A CAUTION,

WHEREAS Mr. MURRAY, Bookseller, in Fleet-street, is now imposing upon the Public a spurious Edition of a Work, entitled the SCHOOL of ARTS, or an Introduction to Useful Knowledge (the original of which was written by me) I think proper to give them this information, that Mr. Murray has printed and is publishing the Work without my authority, for which I am endeavouring to obtain legal redress, trusting that a generous Public will not encourage Mr. Murray in his wicked attempts to violate the property of an injured individual.

JOHN IMISON.

The only true Edition of the above Work, is to be had of the Author, No. 58, Hay-market; James Ridgway, opposite Sackville-street, Piccadilly; Elliot, Kay and Co. No. 332, Strand; W. Lowndes, Fleet-street; and William Nicoll, St. Paul's Church-yard.

As an Action has been some time since brought against Mr. Murray for his publishing the School of Arts—a work my sole property; and as a Court of Justice will soon determine upon the merits of the Case between Mr. Murray and ME—prior to its decision, I thought it would be impertinent in an obscure individual like myself, to trouble the Public with his private transactions or opinions.

In reply to Mr. Murray's letter in the News-papers of the 4th Inst. I shall therefore this once only just observe, that I published this Work first in 1785, which Edition was all sold in eleven months—that, in consequence of Mr. Murray's proposals to me, I did agree to publish another edition, but by the time the ninth number was out, Mr. Murray discovered the rapidity with which the Book sold, and the degree to which I was distressed; in consequence of which, by an artful attempt, *he* endeavoured to possess himself of the Copy-right, Copper-plates, and Letter-press; but not succeeding, he threatened that unless I would deliver them up to him, he would stop the publication.

Mr. Murray finding this menace as ineffectual as his artifice, and that regardless of a man who could attempt to violate the property of another, I was going on with the publication, He to my utter astonishment copied the plates, and printed the remainder to complete such copies as I had delivered to him only in part, and without my permission or knowledge, published the work complete.

I here make no boast of the respectability of my witnesses, but these facts I shall authenticate before a Court, where every hope I have of redress can arrive solely from the responsibility of the characters who are brought to prove them.

As I am by profession a mechanic only, I mean to enter on no farther Paper altercation with Mr. Murray, but rest satisfied, that in making these assertions good, I shall suffer as little in my property from the decision of a Court of Justice, as my character will in the eye of a discerning Public, from a letter replete with untruths.

JOHN IMISON.

Also, by the same Author, this Morning is published, price 7s. 6d. with a box of instruments,

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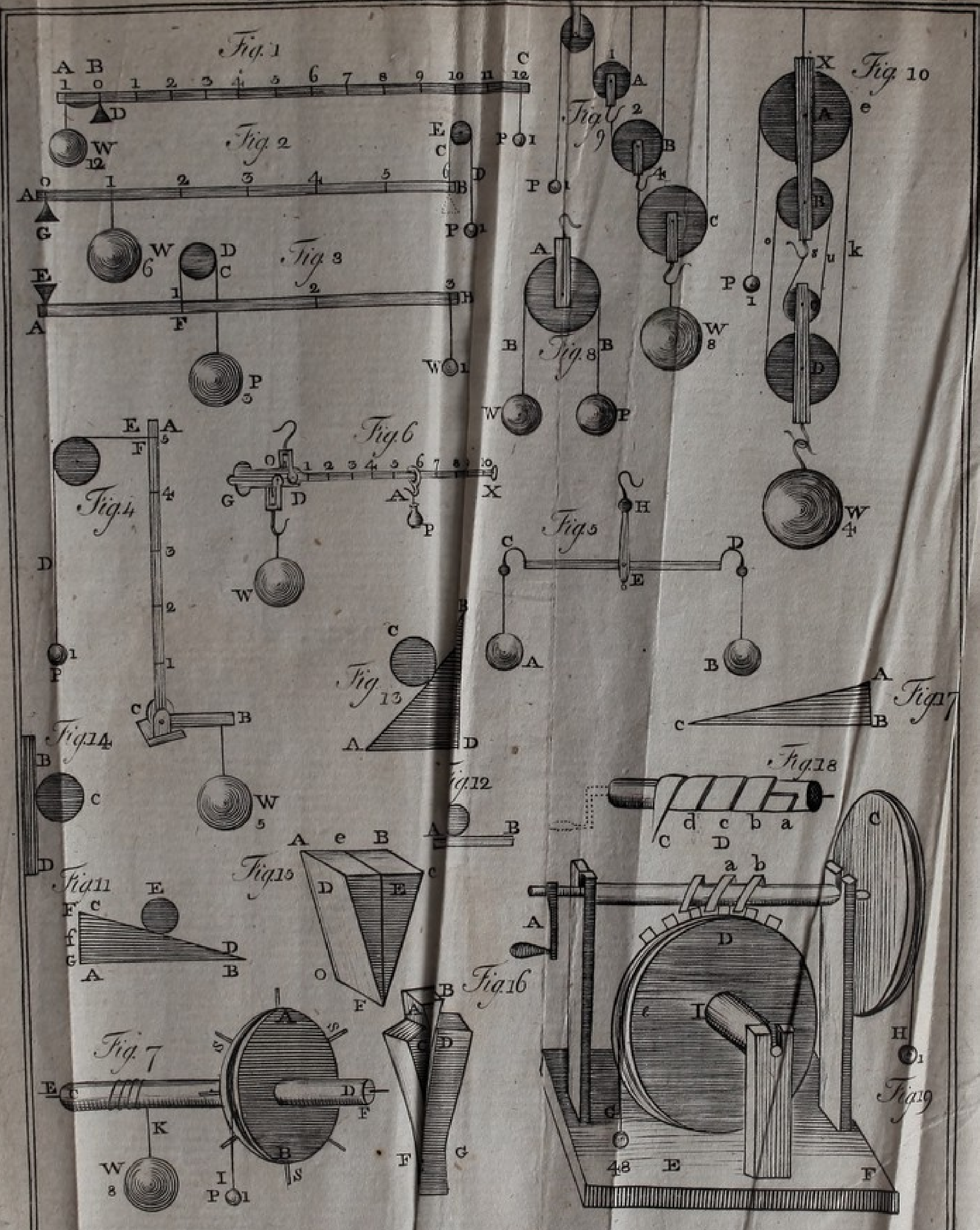
MECHANICAL POWERS PLATE. I



THE SCHOOL OF ARTS;

OR,

An Introduction to Useful Knowledge:

BEING A COMPILATION OF REAL

EXPERIMENTS AND IMPROVEMENTS,

IN SEVERAL PLEASING

BRANCHES OF SCIENCE,

ON THE FOLLOWING SUBJECTS, VIZ.

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Pneumatics,
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M.DCC.LXXXVII.

T O

Samuel More, Efq.

Secretary to the Society infti-tuted at LONDON, for the Encouragement of ARTS, MANUFACTURES, and COMMERCE.

S I R,

IT is with propriety that the following pages are infcribed to you. A treatife upon the arts fhould have a patron who underftands the fubject. No perfon will deny that you are competent to judge upon this point. And although I acknowledge my diffidence, when I think that my work

is to be ſubmitted to a perſon of your ſkill and diſcernment, yet I own that I am in ſome degree flattered that my performance is not wholly deſtitute of merit ſince you are kind enough to accept what I now preſent.

It is with pleaſure alſo that I take this opportunity of publicly acknowledging the obligations I lie under to your friendſhip and good offices in many inſtances, and that I am, with gratitude and eſteem,

SIR,

Your obedient,

And very humble ſervant,

JOHN IMISON.

