its ball *G* to the ball *a* of the
jar

jar, and thence it will run down the wire to the lining on the bottom of the jar, and diffuse itself all over the inside of the jar as far as the lining goes, and will be accumulated and condensed there in the glass.—Continue turning, as long as you see the fire between the prime conductor and ball *a* of the jar; and when the fire ceases, you may leave off turning, for the jar has got its full charge, and can receive no more, if you should continue to turn ever so long afterward.—This done, take hold of the discharger *B* (Fig. 2.) by the middle, and first apply the knob *b* (on the lower end of the discharger) to the outside of the jar near the bottom; and keeping it there, put the upper knob *c* to the ball *a* of the jar wire, and the jar will be discharged of its fire, with a loud snap; but the person who holds the discharger will feel nothing from the fire.

The

The jar has no more fire when it is charged than what it had before ; for the metal coating conducts just as much fire from its outside to the table and ground, as the prime conductor threw into its inside by the wire and the metal lining ; by which means, the inside is electrified *plus* (§ 6.), and the outside *minus*.——So that what we here call charging, is only forcing more fire into the inside than it naturally had, (§ 2. and 4.) whilst the table carries off just as much of the natural quantity from the outside by the coating. And what we call discharging, is only making a conducting communication between the lining and coating of the jar, by means of the bended wire *B*, through which the accumulated fire flies from the overcharged inside to the vacant outside of the jar, and so restores the equilibrium ; which could not have been restored if the outside had not lost as much as was forced into the inside.

When

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

In charging the jar, especially if it be large, it should be set upon a pewter plate; that when it is to be discharged, the lower knob of the bended wire *B* may be applied to the edge of the plate, before the upper knob be applied to the ball *a* of the jar-wire. For then the fire will be diffused all over the plate, and go equally to all parts of the outside of the jar by the coating.

coating.—Experience has taught me this,—having found, that when all the discharged fire has struck upon one point of the outside, it has made a hole quite through the coating, glass, and lining: and when this happens, the jar is rendered useless.

I have sometimes found, that although a jar received the fire very freely into its inside from the prime conductor, yet it could not be in the least charged thereby. For, on applying the discharger *B*, there was no flash. And always, on stripping off the coating from such a jar, I have found the glass to be cracked or rent. So that, all the electric virtue, which the inside had received from the machine, run through the crack to the outside, and was carried off by the coating and table.—This (I think) shews very plainly, that the electric fluid cannot pass through sound glass, unless it comes with a force sufficient

ficient to break it, as lightning often breaks glafs-windows.

EXPERIMENT XXVII.

Shewing, that in charging a Jar, as much Fire is carried off from its Outside by the Coating, as is thrown into its Inside by the Lining.

68. Put a crooked wire, as *de* (Fig. 3. of Plate I.) into a hole in the top of the ball *D*, which is fixed on the top of the bended wire *B* (See § 24.); the point *e* of the wire *de* being made sharp, and of equal height with the top of the great wheel *A* of the mill (Fig. 4. of Plate II.), which, in the 15th experiment, was turned by a stream of electric fire, from the point *C* of the crooked wire (Fig. 6. of Plate I.), when the blunt end *A* was stuck into a hole in the prime conductor.—Things being thus prepared, set the jar *A*

(Fig. 3, of Plate I.) upon a large pane of glass, dry and free from dust; which will cut off all electric communication between the jar and the table. And let the jar and mill be so placed, that the ball *C* of the jar-wire may be within the eighth part of an inch of the prime conductor, and the wings of the great wheel of the mill about an inch from the point *e* of the additional bended wire *d e*. Then turn the glass globe of the electrical machine by the winch, to charge the inside of the jar; and the electric fire from the outside will go off from the coating, by the wire *B D d e*, and turn the mill the same way, and with the same velocity, as it was turned in the 15th experiment by the fire directly from the prime conductor. When the jar has received its full charge, and no more fire appears between the ball *C* and the prime conductor, the mill will stop. But discharge the jar, as in the foregoing experiment, and begin to charge it again; and then the mill will

will begin to go, and continue going till the jar has got its full charge.

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

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

EXPERIMENT XXVIII.

Striking a Hole through a Card.

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

Dr. FRANKLIN has shewn, that electric fire is the very same with that of lightning from the thunder-clouds; for he has drawn it from them, and charged his jars therewith, and found
all


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

Dr. James Lind at Edinburgh has put up a long rod, with a wire twisted round it, on one of the chimneys of his house, and hooked one end of a long chain to the foot of the rod at the chimney-top, letting the other end go down into the ground. From any convenient part of the chain, he brings a wire to a coated jar in his

G 2

room,

room. When a thunder-cloud passes over the house, the lightning comes silently from it to the rod, and is conducted down by the wire twisted round it, to the chain, which conducts the greatest part of the lightning silently down to the earth, although a sufficient quantity thereof will go by the cross wire from the chain to his electric jars; and when they are fully charged, no more of the lightning can go that way.—I have seen him charge them by that method, and discharge them in the common way; all the same as when he charged them by his electrical machine.

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

as if they were made to ring by electricity.

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

As water is a conductor of lightning, a person, whose hat, wig, and clothes were well wetted, would be in less danger from lightning that broke

upon his head ; because the most of it would run down by his wet clothes to the ground.

No person ought to go near trees, or stand below their tops, in the time of thunder: for, if it should happen to break upon the top of the tree under which he then stood, the tree would conduct the lightning to his body.

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

EXPERIMENT XXIX.

Striking Gold Leaf into Glass.

70. Take two slips of common window-glass, each about an inch broad and four inches long: then take a slip of gold or silver leaf, about the breadth of a straw, and six inches in length; and put it between the glasses lengthwise, in the middle, letting the ends of the leaf hang an inch without the glasses at each end. Tie the glasses close together, by wrapping a strong silk thread round them, and lay them down on the table, so as one end of the metal leaf may be in contact with the coating, at the bottom of a jar, placed so as that it may be charged at the prime conductor. Then charge the jar, and having put one end of the discharger upon that part of the leaf that lies without the glass slips at their

farthest end from the jar, apply the other end of the discharger to the ball on the top of the jar-wire; and all the fire in the jar will be discharged through the metal leaf. If the slips of glass remain whole, you will see that the leaf is missing in several places; and instead of it, a metallic stain upon both the glasses, exactly alike. When they are taken asunder, you will observe that the leaf has been melted by the electric lightning; and actually driven into the very substance of the glass, as neither *aqua fortis* nor *aqua regia* will take it off.

EXPERIMENT XXX.

Giving a Person an Electric Shock.

71. Let the person put a finger of one hand to the coating of a charged jar near the bottom, and then put a finger of the other hand to the ball of the jar-wire. He will then act the
part

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

EXPERIMENT XXXI.

Confining a Shock to any Part of the Body.

72. Suppose it were required to confine the whole of a shock to that part of the arm which is between the shoulder and elbow. Tie one end of
a me-

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

as metal conducts electric fire better than the human body does, the assistant who holds the chain will receive no shock.

If it were required to give a shock to any tooth, or part of the gum; take the machine described in § 33, and represented by Fig. 5. of Plate 2. And holding it on the gum, with the tooth between the ends *c* and *f* of the wires *a b c* and *d e f*, hook the chains *g* and *h* on the other ends of these wires; put the other end of the chain *g* round the bottom of a coated jar, and desire an assistant to hold the chain *h*, hanging down from his hand, as in the above experiment; the chains not touching one another, and both of them clear of the table. Then, having charged the jar, desire the assistant to strike the prime conductor with the loose end of the chain *h*; this will discharge the jar, and give the person a shock, which will be felt only in the tooth
and

and gum that is taken in between the wires at *c* and *f*.

EXPERIMENT XXXII.

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

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

As all the persons are connected together, they form a complete discharger.

charger. The one who holds the wire on which the jar stands, acts the part of the end *b* (Fig. 2. of Plate 1.) of the discharging wire that touches the bottom of the jar: and the person who touches the prime conductor (which is the same in effect as if he had touched the ball *a* of the jar-wire) acts the part of the end *c* of the discharging wire that touches the ball *a*.
 — The reason why all the persons feel the shock at the same instant may be understood by reading the second, third, and fourth paragraphs of the first section.

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

And,

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

* Phil. Transf. abridged, vol. x. p. 363.

EXPERIMENT XXXIII.

Giving a Shock by the Magic Picture.

74. Set the face of the picture (§ 27.) to the ball *G* of the prime conductor, and turn the globe by the winch to electrify it. Then take it away, and holding it by the top of the frame, in a horizontal position, with the face upward, lay a small gilt piece of metal, made in the form of a crown, upon the head. This done, desire any person to take hold of the foot of the frame with one hand, and take off the crown with the other.—In attempting to do this, he will fail of his design; for the moment he touches the crown, he will receive a strong shock.—You must continue to hold by the top of the frame all the while, and will have nothing to fear; because none of the electric virtue with which

the picture was charged can come to your hand. But if you quit your hold, and trust to him who holds by the foot of the frame, the shock will make him quit his hold; and the picture may be broke by the fall.

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

E X P E-

EXPERIMENT XXXIV.

The seemingly animated Spider.

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

The inside of the jar is electrified *plus*, or positively, and so is its wire and ball *C*; but the outside of the jar,

H and

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

The silk thread *a b*, by which the spider is hung, being a non-conductor, makes him retain the electric virtue

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

EXPERIMENT XXXV.

The Use of pointed Metal Rods.

76. Every thing having been removed from the prime conductor, take a small lock of cotton, and draw out part of it into the form of a thread, about an inch long, and fix the end thereof by a little bit of bees-wax to the undermost side of the conductor, so that it may hang down therefrom,

as between Q and X; and, with both your hands, pull out the rest of the cotton till it be very thin, and hang together by little shreds. Then hold a needle in your left hand, keeping the point of it covered with the top of the fore-finger.—This done, turn the globe of the electrical machine by the winch, to electrify the cotton, which will make all the parts of it repel each other, and swell out into a larger size than before. Continue turning the winch, and hold the tip of the finger, that covers the needle's point, upward, below the cotton, which will then stretch itself downward to meet your finger.—But withdraw the finger, to shew the point of the needle toward the cotton, and the cotton will immediately shrink upward from the point toward the prime conductor.—And thus, by alternately covering and uncovering the point of the needle, the cotton will stretch downward and shrink upward, as long as you keeps turning

turning the winch. *This is one of Dr. FRANKLIN'S Experiments.*

When the cotton is replete with electric fire, it expands, and stretches itself toward the earth, like a cloud filled with lightning and highly electrified therewith. The unelectrified finger attracts the cotton toward it; as the thunder-cloud, being more highly electrified than the earth below it, is attracted by the earth. The point of the needle draws off the electric virtue from the cotton, and then it naturally re-assumes its former state and figure: so the point of a metal rod draws off the lightning from a thunder-cloud, by which the cloud was expanded, and the metal conducts the lightning silently from the cloud down to the ground: and then the cloud being divested of its repulsive lightning, shrinks into a less space by the mutual attraction of its particles which the lightning had left; and thus makes the distance greater between

the cloud and building, and a stroke therefore, less likely to happen.— This shews, that a long metal rod, whose lower end goes down into the ground, and its upper end terminates in a sharp point, at some height (suppose five or six feet) above the top of the highest chimney of a house, will draw down the lightning from a thunder-cloud over the house, gradually and silently, into the earth, so as not to let the lightning accumulate in the cloud, to endanger the house by breaking thereon. Or, if such a cloud comes suddenly over the house, and breaks, the rod will attract all the lightning, and conduct it into the ground, where it will harmlessly disperse into the moist earth; and the house will receive no damage from it. — This safety-rod may be bent at different places, to fit the wall and tiling, and may be fixed thereto with iron staples, which will be so far from endangering the wall, that if any lightning were in it, they would draw it

it out to the rod.—I need not tell the public how much the world is indebted to Divine Providence for having inspired Dr. FRANKLIN with this invention; and to him for communicating it. Experience has fully proved its utility, and no high building should be without it, especially such as have steeples or spires.

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

These rods may be made of different pieces of metal, screwed into one ano-

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

It is amazing to think how great a flash of lightning may be accumulated
into

into a small wire, and conducted thereby.—In confirmation of this, I shall here take the liberty to transcribe an account from Dr. FRANKLIN'S book of *Experiments and Observations on Electricity**; printed in London, A. D. 1769.

“ Being” (says the Doctor) “ in the
 “ town of *Newbury* in *New England*, in
 “ *November* last †, I was shewn the ef-
 “ fect of lightning on their church,
 “ which had been struck a few months
 “ before. The steeple was a square
 “ tower of wood, reaching seventy
 “ feet up from the ground to the
 “ place where the bell hung, over
 “ which rose a taper spire, of wood
 “ likewise, reaching seventy feet
 “ higher, to the vane of the weather-
 “ cock. Near the bell was fixed an
 “ iron hammer to strike the hours;
 “ and from the tail of the hammer a

* Pages 162, 163, 164.