THE

PREFACE.

WHEN I first compiled the following sheets, they were not intended for the press, but for my private amusement, because they contained the principal matters of what I had either read, seen or experienced; or indeed what accorded to my inclination upon these subjects: I laboured daily to increase my little store, and having an extensive apparatus, I carefully proved every experiment, before I gave it a place in my repository: I have also tried a variety of other experiments from Smith, Barrow, Salmon, &c. &c. *without the desired success, which was one principal motive for the present publication, as it is my wish that my labours may prove useful to those whose ingenuity may lead them to practise and improve upon my experience. I have given without reserve, the best descriptions I could collect of every thing I have treated. And I can affirm that every page in the book contains matter of real value when applied to practice. Numerous are the authors who have written upon the miscellaneous part of these subjects,*

but

but few of them have proved by actual experiment what they have asserted; and indeed this is not to be wondered at, when it is known that experiments are attended with much expence. And although I have used my best endeavours, yet I will not assert but that better methods in several things may be discovered: nevertheless the reader may rely that the facts I have advanced will bear the test of any enquiry.

The particular branches of science which I have endeavoured to explain, are those of the Mechanical powers, Electricity, Pneumatics, Hydrostatics and Hydraulics, Optics, and Astronomy; a treatise on Clock-making, the nature, use, and construction of the Barometer, and the construction of optical and many philosophical Instruments; all which I flatter myself, the students will find to be exact, whether they are consulted with a view to theory or practice.

A knowledge of the mechanic powers is now become a part of polite education, and their utility is manifested by daily experience; therefore such definitions, postulates, and axioms are premised as were thought necessary to form a right conception of the principles, so as to form a just idea of their application on any particular occasion; and as my reasoning on these subjects has been general, so no regard has been paid to the weight of the beam or lever; it being

ing well known that these must be equipoised before such theorems can be applied.

So many books have been written upon the subject of the arts and sciences that any person would imagine that more would be superfluous. Books however, which have been written by authors of credit are very expensive and very voluminous, and it would take too much time to read over, and attain a thorough knowledge of the doctrine they contain. In the present performance every thing is rendered familiar to the meanest capacity; and with a little practice and perseverance, the most illiterate artizan cannot fail of making a considerable progress in almost every art and science it treats of; besides every artificer cannot furnish himself easily with the best authors upon all the subjects contained in this work; the expence of which, and waste of time would be too considerable. I have inserted not only known useful rules upon the subjects I have noticed, but a great many others that are entirely new, and of very great use, both in theory and practice to the working mechanic.

I pretend not to communicate my ideas with the embellishments of elegant language; my employment as a mechanic, pleading an excuse for errors or inaccuracies in this respect; but I have endeavoured to be plain, exact and intelligible, and my meaning will not

be

be misunderstood by those who pay competent attention to my book.

In the Miscellaneous part of this performance many secrets are discovered that are worthy of attention, a great number of which were never before published. Some apology may be thought necessary for divulging them; but as I obtained my knowledge chiefly by my own industry and unwearied application, I have a right to communicate it for the benefit of young experimenters, till they can procure better assistance, or be enabled to strike out better methods of improvement by their own experience. At a future period, I intend to publish another volume as an appendix to this, wherein I shall lay down every calculation in different mill-works, water-works, steam-engines, &c. together with a variety of useful rules for the working mechanic, to which I shall also add sundry Miscellaneous Articles.

The most valuable improvements in arts and sciences which have appeared of late years are, 1st. Messrs. Watts *and* Bolton's *steam engine, a brief description of which I have given in the following treatise. 2d.* Rev. Mr. Cooke's *drill plough**; *and although I have not admitted an account of it*

* See description in his Drill Husbandry perfected, price 1s. published by Mr. MURRAY; also YOUNG's Memoir's of Agriculture, &c.

in

in this treatiſe, yet I cannot help obſerving concerning it, that it is an aſſemblage of the mechanic powers ſimply diſpoſed to great advantage, ſo as to aſſiſt that important deſign of the inventor—the improvement of agriculture—in the beſt manner yet attempted. 3d. A teleſcope which is the moſt noble inſtrument of the kind ever conſtructed, and which diſplays Dr. Herſchell's *optical and aſtronomical abilities beyond all of his cotemporaries.*

Before I conclude I muſt acknowledge my obligations to Mr. James Wood, *oppoſite the Sunday Toll Bar, Kent Street Road, Southwark, late Collector for the London Bridge Water Works; whoſe extenſive knowledge both in theory and practice of every ſcience is greater than is generally to be met with united in one perſon; and to him I would recommend thoſe gentlemen, who are in want of curious models in every branch of experimental philoſophy.*

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TO THE

Introduction to Useful Knowledge.

Compositions

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Table

MECHANICS.

DEFINITIONS.

1. MECHANICS, is a ſcience, which treats of the forces, motions, velocities, and in general, of the actions of bodies upon one another; it teaches how to move any given weight with any given power; how to contrive engines to raiſe great weights, or to perform any kind of motion.

2. Body, is the maſs or quantity of matter; an elaſtic body is that which yields to a ſtroke, and recovers its figure again; otherwiſe, it is called an unelaſtic body.

3. Denſity, is the proportion of the quantity of matter in any body, to the quantity of matter in another body of the ſame dimenſions.

4. Force, is a power exerted on a body to move it; if it act inſtantaneouſly, it is called percuſſion, or impulſe; if conſtantly, it is an accelerative force.

5. Velocity, is a property of motion, by which a body paſſes over a certain ſpace in a certain time; and is greater

or lefs, as it paffes over a greater or lefs fpace in a certain time, fuppofe a fecond.

6. Motion, is a continual and fucceffive change of place; if the body moves equally, it is called equable or uniform motion; if it increafes or decreafes, it is called accelerated or retarded motion; when it is compared with a body at reft, it is called abfolute motion; but when compared with a body in motion, it is called relative motion.

7. Direction of motion, is the courfe or way the body tends, or the line it moves in.

8. Quantity of motion, is the motion a body has, confidered both in regard to its velocity and quantity of matter; this is called the momentum of a body.

9. Vis inertiæ, is the innate force of matter, by which it refifts any change, ftriving to preferve its prefent ftate of reft or motion.

10. Gravity, is that force wherewith a body endeavours to fall downwards; it is called abfolute gravity in empty fpace; and relative gravity when immerfed in a fluid.

11. Specific gravity, is the greater or lefs weight of bodies of the fame magnitude, or the proportion between their weights. This proceeds from the natural denfity of bodies.

12. Center of gravity, is a certain point of a body; upon which the body, when fufpended, will reft in any pofition.

13. Center of motion, is a fixed round about which a body moves; and the axis of motion is a fixed line it moves about.

14. Power and weight, when oppofed to one another, fignify the body that moves another, and the other which is moved; the body which begins and communicates motion is the power; and that which receives the motion, is the weight.

15. Equilibrium, is the balance of two or more forces, fo as to remain at reft.

16. Machine or engine, is any inftrument to move bodies, made of levers, wheels, pullies, &c.

17. Mechanic powers, are the lever, wheel, pully, fcrew, wedge, and the inclined plane.

18. Strefs, is the effect any force has to break a beam, or any other body; and the ftrength is the refiftance it is able to make againft any ftraining force.

19. Friction, is the refiftance which a machine fuffers, by the parts rubbing againft one another.

POSTULATA.

1. That a fmall part of the furface of the earth may be looked upon as a plane; for though the earth be round, yet fuch a fmall part of it as we have any occafion to confider, does not fenfibly differ from a plane.