† Meaning November, in the year 1754.

“ wire

“ wire went down through a small
 “ gimlet-hole in the floor that the bell
 “ stood upon, and through a second
 “ floor in like manner ; then horizon-
 “ tally under and near the plaistered
 “ cieling of that second floor, till it
 “ came near the plaistered wall ; then
 “ down by the side of that wall to a
 “ clock, which stood about twenty
 “ feet below the bell. The wire was
 “ not bigger than a common knitting
 “ needle. The spire was split all to
 “ pieces by the lightning, and the
 “ parts flung in all directions over the
 “ square in which the church stood, so
 “ that nothing remained above the
 “ bell.

“ The lightning passed between the
 “ hammer and the clock in the above-
 “ mentioned wire, without hurting
 “ either of the floors, or having any
 “ effect upon them, (except making
 “ the gimlet-holes, through which
 “ the wire passed, a little bigger), and
 “ without

“ without hurting the plaistered wall,
“ or any of the building, so far as the
“ above-said wire and the pendulum
“ wire of the clock extended; which
“ latter wire was about the thickness
“ of a goose-quill. From the end of
“ the pendulum, quite down to the
“ ground, the building was exceed-
“ ingly rent and damaged, and some
“ stones in the foundation-wall torn
“ out and thrown to the distance of
“ twenty or thirty feet. No part of
“ the afore-said long small wire, be-
“ tween the clock and the hammer,
“ could be found, except about two
“ inches that hung to the tail of the
“ hammer, and about as much that
“ was fastened to the clock; the rest
“ being exploded, and its particles dis-
“ sipated in smoke and air, as gun-
“ powder is by common fire; and had
“ only left a black smutty track on
“ the plaistering three or four inches
“ broad, darkest in the middle, and
“ faintest about the edges, all along
“ the cieling under which it passed,
“ and

“ and down the wall. These were the
 “ effects and appearances on which I
 “ would only make the few following
 “ remarks.

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

“ 2. The quantity of lightning that
 “ passed through this steeple must have
 “ been very great by its effects on the
 “ lofty spire above the bell, and on
 “ the square tower all below the end
 “ of the clock pendulum.

“ 3. Great as this quantity was, it
 “ was conducted by a small wire and
 “ a clock pendulum, without the least
 “ damage

“ damage to the building so far as
“ they extended.

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

“ 5. Though the small wire was it-
“ self destroyed, yet it had conducted
“ the lightning with safety to the
“ building.

“ 6. And from the whole, it seems
“ probable, that if even such a small
“ wire had been extended from the
“ spindle of the vane to the earth be-
“ fore the storm, no damage would
“ have been done to the steeple by that
“ stroke of lightning, though the wire
“ itself had ben destroyed.”——So far
Dr. FRANKLIN.

EXPERIMENT XXXVI.

The THUNDER-HOUSE,

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

The whole of this part of the apparatus (Fig. 5. of Plate I.) being put together as represented by the figure, and as described in the 26th paragraph of the 3d Section, with the diagonal wire *a N c* of the square piece of wood *a b c d* lying in the position as shewn in the figure, and the jar *M* set to the prime conductor; charge the jar, and continue turning the globe by the

2

winch

winch till the jar discharges itself with a flash. While the jar is charging, the feathers *H* being electrified, they repel each other, and expand like a thunder-cloud; but the instant when the jar discharges itself, they shrink and come together, and the square piece *a b c d* is driven out by the flash of electric lightning to a good distance from the gable-board *A*.

The jar discharges itself along the metal chain *K T* and the crooked wire *E w F*; the fire snaps from the ball *F* to the ball *G*, and thence runs down the wire *g d* to *d*; where finding no further metal conductor to carry it onward, it spends its whole force on the square piece *a b c d*, and drives it out of the hole in the board *A*.—This shews how dangerous weather-cocks are on the tops of buildings. For, when the thunder breaks upon them, the lightning is collected into the iron spindle of the weather-cock,
runs

runs down to the lower end thereof, and finding no farther metal conductor, it spreads about, and spends its whole force on that part of the building. If there be iron clamps in the stones, near the foot of the spindle, and near to each other, and these clamps be not connected by wires, the lightning splits the building from *m* p to clamp; as was the case of St. Bride's church steeple.

Put the square piece of wood *a b c d* into its place again, so as the diagonal wire *a N c* may be in the position *d N b*; and then its ends *a* and *c* will touch the ends *d* and *b* of the two wires *g d* and *b h*, and the metal conductor *G g d N b h i k* will be complete.— This done, turn the winch to charge the jar again; and continue turning till it discharges itself as before: and all the electric fire that it contained will go off with a flash, through the whole metal course *K I w F*, from *F* to *G*,

G, and thence through *g d N b h i k* to the coating of the jar, (which fiery course may be seen in a darkened room); and the square board *a b c d* will remain in its place, without being moved in the least, even if it lies ever so easy in the hole. Which manifestly shews, that complete metal conductors will preserve houses from damage by lightning.

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

I

dually draw down the lightning from the cloud, and so prevent its accumulating therein, in any sufficient quantity to break.

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

SECTION VI.

Medical Electricity.

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

when the whole account was read there, on the 10th of February 1763: and it was afterwards published in the 53^d volume of the Philosophical Transactions.

79. Mr. J A L L A B E R T, Profefſor of Mathematics at Geneva, mentions the cure of a palsy that he had performed on the arm of a locksmith, which had continued fifteen years; and was occasioned by the blow of a hammer. The method was by taking sparks frequently from the paralytic arm, and sometimes sending the electric shock through it*.

80. Mr. Wilſon, by electricity, cured a woman of a deafneſs which had continued ſeventeen years. But he owns that he had tried the ſame expe-

* Hiftoire, pt. 3. p. 36.

riment on fix other deaf persons without any success *.

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

82. The Reverend Mr. Wesley has followed Mr. Lovet's method, and often quotes him.—He says he has scarce known an instance in which electrical shocks over all the body have

* Wilson's Treatise on Electricity, p. 207.