2. That heavy bodies defcend in lines parallel to one another; for though they all tend to a point, which is the center of the earth, yet that center is at fuch a diftance, that thefe lines differ infenfibly from parallel lines.

3. The fame body is of the fame weight in all places on or near the earth's furface; for the difference is not fenfible in the feveral places we can go to.

4. Though all matter is rough, and all engines imperfect; yet, for the eafe of calculation, we muft fuppofe all planes perfectly even; all bodies perfectly fmooth; and all bodies and machines to move without friction or refiftance; all lines ftreight and inflexible, without weight or thicknefs; cords extremely pliable, and fo on.

AXIOMS.

1. Every body endeavours to remain in its prefent ftate, whether it be at reft, or moving uniformly in a right line.

2. The alteration of motion by any external force is always proportionable to that force, and in direction of the right line in which the force acts.

3. Action and re-action, between any two bodies, are equal and contrary.

4. The motion of any body is made up of the fum of the motions of all the parts.

5. The weights of all bodies in the fame place, are proportional

proportional to the quantities of matter they contain, without any regard to their figure.

6. The vis inertiæ of any body, is proportional to the quantity of matter.

7. Every body will defcend to the loweft place it can get to.

8. Whatever fuftains a heavy body, bears all the weight of it.

9. Two equal forces acting againft one another in contrary directions, deftroy one anothers effect; and unequal forces act only with the difference of them.

10. When a body is kept in equilibrium; the contrary forces in any line of direction are equal.

11. If a certain force generate any motion; an equal force acting in a contrary direction, will deftroy as much motion in the fame time.

12. If a body be acted on by any power in a given direction; it is all one in what point of that line of direction the power is applied.

13. If a body is drawn by a rope, all the parts of the rope are equally ftretched; and the force in any part acts in direction of that part; and it is the fame thing whether the rope is drawn out at length, or goes over feveral pullies.

14. If ſeveral forces at one end of a lever, act againſt ſeveral forces at the other end; the lever acts, and is acted on, in direction of its length.

Of the Mechanical Powers.

The foundation of all mechanics.

NOW, if we conſider bodies in motion, and compare them together, we may do this either with reſpect to the quantities of matter they contain, or the velocities with which they are moved. For the heavier any body is, the greater is the power required either to move or ſtop its motion: and again, the ſwifter it moves, the greater is its force. So that the whole force of a moving body is the reſult of its quantity of matter multiplied by the velocity with which it is moved. And when the product ariſing from the multiplication of the particular quantities of matter in any two bodies, by their reſpective velocities, are equal, the entire forces are ſo too. Thus, ſuppoſe a body, which we call A, to weigh 40 pounds, and to move at the rate of two miles in a minute; and another body, which we call B, to weigh only 4 pounds, and to move 20 miles in a minute; the entire forces with which theſe two bodies would ſtrike againſt any obſtacle would be equal to each other, and therefore it would require equal powers to ſtop them. For 40 multiplied by 2 gives 80, the force of the body A: and 20 multiplied by 4 gives 80, the force of the body B. Upon this eaſy principle depends the whole of mechanics: and it holds univerſally true, that when two bodies are ſuſpended on any machine, ſo as to act contrary to each other; if the machine

machine be put into motion, and the perpendicular aſcent of one body multiplied into its weight, be equal to the perpendicular deſcent of the other body multiplied into its weight, thoſe bodies, how unequal ſoever in their weights, will balance one another in all ſituations: for, as the whole aſcent of one is performed in the ſame time with the whole deſcent of the other, their reſpective velocities muſt be directly as the ſpaces they move through; and the exceſs of weight in one body is compenſated by the exceſs of velocity in the other. Upon this principle, it is eaſy to compute the power of any mechanical engine, whether ſimple or compound; for it is but only finding how much ſwifter the power moves than the weight does (i. e. how much farther in the ſame time) and juſt ſo much is power increaſed by the help of the engine.

How to compute the power of any mechanical engine.

In the theory of this ſcience we ſuppoſe all planes perfectly even, all bodies perfectly ſmooth, levers to have no weight, cords to be extremely pliable, machines to have no friction; and, in ſhort, all imperfections muſt be ſet aſide until the theory be eſtabliſhed; and then, proper allowances are to be made.

The ſimple machines, uſually called mechanical powers, are ſix in number, viz. the lever, the wheel and axle, the pully, the inclined plane, the wedge, and the ſcrew; they are called mechanical powers, becauſe they help us mechanically to raiſe weights, move heavy bodies, and overcome reſiſtances, which we could not effect without them.

The mechanic powers what.

1. A lever is a bar of iron or wood, one part of which being ſupported by a prop, all the other parts turn upon that prop as their center of motion: and the velocity of every part

Of the lever.

part or point is directly as its diſtance from the prop. Therefore, when the weight to be raiſed at one end is to the power applied to the other to raiſe it; as the diſtance of the power from the prop, is to the diſtance of the weight from the prop, the power and weight will exactly balance or counterpoiſe each other: and as a common lever has nearly no friction on its prop, a very little additional power will be ſufficient to raiſe the weight.

There are four kinds of levers. 1. The common ſort, when the prop is placed between the weight and power; but much nearer to the weight than to the power. 2. When the prop is at one end of the lever, the power at the other, and the weight between them. 3. When the prop is at one end, the weight at the other, and the power applied between them. 4. The bended lever, which differs only in form from the firſt ſort, but not in property. Thoſe of the firſt and ſecond kind are often uſed in mechanical engines; but there are few inſtances in which the third ſort is uſed.

The balance. The balance is a ſtraight inflexible rod or beam, turning round a fixed point or axle in the middle of it, to be loaded at each end with weights ſuſpended there; it is by ſome reckoned a lever of the firſt kind, but as both ends are ſet at equal diſtances from its center of motion, they move with equal velocities; and therefore, as it gives no mechanical advantage, it cannot properly be reckoned among the mechanical powers.

Plate I. Fig. 5. Let C D be a beam or lever, E the middle point or center of motion; A B, the weights, hanging at the ends C and D, then let the beam and the weights, or the whole machine,

machine, be ſuſpended at E; and ſuppoſe the beam Fig. 5.
and the weights be turned upon the center E, then the points C D being equidiſtant from E, will deſcribe equal arches, and therefore their velocities will be equal; and if the bodies A and B be equal, then the motion of A will be equal to the motion of B, as the quantities of matter and velocities are equal; and conſequently, if the beam and weights are ſet at reſt, neither of them can move the other, but they will remain in equilibrium, if one weight be greater than the other; that weight and ſcale will deſcend and raiſe the other.

Now, the uſe of the balance, or a common pair of ſcales, is to compare the weights of different bodies; for any body, whoſe weight is required, be put into one ſcale, and balanced by known weights put into the other ſcale, theſe weights will ſhew the weight of the body.

To have a pair of ſcales perfect, they muſt have theſe properties. 1. The points of ſuſpenſion of the ſcales, and the center of motion of the beam C, E, D, muſt be in a right line. 2. The arms C E, D E, muſt be of equal length from the center. 3. That the center of gravity be in the center of the motion E. 4. That there be as little friction as poſſible, 5. That they be in equilibrium when empty.

The Properties of Scales.

If the center of gravity of the beam be above the center of motion and the ſcales be in equilibrium, if they be put a little out of that poſition, by putting down one end of the beam, that end will continually deſcend until it be ſtopt at the handle H. For by that motion, the center of gravity is continually deſcending, according to the nature of it, but

if the center of gravity of the beam be below the center of motion; if one end of the beam be put down a little, to deſtroy the equilibrium, it will return back and vibrate up and down. For by the motion the center of gravity is endeavouring to deſcend.