† Lovet's Essay.

failed to cure a quotidian or tertian ague*. He mentions a case of blindness cured by it, and even of its having given hearing to a man who was born deaf. He further says, it has cured bruises, running sores, a palsy in the tongue, and has brought away gravel from the kidneys. In deep hysterical cases, he advises that the patients be simply electrified, sitting on cakes of rosin, at least half an hour morning and evening: then begin to take small sparks from them, and afterwards give them shocks, more or less strong, as their cases require; always beginning with gentle shocks. — This method seems very rational; and the Reverend Dr. PRIESTLEY very justly observes, that as electricity has done so much good in the hands of those who are not physicians, and consequently cannot be supposed always to distinguish between cases where it might be advantageously applied,

* Wesley's Desideratum.

and where it might not; 'tis pity but that it were in the hands of able physicians*.

83. DR. ANTONIUS DE HAEN, in his *Ratio Medendi* (quoted by Dr. PRIESTLEY †) one of the most eminent physicians of the present age, says, that a paralysis and trembling of the limbs, from whatever cause it arose, never failed of being relieved by electricity; and he relates one instance of a particular case of this nature, where a person was cured after having received ten shocks. And he assures us, that it has never failed to cure the St. Vitus's dance; but it entirely failed in its application to a gutta serena, and to a strumous neck.—He says, that it ought not to be administered to women with child: and Veratti advises,

* Priestley's *History of Electricity*, p. 419. and 422.

† *Ibid.*

that it be by all means avoided in the venereal disease.

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

84. A woman, who complained much of a pain in her stomach, came to be electrified.—I gave her only one shock across the stomach, and the pain immediately left her. But, on the next day, she came and told me, I had driven the pain from her stomach into one of her teeth, so that she was almost mad by the toothach.-----I then gave her a strong shock through her tooth and gum (as described in the 19th experiment) on which the toothach directly left her. I saw her about a week afterward, and she told me that she was quite well, and had

no return of her late cause of complaint.—I have tried the like experiment on many others since, who were afflicted with the toothach, and it failed only with three; in one of whom I observed the tooth was much spoiled and decayed.

85. A poor woman brought her daughter (who was about eight years of age) to be electrified for the rheumatism, which (as the woman said) had settled upon the child's left knee, and so far taken away all the use of her left leg that she had been quite lame for a month.—I drew several sparks from the knee, which the child told me at first she did not feel; but then she began to feel them more and more acute.—I desired her mother to bring her on the next day, which accordingly she did.—I drew sparks from the knee for about a quarter of an hour, and from two or three inches both above and below it, till the skin became

became red and full of pimples; when the child told me she felt it very warm, and could no longer endure the pain that the sparks gave. I then sent a gentle shock through her knee, after that a somewhat greater one, and lastly a pretty strong one, which made the child cry. I gave her twopence for her good courage, and she told me I had now made her quite a gentlewoman, and that she would never cry out again when she was brought to be electrified.—On the next day, the woman came alone, and told me she had been very agreeably surpris'd; for her daughter came down stairs * to breakfast, without any help; but had got a sad pain in her stomach, which must have been the rheumatism driven into it from her knee. I desired her to bring the child directly; which she did, and I sent a tolerably

* The woman lodged in a garret, but dressed her victuals in the kitchen.

strong shock through the child's stomach; on which the pain ceased, and I heard nothing afterward of any return.

86. A man, whose left shoulder had been dislocated by a fall from his horse, and his arm very much bruised all from the shoulder to the elbow; came about a year after to be electrified.—He told me that a surgeon had replaced the bone very well, (as indeed it appeared to be;) but the muscles had been so much bruised, that he had never since been able to move his left hand a foot from his side, without the assistance of the right.—I told him, there was but very little reason to hope for any cure by electricity; however, I would try; and so gave him three shocks from the shoulder to the elbow, at the last of which, he held his arm out, almost half way into a horizontal position. I desired him to come again the next day,

day, which he did, and I gave him a couple of strong shocks: then he held his arm directly right out; and without the assistance of his right hand, he unbuttoned and buttoned the collar of his shirt with the left. Whether the use of his arm continued or not, I cannot tell; for he went away, and I never saw him nor heard of him again.

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

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

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

89. A young man, who had well-nigh lost his hearing, so that those who spoke to him were obliged to speak very loud, came twice to be electrified.

electrified. I only drew sparks from his ears, and at the second time he heard very well, and continued to do so afterward.—But, since that time, I have tried the experiment on three persons, without the least success; although, after finding no good from the sparks, I sent gentle shocks through each ear alternately, to the opposite side of the throat.

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

91. I was once deceived by a man who had the venereal distemper, (as I afterward found out) who came several times to be electrified, as he said,
for

for the rheumatism; but, on finding him grow worse and worse, I suspected the cause, and questioned him. He strongly denied the fact, even though I told him that if he had that complaint, electrifying would not only hurt him greatly, but might even kill him: and so I sent him away, telling him that he needed not come any more.—He then thought proper to apply to a surgeon, who cured him, and told me afterward what his real case was.

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

93. The ingenious Mr. William Swift, a turner at Greenwich (who makes good electrical machines), has lately cured Mrs. Allmey, a baker's wife in that town, of a hemiplegia or
dead

dead palsy in one side, in which she was so far gone, that boiling water might have been applied from her hand to her shoulder, and from her shoulder to her foot, on that side, without being felt by her. Dr. Green, who attended her, ordered Mr. Swift to electrify her, which he accordingly did, sometimes drawing sparks for a whole hour together, and sometimes for two hours, all over where the palsy was; and then giving shocks. Her feeling is now quite restored, she walks very well, and I saw her name, which was well wrote by the hand of which she had quite lost the use.—As this is a very remarkable case, I shall set down the different times of electrifying, and the number of shocks given each time, from the account sent me by Mr. Swift, with whom I am very well acquainted. He first gave strong shocks till she began to feel them, and then moderate ones.

Times.

Times of electrifying. Sho cks.

Sept. 3, 1769, for 1 hour 4

5 1 6

7 2 hours 12

8 2 12

9 $1\frac{1}{2}$ hour 12

11 2 hours 9

12 2 12

13 2 12

16 2 9

19 $1\frac{1}{2}$ hour 6

23 $1\frac{1}{2}$ 8

24 2 hours 7

Oct. 3 $1\frac{1}{2}$ hour 6

4 $1\frac{1}{2}$ 6

6 2 hours 5

9 2 7

16 2 4

18 2 4

In all, 18 times. $31\frac{1}{2}$ hrs. 141 shocks.

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

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

96. One time my wife happened to scald her wrist by boiling water. I set her upon the glass-footed stool directly, and took sparks from the wrist. In a short time I found the redness of the skin (occasioned by the scald) begin to disappear, and she felt immediate relief. A linen bandage was then put
round

round her wrist, and in a few hours after, I repeated the operation, which entirely cured her, and there was not the least blister on the skin, nor any difference in its colour from what it had before the accident. If it had not been taken immediately, and before a blister had risen, perhaps electrifying would have been of little or no service.

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

F I N I S.

**The Binder is desired to put the Plates at
the End.**

A
CATALOGUE

OF THE
APPARATUS

*On which Mr. FERGUSON reads his
Course of twelve Lectures, on Me-
chanics, Hydrostatics, Hydraulics,
Pneumatics, Electricity, and
Astronomy.*

[The Numbers relate to the Lectures read on
the Machinery to which they are prefixed.]

I.

SIMPLE machines for demonstrating the
powers of the lever, the wheel and axle,
the pullies, the inclined plane, the wedge, and
the screw.

A compound engine, in which all these simple
machines work together.

A working model of the great crane at *Bristol*, which is reckoned to be the best crane in Europe.

A working model of a different crane that has powers adapted for raising different weights; invented by Mr. *Ferguson*.

A pyrometer, that makes the expansion of metals by heat visible to the 90th thousandth part of an inch, so as to be seen by the bare eye at two feet distance from the machine.

II.

Simple machines for shewing the center of gravity of bodies, and how far a tower may incline without falling.

A double cone, that seems to roll up-hill of itself while it is actually descending.

A machine made in the figure of a human creature, that tumbles backward by continually oversetting the center of gravity.

Models of wheel-carriages, some with broad wheels, others with narrow; some with large wheels and others with small; for proving experimentally

perimentally which fort is best, and what is the best way of loading waggons.

A machine for shewing what degree of power is sufficient to draw a cart or waggon up-hill, when the quantity of weight to be drawn up, and the angle of the hill's height, are known.

A machine for diminishing friction; and shewing that friction depends not on the quantity of surface that rubs or rolls, but on the weight of the machine and its load.

A model of a curious filk-reel, invented by Mr. *Verrier* near *Wrington* in Somersetshire.

A large working model of a water-mill for sawing timber.

A model of a hand-mill for grinding corn.

A model of a water-mill for winning and grinding corn, drawing up the sacks, and boulding the flour.

A model of the engine by which the piles were driven for a foundation to the piers of *Westminster*-bridge.

A ma-

A machine for demonstrating that the power of the wind, on windmill sails, is as the square of the velocity of the wind.

III.

Machines for shewing that fluids weigh as much in their own elements as they do in air: —that fluids press equally in all manner of directions: —that their pressures are in proportion to their perpendicular heights, without any respect to their quantities: —that on equal bottoms, their pressures are as their perpendicular heights, be their quantities ever so great or ever so small: —that an ounce of water in a small glass-tube will raise and support sixteen pound weight, or any other assigned quantity of weight: —that solid lead may be made to swim in water, and light wood to sink therein: —for demonstrating the hydrostatical paradox: —for proving that the quantity of water displaced by a ship is equal to the whole weight of the ship and cargo: —the working of syphons: —the *Tantalus's* cup: —the cause and phenomena of ebbing and flowing wells, and of intermitting and reciprocating springs.

IV.

Machines for shewing that when solid bodies are immersed and suspended in fluids, the solid loses as much of its weight as its bulk of the fluid weighs; and that the weight lost by the solid is imparted to the fluid.

A hydrostatic balance, for shewing the specific gravities of bodies, and detecting counterfeit gold.

A working model of ARCHIMEDES's spiral pump.

Working models of sucking, lifting, and forcing pumps.

A working model of a quadruple pump-mill, for raising water by means of water turning a wheel,

A working model of the *Hungarian* engine for raising water from mines,

A working model of Mr. *Blakey's* fire engine.

A working model of the Persian wheel for raising water.

A model

A model of the great engine at *London* bridge for raising water to supply the city.

V. and VI.

An air-pump, with a very large apparatus, for experiments shewing the weight and spring of the air.

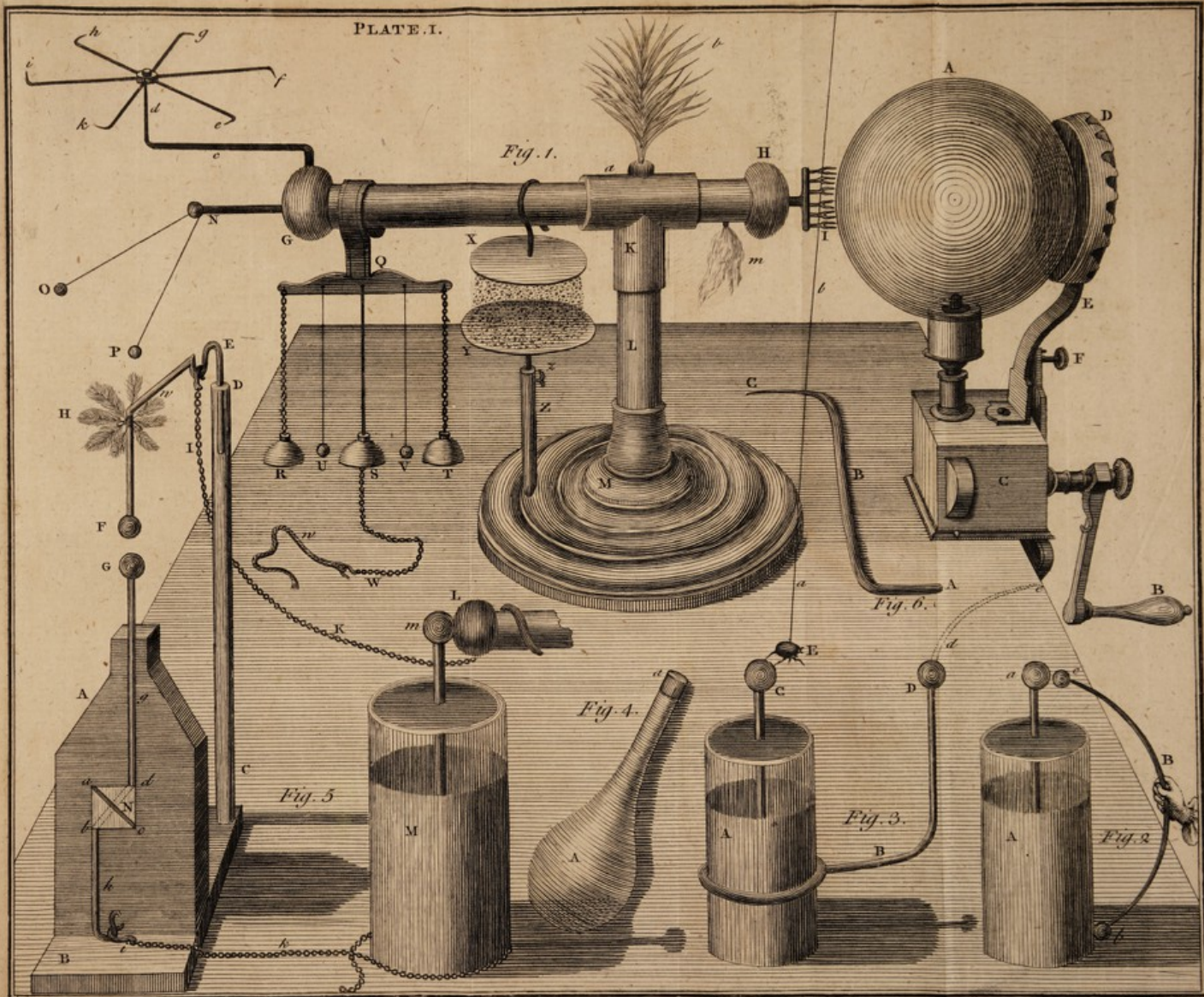
VII.