To prove Scales whether they are good.

To diſcover a falſe balance, make the weights in the two ſcales to be in equilibrium; then change the weights to the contrary ſcales, and if they be not in equilibrium, the balance is falſe.

Hence alſo, to prove a pair of good ſcales, they muſt be in equilibrium when empty, and likewiſe in equilibrium with the two weights. Then, if the two weights be changed to the contrary ſcales, the equilibrium will ſtill remain, if the ſcales are good.

Fig. 1. The firſt kind of lever.

A lever of the firſt kind is repreſented by the bar A B C, ſupported by the prop D. Its principal uſe is to looſen large ſtones in the ground, or to raiſe great weights to ſmall heights, in order to have ropes put under them for raiſing them higher by other machines. The parts A B and B C on different ſides of the prop D, are called the arms of the lever: the end A of the ſhorter arm A B being applied to the weight intended to be raiſed, or to the reſiſtance to be overcome; and the power applied to the end C of the longer arm B C.

In making experiments with this machine, the ſhorter arm A B muſt be as much thicker than the longer arm B C, as will be ſufficient to balance it on the prop D. This ſuppoſed, let P repreſent a power whoſe gravity is equal to 1 ounce, and W a weight, whoſe gravity is equal to 12

ounces.

ounces. Now, if the power be twelve times as far from the prop as the weight is, they will exactly counterpoiſe; and a ſmall addition to the power P will cauſe it to deſcend, and raiſe the weight W; and the velocity with which the power deſcends will be to the velocity with which the weight riſes, as 12 to 1: that is, directly as their diſtances from the prop; and conſequently, as the ſpaces through which they move. Hence, it is plain that a man, who by his natural ſtrength, without the help of any machine, could ſupport an hundred weight, will by the help of this lever be enabled to ſupport twelve hundred. If the weight be leſs, or the power greater, the prop may be placed ſo much farther from the weight; and then it can be raiſed to a proportionable greater height. For, univerſally, if the intenſity of the weight multiplied into its diſtance from the prop, be equal to the intenſity of the power multiplied into its diſtance from the prop, the power and weight will exactly balance each other; and a little addition to the power will raiſe the weight. Thus, in the preſent inſtance, the weight W is 12 ounces, and its diſtance from the prop is 1 inch; and 12 multiplied by 1 is 12; the power P is equal to 1 ounce, and its diſtance from the prop is 12 inches, which multiplied by 1 is 12 again; and therefore there is an equilibrium between them. So, if a power equal to 2 ounces be applied at the diſtance of 6 inches from the prop, it will juſt balance the weight W; for 6 multiplied by 2 is 12, as before. And a power equal to 3 ounces placed at 4 inches diſtant from the prop would be the ſame; for 3 times 4 is 12; and ſo on, in proportion. Fig. 1.

Properties of the firſt kind of lever.

To this kind of lever may be reduced ſeveral ſorts of inſtruments, ſuch as ſciſſars, pincers, ſnuffers, &c. which are made of two levers acting contrary to one another: their prop, or center of motion being the pin which keeps them together. In common practice, the longer end of

this lever greatly exceeds the weight of the ſhorter: which gains great advantage, becauſe it adds ſo much to the power.

Fig. 6. The ſteelyard.

The ſtatera or Roman ſteelyard, is a lever of this kind, and is uſed for finding the weights of different bodies by one ſingle weight placed at different diſtances from the prop or center of motion D. For, if a weight hangs at A the extremity of the ſhorter arm D G, is of ſuch a weight as will exactly counterpoiſe the longer arm D X; if this arm be divided into as many equal parts as it will contain, each equal to O D, the ſingle weight P (which we may ſuppoſe to be 1 pound) will ſerve for weighing any thing as heavy as itſelf, or as many times heavier as there are diviſions in the arm D X, or any quantity between its own weight and that quantity. As for example, if P be 1 pound and placed at the firſt diviſion 1 in the arm D X, it will balance 1 pound in the ſcale at W; if it be removed to the ſecond diviſion at 2, it will balance 2 pounds in the ſcale; if to the third 3 pounds; and ſo on to the end of the arm D X. If each of theſe integral diviſions be ſubdivided into as many equal parts as a pound contains ounces, and the weight P be placed at any of theſe ſubdiviſions, ſo as to counterpoiſe what is in the ſcale, the pounds and odd ounces therein will by that means be aſcertained.

The ſecond kind of lever.

A lever of the ſecond kind has the weight between the prop and the power. In this, as well as the former, the advantage gained is as the diſtance of the power from the prop to the diſtance of the weight from the prop: for the reſpective velocities of the power and weights are in that proportion; and they will balance each other when the intenſity of the power multiplied by its diſtance from the prop is equal to the intenſity of the weight multiplied by its diſtance from the prop. Thus, if A B be a lever

lever on which the weight W of 6 ounces hangs at the diſtance of 1 inch from the prop G, and a power P equal to the weight of 1 ounce hangs at the end B, 6 inches from the prop; by the cord C D going over the fixed pulley E, the power will juſt ſupport the weight: and a ſmall addition to the power will raiſe the weight, 1 inch for every 6 inches that the power deſcends. This lever ſhews the reaſon why two men carrying a burden upon a ſtick between them, bear unequal ſhares of the burden in the inverſe proportion of their diſtances from it. For it is well known, that the nearer either of them is to the burden, the greater ſhare he bears of it: and if he goes directly under it, he bears the whole. So if one man be at G, and the other at B, having the pole or ſtick A B reſting on their ſhoulders; if the burden or weight W be placed five times as near the man at G, as it is to the man at B, the former will bear five times as much weight as the latter.

This is likewiſe applicable to the caſe of two horſes of unequal ſtrength to be ſo yoked, as that each horſe may draw a part proportionable to his ſtrength; which is done by ſo dividing the beam they pull, that the point of traction may be as much nearer to the ſtonger horſe than to the weaker, as the ſtrength of the former exceeds that of the latter. Properties of the ſecond kind of lever.

To this kind of lever may be reduced oars, rudders of ſhips, doors turning upon hinges, cutting-knives which are fixed at the point, &c.

If in this lever we ſuppoſe the power and weight to change places, ſo that the power may be between the weight and the prop, it will become a lever of the third kind; in which, that there may be a balance between the The third kind of lever.

the power and the weight, the intenſity of the power muſt exceed the intenſity of the weight, juſt as much as the diſtance of the weight from the prop exceeds the diſtance of the power. Thus, let E be the prop of the lever A B, and W a weight of 1 pound, placed 3 times as far from the prop, as the power P acts at F, by the cord C going over the fixed pulley D; in this caſe, the power muſt be equal to 3 pounds, in order to ſupport the weight of 1 pound.

Fig. 3.

Properties of the third kind of lever.

To this ſort of lever are generally referred the bones of a man's arm; for when he lifts a weight by the hand, the muſcle that exerts its force to raiſe that weight, is fixed to the bone about one tenth part as far below the elbow as the hand is. And the elbow being the center round which the lower part of the arm turns, the muſcle muſt therefore exert a force ten times as great as the weight that is raiſed.

As this kind of lever is a diſadvantage to the moving power, it is uſed as little as poſſible; but in ſome caſes it cannot be avoided, ſuch as that of a ladder, which, being fixed at one end, is by the ſtrength of a man's arms reared againſt a wall.

And in clock-work, where all the wheels may be reckoned levers of this kind, becauſe the power that moves every wheel, except the firſt, acts upon it near the center of motion by means of a ſmall pinion, and the reſiſtance it has to overcome, acts againſt the teeth round its circumference.

The fourth kind of lever.
Fig. 4.

The fourth kind of lever differs nothing from the firſt but in being bended for the ſake of convenience. ACB is a lever of this ſort, bended at C, which is its prop or center of

of motion. P is a power acting upon the longer arm A C at F, by means of the cord D E going over the pulley G; and W is a weight or resistance acting upon the end B of the shorter arm C B. If the power is to the weight, as C B is to C F, they are in equilibrium. Thus, suppose W to be 5 pounds acting at the distance of one foot from the center of motion C, and P to be 1 pound acting at F, five feet from the center C, the power and weight will just balance each other. A hammer drawing a nail is a lever of this sort.

2. The second mechanical power is the wheel and axle, in which the power is applied to the circumference of the wheel, and the weight is raised by a rope which coils about the axle as the wheel is turned round. Here it is plain, that the velocity of the power must be to the velocity of the weight, as the circumference of the wheel is to the circumference of the axle: and consequently, the power and weight will balance each other, when the intensity of the power is to the intensity of the weight, as the circumference of the axle is to the circumference of the wheel. Let A B be a wheel, C D its axle, and suppose the circumference of the wheel to be 8 times as great as the circumference of the axle; then, a power P equal to 1 pound hanging by the cord I, which goes round the wheel, will balance a weight W of 8 pounds hanging by the rope K, which goes round the axle. And as the friction on the pivots or gudgeons of the axle E F is but small, a small addition to the power will cause it to descend, and raise the weight: but the weight will rise with only an eighth part of the velocity wherewith the power descends, and consequently, through no more than one eighth part of an equal space, in the same time. If the wheel be pulled round by the

The wheel and axle.

Fig. 7.

Fig. 7. the handles S, S, the power will be increafed in proportion to their length. And by this means, any weight may be raifed as high as the operator pleafes.

Its ufes. To this fort of engine belong all cranes for raifing great weights; and in this cafe, the wheel may have cogs all round it inftead of handles, and a fmall lanthorn or trundle may be made to work in the cogs, and be turned by a winch; which will make the power of the engine to exceed the power of the man who works it, as much as the number of revolutions of the winch exceeds thofe of the axle C D, when multiplied by the excefs of the length of the winch above the length of the femidiameter of the axle, added to the femidiameter or half thicknefs of the rope K, by which the weight is drawn up. Thus, fuppofe the diameter of the rope and axle taken together, to be 13 inches, and confequently, half their diameters to be 6 $\frac{1}{2}$ inches; fo that the weight W will hang at 6 $\frac{1}{2}$ inches perpendicular diftance from below the center of the axle. Now, let us fuppofe the wheel A B, which is fixed on the axle, to have 80 cogs, and to be turned by means of a winch 6 $\frac{1}{2}$ inches long, fixed on the axle of a trundle of eight ftaves or rounds, working in the cogs of the wheel. Here it is plain, that the winch and trundle would make 10 revolutions for one of the wheel A B, and its axis D, on which the rope K winds in raifing the weight W; and the winch being no longer than the fum of the femidiameters of the great axle and rope, the trundle could have no more power on the wheel, than a man could have by pulling it round by the edge; becaufe the winch would have no greater velocity than the edge of the wheel has, which we here fuppofe to be ten times as great as the velocity of the rifing weight; fo that, in this cafe, the power gained would be

How power may be increafed.

as

as 10 to 1. But if the length of the winch be 13 inches, the power gained will be as 20 to 1: if 19 ½ inches (which is long enough for any man to work by) the power gained will be as 30 to 1; that is, a man could raiſe 30 times as much by ſuch an engine, as he could do by his natural ſtrength without it, becauſe the velocity of the handle of the winch would be 30 times as great as the velocity of the riſing weight; the abſolute force of any engine being in proportion of the velocity of the power, to the velocity of the weight raiſed by it. But then, juſt as much power or advantage as is gained by the engine, ſo much time is loſt in working it; which is common in all mechanical caſes whatever. Force of any engine.

In this ſort of machines it is requiſite to have a ratchet wheel on the end of the axle C, with a catch to fall into its teeth; which will at any time ſupport the weight, and keep it from deſcending, if the perſon who turns the handle ſhould, through inadvertency or careleſſneſs, quit his hold while the weight is raiſing. Thus, by this means, the danger is prevented which might otherwiſe happen by the running down of the weight when left at liberty. Caution.

The third mechanical power or engine conſiſts either of one moveable pulley, or a ſyſtem of pullies; ſome in a block or caſe which is fixed, and others in a block which is moveable, and riſes with the weight. For though a ſingle pulley that only turns on its axis, and moves not out of its place, may ſerve to change the direction of the power, yet it can give no mechanical advantage thereto; but is only as the beam of a balance, whoſe arms are of equal length and weight. Thus, A is a ſingle pulley, and if it ſupport the The pulley. Fig. 8.

D equal

equal weights P and W, the cord B B to which they are appended, is equally ſtretched throughout, and the pulley A ſuſtains both the weights, or is drawn with a force equal to twice P. It is properly, but another form of the balance.

Fig. 9. Three moveable pullies.

A combination of three moveable pullies A, B, C, connected by three diſtinct cords, each faſtened at one end to an immoveable block above. The power of the whole is diſcovered by ſuppoſing two ſuch weights P and W ſuſpended, as will keep the machine in equilibrium, and then beginning with the leaſt weight, or power P, and conſidering what force each ſeparate pulley ſuſtains. Thus, if P be one pound, the cord which ſuſtains it, acts at its other end upon the fixed block above, and is conſequently re-acted upon by the block with a force equal to one pound, and the pulley A, as in fig. 8, is drawn with a force equal to two pounds.

By tracing the ſecond cord in the ſame manner, it will appear that the pulley B is drawn with twice the force of A, or 4 pounds. And C is drawn with twice the force of B, or 8 pounds. So that the purchaſe of this machine is ſuch, that the weight W has 8 times the power of P.

Velocity and power as 8 to 1.

The velocity of the weight to that of the power is (in a ſimilar way of arguing) thus, if P deſcend 8 inches, A will aſcend 4; B, 2; and C or W 1 inch; ſo that the velocities are reciprocally as the power and weight.

Fig. 10.

Another combination of pullies, whereof two, A and B, run in the fixed block X. And two others, C and D, in a moveable block, which raiſe the weight W, by pulling the

the cord at P, which goes ſucceſſively over the pullies A, D, B, C, and is faſtened to the fixed block at s. The purchaſe of this machine is known by conſidering that the cord is equally ſtretched throughout, by putting two ſuch weights P and W, as will counterpoiſe each other. For P is ſuſtained by the ſingle cord, and W by four fold of the ſame, viz. by the parts o, s, u, k, ſo that if P be one pound, W will be four pounds.

Four moveable pullies

The velocity of the power is to that of the weight as four to one. For if P deſcend four inches, the parts of the cord at k will aſcend towards e four inches, and all the other parts of the cord, from the pulley C, will equally follow each other, and C or W will aſcend one inch towards s; or the four parts of the cord o, s, u, k, will each be ſhortened 1 inch.

Velocity as 4 to 1.

In like manner may the purchaſe of any other combination of pullies be determined. And it will always happen, that the momenta of the weight and power will be equal, as in the other mechanical powers. That is, if any power will raiſe one pound with a certain velocity, it will raiſe two pounds with half that velocity, or one hundred pounds with one hundredth part of that velocity, &c.