An electrical machine, with such an apparatus to it as is described in this treatise.

VIII.

A whirling table, for explaining and demonstrating the laws by which the planets move, and are retained in their orbits: that the sun and all the planets move round the common center of gravity of the SOLAR SYSTEM: that the earth and moon go round the center of gravity between them, once every month: that the earth goes round the sun, in common with the rest of the planets, and turns round its own axis: that the power of gravity diminishes in propor-

PLATE I.



J. Ferguson delin.

J. Bayly sculp.

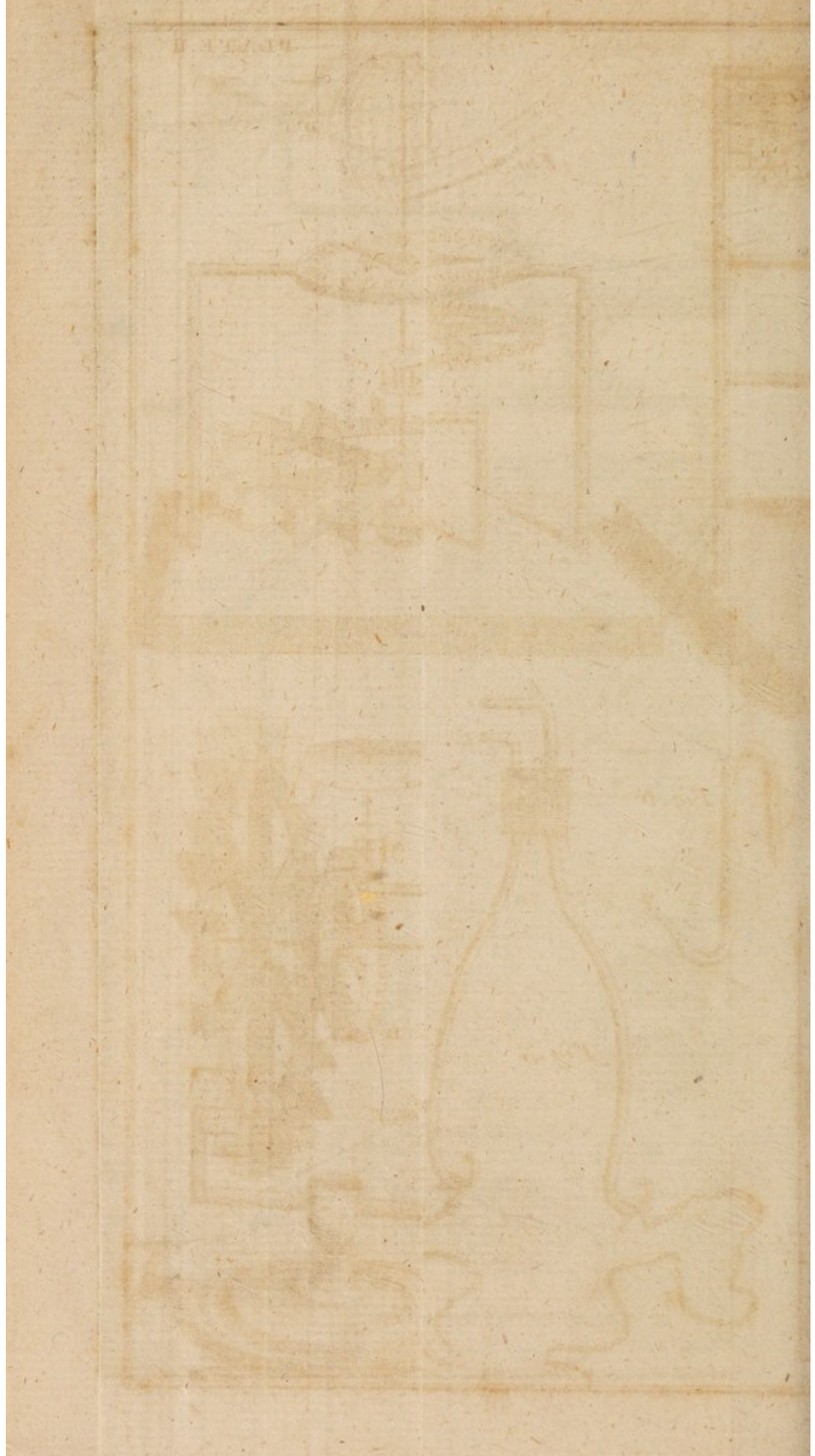


Fig. 1

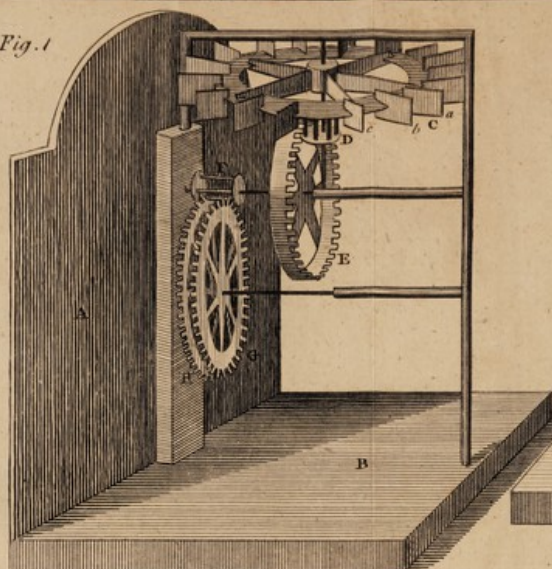


Fig. 3

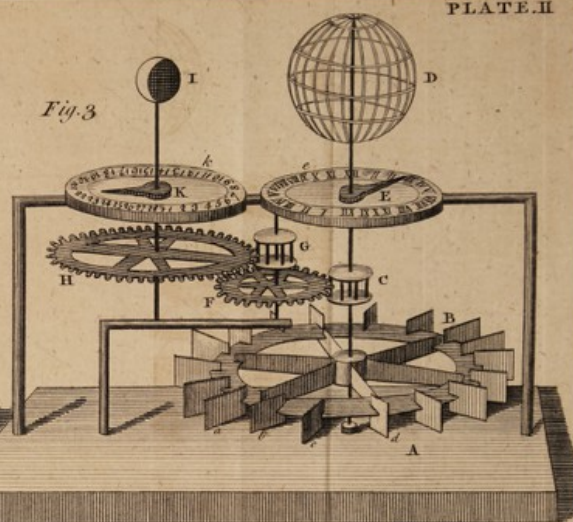


Fig. 2

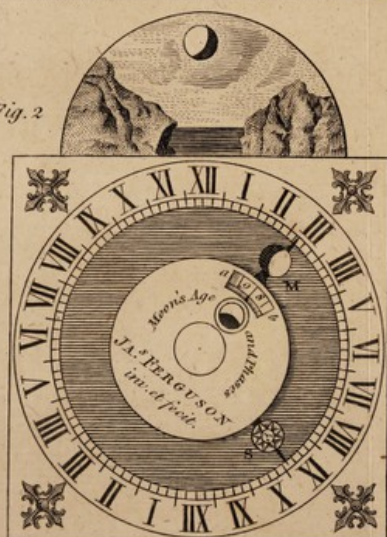


Fig. 6

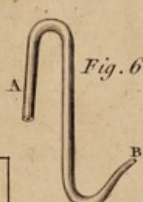


Fig. 5

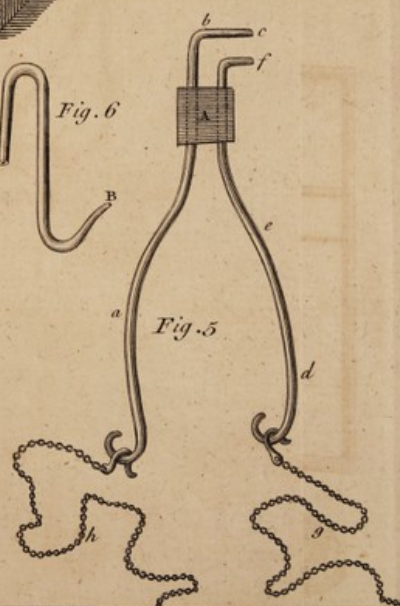