But as a ſyſtem of pullies has no great weight, and lies in a ſmall compaſs, it is eaſily carried about; and can be applied, in a great many caſes, for raiſing weights, where other engines cannot; but they have a great deal of friction on three accounts---1. Becauſe the diameters of their axis's bear a very conſiderable proportion to their own diameters. 2. Becauſe in working they are apt to rub againſt one ano-

ther, or againſt the ſides of the blocks. 3. Becauſe of the ſtiffneſs of the ropes that paſs over and under them.

The fourth mechanical power is the inclined plane, and

The inclined plane.

the advantage gained by it, is as great as its length exceeds its perpendicular height. Let A B be a plane parallel to the horizon, and C D a plane inclined to it, and ſuppoſe the whole length C D to be three times as great as the perpendicular height G f F: in this caſe the cylinder E will be

Fig. 11.

ſupported upon the plane C D, and kept from rolling down upon it, by a power equal to a third part of the weight of the cylinder. Therefore, a weight may be rolled up this inclined plane with a third part of the power which would be ſufficient to draw it up by the ſide of an upright wall. If the plane was four times as long as it is high, a fourth part of the power would be ſufficient; and ſo on in proportion. Suppoſe a man has occaſion to ſet a weight upon an eminence, and the weight i ſo great, that he cannot lift it by his natural ſtrength, he will take a long ſtout plank, or ſomething equivalent thereto, and ſetting it ſloping, will puſh the weight before him up the plank, to the place deſigned to ſet it in; and ſuch plank, or other contrivance like it, is an inclined plane. Now it is evident, that the ſhorter this inclined plane is, the ſteeper is the aſcent; and the longer the plane is, the aſcent muſt be the eaſier. It is plain alſo, that it is much eaſier to puſh a rolling weight up a hill that riſes gently, than up a hill that is very ſteep, which is univerſally known.

The force wherewith a rolling body deſcends upon an inclined plane, is to the force of its abſolute gravity, by which it would deſcend perpendicularly in a free ſpace, as the height of the plane is to its length. For, ſuppoſe the plane

Fig. 12.

A B to be parallel to the horizon, the cylinder will keep at reſt

reſt upon any part of the plane where it is laid. If the Fig. 13.
plane be ſo elevated, that its perpendicular height from D is equal to half its length A B, the cylinder C will roll down upon the plane with a force equal to half its weight, for it would require a power (acting in the direction of A B) equal to half its weight to keep it from rolling. If the plane D B be elevated, ſo as to be perpendicular to the ho- Fig. 14.
rizon, the cylinder C would deſcend with its whole force of gravity, becauſe the plane contributes nothing to its ſupport or hindrance, and therefore it would require a power equal to its whole weight to keep it from deſcending. To the inclined plane may be reduced all hatchets, chiſels, and other edge-tools, which are chamfered only on one ſide.

The fifth mechanical power or machine is the wedge, The wedge.
which may be conſidered as two equally inclined planes D Fig. 15.
E F, and C E F, joined together at their baſes e E F O: then D C is the whole thickneſs of the wedge at its back A B C D, where the power is applied; E F is the depth or height of the wedge; D F the length of one of its ſides, equal to C F the length of the other ſide; and O F is its ſharp edge, which is entered into the wood intended to be ſplit, by the force of a hammer or mallet ſtriking perpendicularly on its back. Thus, A B is a wedge driven into the cleft C E D of the wood F G. Fig. 16.

When the wood does not cleave at any diſtance before the wedge, there will be an equilibrium between the power impelling the wedge downward, and the reſiſtance of the wood acting againſt the two ſides of the wedge when the power is to the reſiſtance, as half the thickneſs of the wedge at it's back is to the length of either of its ſides; becauſe the reſiſtance then acts perpendicular to the ſides of the wedge.

But

Consequently, if a line G, goes round the groove e, and has a weight of 48 pounds hung to it below the pedestal E F, a power equal to 1 pound at the handle will balance and support the weight. To prove this by experiment, let the circumferences of the grooves of the wheels C and D be equal to one another; and then, if a weight H, of one pound, be suspended by a line going round the groove of the wheel C, it will balance a weight of 48 pounds hanging by the line G; and a small addition to the weight H will cause it to descend, and so raise up the other weight.

Experiment.

If a line G, instead of going round the groove e of the wheel D, goes round its axle I; the power of the machine will be as much increased, as the circumference of the groove e exceeds the circumference of the axle: which, supposing it to be six times, then 1 pound at H will balance 6 times 48, or 288 pounds hung to the line on the axle: and hence the power or advantage of this machine will be as 288 to 1. That is to say, a man, who by his natural strength could lift an hundred weight, will be able to raise 288 by this engine. If a system of pullies were applied to the cord H, the power would be increased to an amazing excess, but it would be here as in all other mechanical cases; for the time lost is always as much as the power gained, because the velocity with which the power moves, will ever exceed the velocity with which the weight rises, as much as the intensity of the weight exceeds the intensity of the power.

Friction.

The friction of the screw itself is very considerable; and there are few compound engines, but what, upon account of the friction of the parts against one another, will require a third part more of the power to work them when loaded than

than what is ſufficient to conſtitute a balance between the weight and the power.

In the lever, the friction is nothing. In the wheel and axle, it is as ſmall as the diameter of the gudgeons (added to the power required to bend the rope) is leſs than the diameter of the wheel; but it increaſes according to the weight with which the axle is charged. The like might be ſaid of the pullies, if they did not rub againſt one another, or againſt the ſides of the mortiſes in the block where they are placed. A new rope of 1 inch diameter, going over a pulley 3 inches diameter, and pulled with a force equal to 5 pounds, requires a force of 1 pound or upwards to bend it; and a rope 2 inches diameter requires 4 times as much force.

Wood greaſed, or metal oiled, have nearly the ſame friction; and the ſmoother they are, their friction is the leſs. Yet metals may be ſo highly poliſhed, as to have their friction increaſed by the coheſion of their parts.

Wood ſlides eaſier upon the ground in wet weather than in dry; and eaſier than an equal weight of iron in dry weather: but iron ſlides eaſier than wood in wet weather. Iron or ſteel running in braſs has the leaſt friction of any. Lead makes a great deal of reſiſtance. In wood, acting upon wood, greaſe makes the motion at leaſt twice as eaſy. Wheel-naves, greaſed or tarred, go four times as eaſy as when wet. Smooth ſoft wood, moving upon ſmooth ſoft wood, has a friction equal to about a third part of the weight. In rough wood, the friction is almoſt equal to half the

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weight. In ſoft wood upon hard, or hard upon ſoft, the friction is equal to about a fifth part of the weight.

In poliſhed ſteel, moving upon poliſhed ſteel or pewter, the friction is about a fourth part of the weight; on copper, a fifth part; and on braſs, a ſixth part of the weight. Metals of the ſame ſort have more friction than different ſorts.

In general, the friction increaſes in the ſame proportion with the weight. The friction is alſo greater with a greater velocity; but not ſo great in proportion as the increaſe of velocity.

To have the friction of machines as little as poſſible, they ought to be made of the feweſt and ſimpleſt parts. The diameters of the wheels and pullies ought to be large, and the gudgeons of the axles as ſmall as can be conſiſtent with the required ſtrength. The ſides of the pullies ought not to be all over flat, but to have a ſmall riſing in the middle, to keep them from rubbing againſt each other's ſides, and againſt the ſides of their mortiſes, at a diſtance from their axle. All the cords and ropes ought to be as pliant as poſſible; and, for that end, rubbed with greaſe. The teeth of the wheels ſhould juſt fit and fill the openings, ſo as not to be ſqueezed nor ſhaked therein. All the parts which work into, or upon one another, ought to be ſmooth; the gudgeons ought juſt to fit their holes, and the working parts muſt be greaſed. The rounds or ſtaves of the trundles may be made to turn about upon iron ſpindles, fixed in the round end boards, which will take off a great deal of friction.

Let

Let the ſtrength of all parts be in proportion to the ſtreſs they are to bear, ſo as they may laſt equally well. He is by no means a perfect mechanic who only adjuſts the ſtrength to the ſtreſs, if he does not contrive all the parts to laſt ſo as that one ſhall not fail before another.

When any motion is to be long continued, contrive the machine ſo, as that the working power may always move to act one way, if it can be done: for this is better and eaſier performed, than when the motion is interrupted by the power's being forced to move firſt one way and then another; becauſe every new change of motion requires a new additional force to effect it; and a body in motion cannot ſuddenly receive a contrary motion without great violence, and danger of tearing the machine to pieces. But, when the nature of the thing requires that a motion ſhould ſuddenly be communicated to a body, or ſuddenly ſtopt; let the force act againſt ſome ſpring, to prevent the machines being damaged by a ſudden jolt.

When a machine is moved by two handles, or winches, on the ends of an axle, the handles are ſo placed as that when the one is up the other is down; which is the worſt way poſſible of placing them, ſave that of their being both up or down together. For, when a man raiſes a weight by means of turning a winch, he loſes half his force when the winch is upward; becauſe he puſhes himſelf as much backward as he puſhes the winch forward; and when the handle of the winch is down, directly below the axle, he loſes half his force; becauſe the winch pulls him as much toward it as he pulls it toward him: and, therefore, the greateſt effect of his force on the machine is when he either pulls the winch upward, on the ſide of the axle next to him, or

pushes it downward on the side farthest from him. Yet, even in these cases, the pulling force is stronger than the pushing.

In order to remedy this defect as much as possible, the handles should be so placed as to stand at right angles to one another; and then, when there is a man at each handle, the effect of the one man's force will be greatest when the effect of the other man's is least upon the machine. Whereas, in the common way of placing these handles, when the effect of one man's force is the greatest, the other man's is so too; and when the effect of that man's force is the least, so also is the other's; which is working at the greatest disadvantage possible.

MILL

MILL WORK.

In the Conſtruction of Water Mills, it will be neceſſary to obſerve the following Rules.

I. MEASURE the perpendicular height of the fall of water, in feet, above that part of the wheel on which the water begins to act, and call that the height of the fall.

II. Multiply this conſtant number 64,2882 by the height of the fall in feet, and the ſquare root of the product ſhall be the velocity of the water at the bottom of the fall, or the number of feet that the water there moves per ſecond.

III. Divide the velocity of the water by three, and the quotient ſhall be the velocity of the float-boards of the wheel; or the number of feet they muſt each go through in a ſecond, when the water acts upon them ſo as to have the greateſt power to turn the mill.

IV. Divide the circumference of the wheel in feet by the velocity of its floats in feet per ſecond, and the quotient ſhall be the number of ſeconds in which the wheel turns round.

V. By

V. By this laſt number of ſeconds divide 60, and the quotient ſhall be the number of turns of the wheel in a minute.

VI. Divide 120 (the number of revolutions a millſtone 4 ½ feet diameter ought to have in a minute) by the number of turns of the wheel in a minute, and the quotient ſhall be the number of turns the millſtone ought to have for one turn of the wheel.

VII. Then, as the number of turns of the wheel in a minute is to the number of turns of the millſtone in a minute, ſo muſt the number of ſtaves in the trundle be to the number of cogs in the wheel, in the neareſt whole numbers that can be found.

By theſe rules the following table is calculated to a water wheel 18 feet diameter, which, I apprehend, may be a good ſize in general.

Velocity of water.

To aſcertain the force or power of any moderate ſtream of water, let the ſame be obſtructed by a dam acroſs the ſtream, ſo as to force all the water through a trough or open ſpout into a large veſſel or reſervoir; by meaſuring ſo much water as ſhall be received as above, in any given time, viz. a ſecond, minute, &c. and multiplying the ſame by the number of ſeconds or minutes in an hour, the whole force or impulſe of ſuch ſtream of water per hour, at any given height, may be readily aſcertained. In rivers too large to be meaſured as above, the force or impulſe may be calculated from the ſpace that a ſtraw, floating upon the ſurface of the water, in any given time, and at a medium depth and width of the river, will deſcribe.

The

The Mill Wright's Table.

Height of the fall of water.	Velocity of the fall of water per second.		Velocity of the wheel per second.		Revolutions of the wheel per minute.		Revolution of the millstone for one of the wheel		Cogs in the wheel, and staves in the trundle		Revolutions of the millstone per minute by these staves and Cogs.	
Feet.	Feet.	100 parts of a foot.	Feet.	100 parts of a foot.	Revolutions.	100 parts of a rev.	Revolutions.	100 parts of a rev.	Cogs.	Staves.	Revolutions.	100 parts of a rev.
1	8	02	2	67	2	83	42	40	254	6	119	84
2	11	34	3	78	4	00	30	00	210	7	120	00
3	13	89	4	63	4	91	24	44	196	8	120	28
4	16	04	5	35	5	67	21	16	190	9	119	·74
5	17	93	5	98	6	34	18	92	170	9	119	68
6	19	64	6	55	6	94	17	28	156	9	120	20
7	21	21	7	07	7	50	16	00	144	9	120	00
8	22	68	7	56	8	02	14	96	134	9	119	34
9	24	05	8	02	8	51	14	10	140	10	119	14
10	25	35	8	45	8	97	13	38	134	10	120	18
11	26	59	8	86	9	40	12	76	128	10	120	32
12	27	77	9	26	9	82	12	22	122	10	119	80
13	28	91	9	64	10	22	11	74	118	10	120	36
14	30	00	10	00	10	60	11	32	112	10	118	72
15	31	05	10	35	10	99	10	92	110	10	120	96
16	32	07	10	09	11	34	10	58	106	10	120	20
17	33	06	11	02	11	70	10	26	102	10	119	34
18	34	02	11	34	12	02	9	98	100	10	120	20
19	34	95	11	65	12	37	9	70	98	10	121	22
20	35	86	11	95	12	68	9	46	94	10	119	18
1	2		3		4		5		6		7	

To conſtruct a mill by this table, find the height of the fall of water in the firſt column, and againſt that height in the ſixth column, you have the number of cogs in the wheel, and ſtaves in the trundle, for cauſing the millſtone 4 feet 6 inches diameter, to make about 120 revolutions in a minute, as near as poſſible, when the wheel goes with one third part of the velocity of the water. And it appears by the 7th column, that the number of cogs in the wheel, and ſtaves in the trundle, are ſo near the truth for the required purpoſe, that the leaſt number of revolutions of the millſtone in a minute is 118, and the greateſt number never exceeds 121; which is according to the ſpeed of ſome of the beſt mills I have yet ſeen.

A leſs quantity of water will turn an overſhot, than what will turn an underſhot or breaſt wheel; as an overſhot is actuated by the ſtatical weight, or gravity, and the underſhot or breaſt by impulſe only; ſo that where there is but a ſmall quantity of water, and a fall great enough for the wheel to lie under it, the overſhot wheel is always uſed. But where there is a large body of water, and little fall, the underſhot wheel muſt take place. Where the water runs only upon a little declivity, it can act but ſlowly upon the under part of the wheel; in which caſe, the motion of the wheel will be very ſlow: and therefore, the floatboards ought to be very long, though not high, that a large body of water may act upon them; ſo that what is wanting in velocity, may be made up in power; and then the cog-wheel may have a greater number of cogs, in proportion to the rounds in the trundle, in order to give the millſtone a ſufficient degree of velocity.