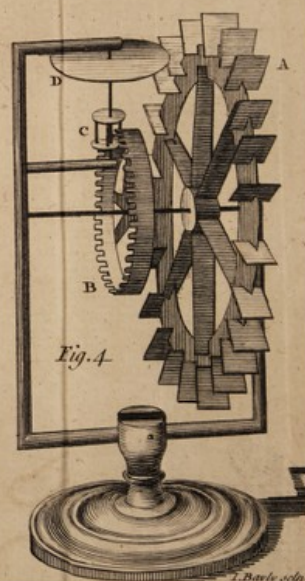
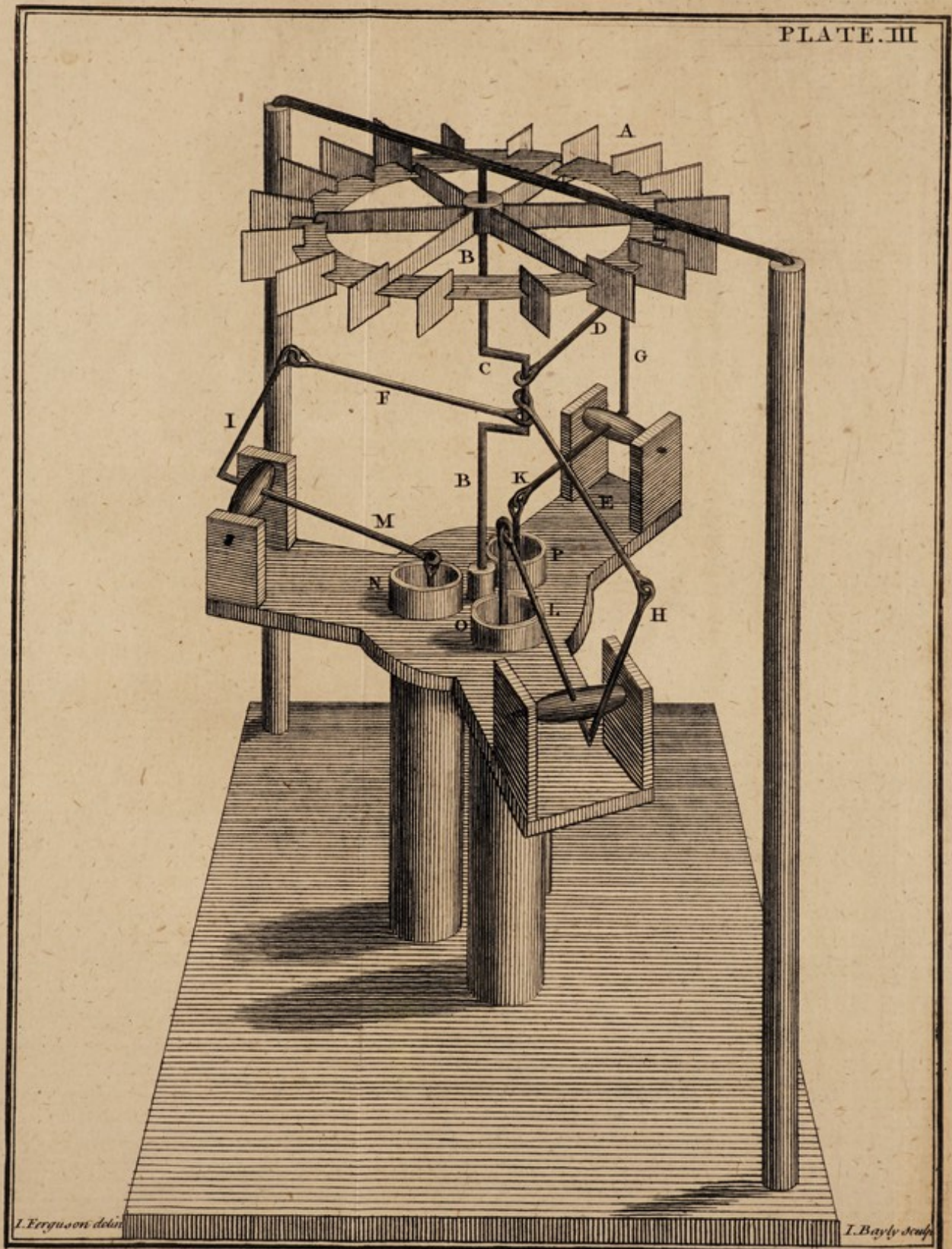
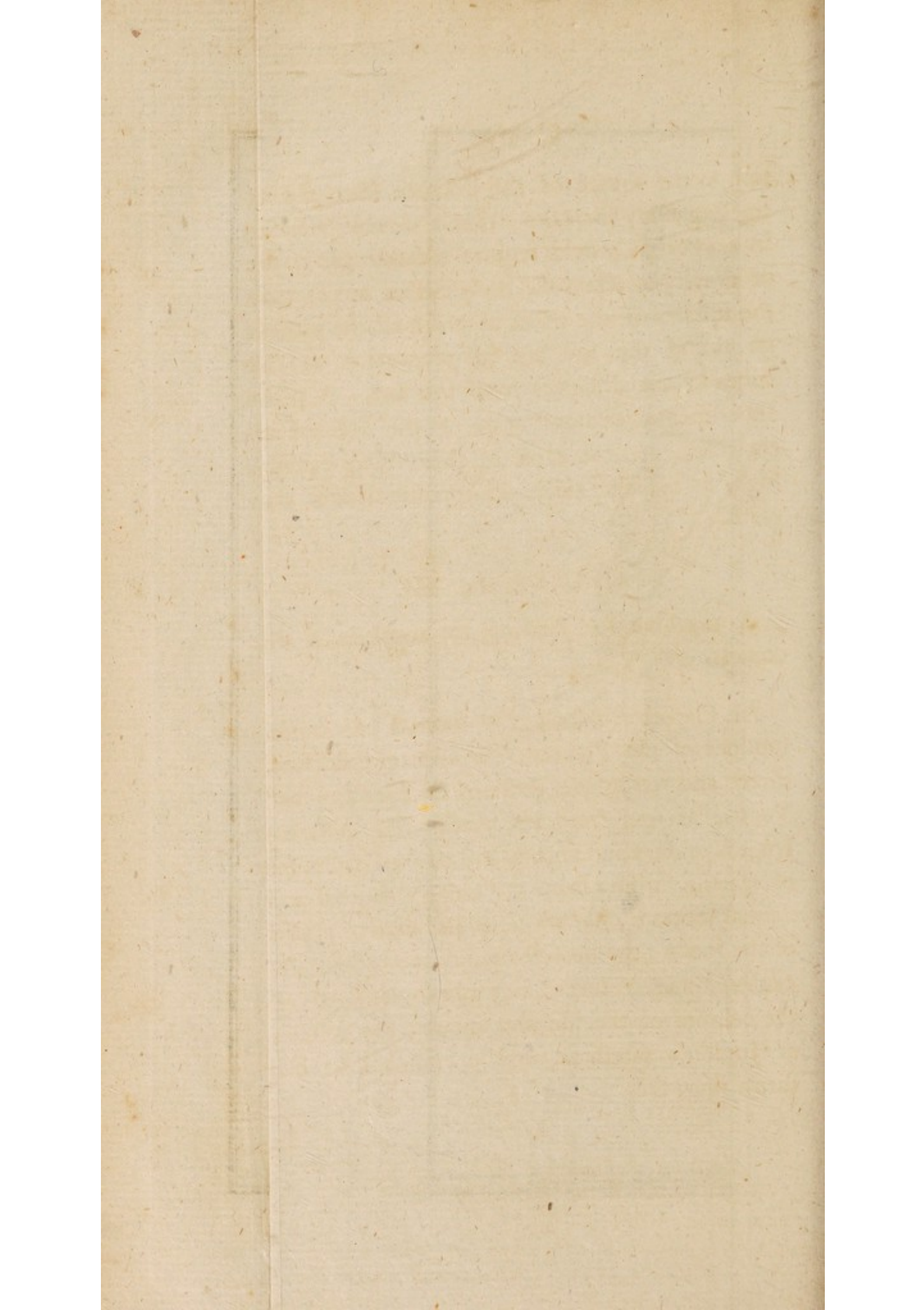


Fig. 4









tion as the square of the distance from the attracting body increases: that a double velocity in any orbit, would require a duadruple power of gravity to retain the body in that orbit: that the squares of the times in which all the planets go round the sun are in proportion to the cubes of the distances from the sun. A plain experimental demonstration of the doctrine of the tides; and the cause of their rising equally high, at the same time, on opposite sides of the earth.

IX, X, XI, and XII.

A machine for shewing the motions of the comets.

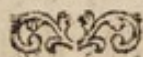
AN ORRERY, shewing the diurnal and annual motions of the Planets; the apparent stations, direct and retrograde motions of Mercury and Venus, as seen from the earth: the different lengths of days and nights, and all the vicissitudes of seasons, arising from the earth's diurnal and annual motions: the motions and various phases of the moon: the harvest moon: the tides: the causes, times, returns, and phenomena, of all the eclipses of the sun and moon: the eclipses of Jupiter's satellites, and phenomena of Saturn's ring, &c.

In

In London, any number of persons, not less than thirty, who will subscribe one guinea each, may have a course of twelve lectures read on the above-mentioned apparatus, provided they agree to have at least three lectures a week : in which they may appoint the days and hours that are most convenient for themselves : *Sundays* excepted.

Within ten miles of London, any number of persons, not less than forty, may have a course ; each subscriber paying a guinea, and agreeing to have six lectures a week. And

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