The Method for setting out a Spur Wheel and Wallower.

DRAW the pitch lines A 1, B 1, A 2, 2 B; then divide them into the number of teeth or cogs required, as a b c. Plate II. Fig. 1.

Divide one of those distances, as b c, into seven equal parts, as 1, 2, 3, 4, 5, 6, 7; three parts allow for the thickness of the cogs, as 1, 2, 3 in the cog a, and four for the thickness of the stave, of the wallower (one reason for allowing three parts for the cog, and four for the stave, is, the wallower is in general of less diameter than the wheel, therefore subject to more wear in proportion of the number of cogs, to the number of staves; but if there is the same number of staves as of cogs, they may be of equal thickness) as 1, 2, 3, 4, in the stave m, Fig. 2; the height of the cog is equal to four parts; then divide its height into five equal parts, as 1, 2, 3, 4, 5, in the cog C; allow three for the bottom to the pitch line of the cog; the other two parts for epicycloid, so as to fit and bear on the stave equally. The millwrights in general put the point of a pair of compasses in the dot 3, of the cog a, and strike the line d, e; then remove the point of the compasses to the point d, and strike the curve line 3 f, which they account near enough the figure of the epicycloid.

The method for a face wheel is thus; divide the pitch line A B into the number of cogs intended, as a b c; divide the distance b c, into seven equal parts; three of those parts allow for the thickness of the cogs, as 1, 2, 3 in the cog a, four for the height, and four for the width, as d e, and four for the thickness of the stave m; draw a line through the Fig. 2.

center of the cog, as the line A I, at S; and on the point 5, defcribe the line d e; remove the compaffes to the point A, and draw the line f g, which forms the fhape of the cog; then fhape the cog on the fides to a cycloid, as d e f g, Fig. 1. But this method of fetting out the fhape of a cog is variable, according to the cycloid in different diameters of wheels.

Spur Nuts. Fig. 3.

In common fpur nuts, divide the pitch line A, into twice as many equal parts as you intend teeth, as a, b, c, d, e; with a pair of compaffes opened to half the diftance of any of thofe divifions, from the points a 1, c 3, e 5, draw the femicircles a, c, and e, which will form the ends of the teeth. From the points 2, 4, and 6 draw the femicircles g h i, which will form the hollow curves for the fpaces; but if the ends of the teeth were epicycloids, inftead of femicircles, they would act much better.

The Principle of Bevel Geer,

Bevel Geer. Fig. 4.

CONSISTS in two cones, rolling on the furface of each other, as the cone A and B revolving on their centers a b, a c,; if their bafes are equal, they will perform their revolutions in one and the fame time, or any other two points equally diftant from the center a, as d 1, d 2, d 3, &c, will revolve in the fame time as f 1, f 2, f 3, &c. In the like

Fig. 5 and 6.

manner, if the cones, a d e, be twice the diameters at the bafe d e, as the cones a f d are, then if they turn about their centers, when the cone a f d has made one revolution, the cone a d e will have made but half a revolution; or when a f d has made two revolutions, a d e will have made but one, and every part equally diftant from the center a, as

f 1,

f 1, f 2, f 3, &c. will have made two revolutions to e 1, e 2, e 3, &c. and if the cones were fluted, or had teeth cut in them, diverging from the center a, to the bafes d c, e f, they would then become bevel geer. The teeth at the point of the cone being fmall and of little ufe, may be cut off at E and F, Fig. 8, as feen by Fig. 9, where the upright fhaft, a b, with the bevel wheel, c d, turns the bevel wheel, e f, with its fhaft b g, and the teeth work freely into each other, as a b Fig. 10. The teeth may be made of any dimenfion, according to the ftrength required; and this method will enable them to overcome a much greater refiftance, and work fmoother than a face wheel and wallower of the common form can poffibly do; befides, it is of great ufe to convey a motion in any direction, or to any part of a building with the leaft trouble and friction.

Fig. 7 and 8.

Fig. 8 & 9.

Fig. 10.

The method of conveying motion in any direction, and proportioning or fhaping the wheels thereto, is as follows: let the line a b, reprefent a fhaft coming from a wheel; draw the line c d to interfect the line a b, in the direction, that the motion to be conveyed is intended, which will now reprefent a fhaft to the intended motion.

Fig. 11.

Again, fuppofe the fhaft c d is to revolve three times, whilft the fhaft a b revolves once, draw the parallel line i i, at any diftance not too great, fuppofe 1 foot by a fcale, then draw the parallel line k k at 3 feet diftance, after which, draw the dotted line w x, through the interfection of the fhafts a b, and c d, and likewife through the interfection of the parallel lines i i and k k, in the points x and y; which will be the pitch line of the two bevel wheels, or the line where the teeth of the two wheels act on each other, as may

Fig. 12. be feen Fig. 12, where the motion may be conveyed in any direction.

Fig. 13. The univerfal joint, as reprefented, Fig. 13 may be applied to communicate motion inftead of bevel geer. Where the fpeed is to be continued the fame, and where the angle does not exceed 30 or 40 degrees, and the equality of motion is not regarded, for as it recedes from a right line, its motion becomes more irregular. This joint may be conftructed by a crofs, as reprefented in the figure; or with four pins faftened at right angles upon the circumference of a hoop, or folid ball, it is of great ufe in cotton mills where the tumbling fhafts are continued to a great diftance from the moving power. But by applying this joint, the fhafts may be cut into convenient lengths, by which it will be enabled to overcome geater refiftance.

To defcribe the Cycloid and Epicycloid, of Ufe in Shaping the Teeth of Wheels, &c.

Fig. 14. IF a point or pencil a, on the circumference of the circle B, proceeds along the plane a C, in a right line, and at the fame time revolves round its center, it will defcribe a cycloid.

Fig. 15. And, if the generating circle D, moves along the circumference of another circle E, and at the fame time turns round its center, the point o will defcribe an epicycloid.

A Brief

A

Brief Hiſtory of Electricity.

THOUGH it is certain ever ſince the creation of the world the electric fluid had all the operations it has at preſent; yet, the diſcovery of its action and even of its exiſtence is (comparatively ſpeaking) of a very late date. *Thales* the *Mileſian*, who lived 600 years before Chriſt, was the firſt who obſerved the electrical properties of amber. Of theſe indeed, he knew no more than that this ſubſtance would attract light bodies when it was rubbed. For 300 years after his time, we hear nothing further concerning this ſubject. Theophraſtus then tells us that the *Lyncurium* (now called the *Tourmalin*), has the property of attracting light bodies, as well as amber From this time there is a chaſm in the hiſtory of electricity for 1900 years. It was in the beginning of the 17th century that the ſubject of electricity became a diſtinct ſcience, and the foundation was laid of thoſe diſcoveries (which have ſince taken place;) by Dr. William Gilbert, an Engliſh phyſician, who may juſtly be called the father of electricians; in the year 1600 he wrote a book *De Magnette* which contains a variety of electrical experiments. All theſe however, conſidered only the attractive property of certain ſubſtances, which, from their agreement in this reſpect with amber, were called electric. Dr. Gilbert's merit conſiſts in his having been at great pains to find out a number of ſuch ſubſtances,

Electricity when firſt mentioned.

Diſcoveries of Dr. Gilbert.

fubftances, and thus confiderably enlarge the number of electrics.

Mr. Boyle's improvements.

Till the year 1670, it does not appear that any farther difcoveries were made; except fome trifling additions to the Catalogue of electrics. About this time Mr. Boyle applied himfelf to the ftudy of electricity, he enlarged the catalogue of electrics; and found that their electric properties were increafed by warming and wiping them before they were rubbed.

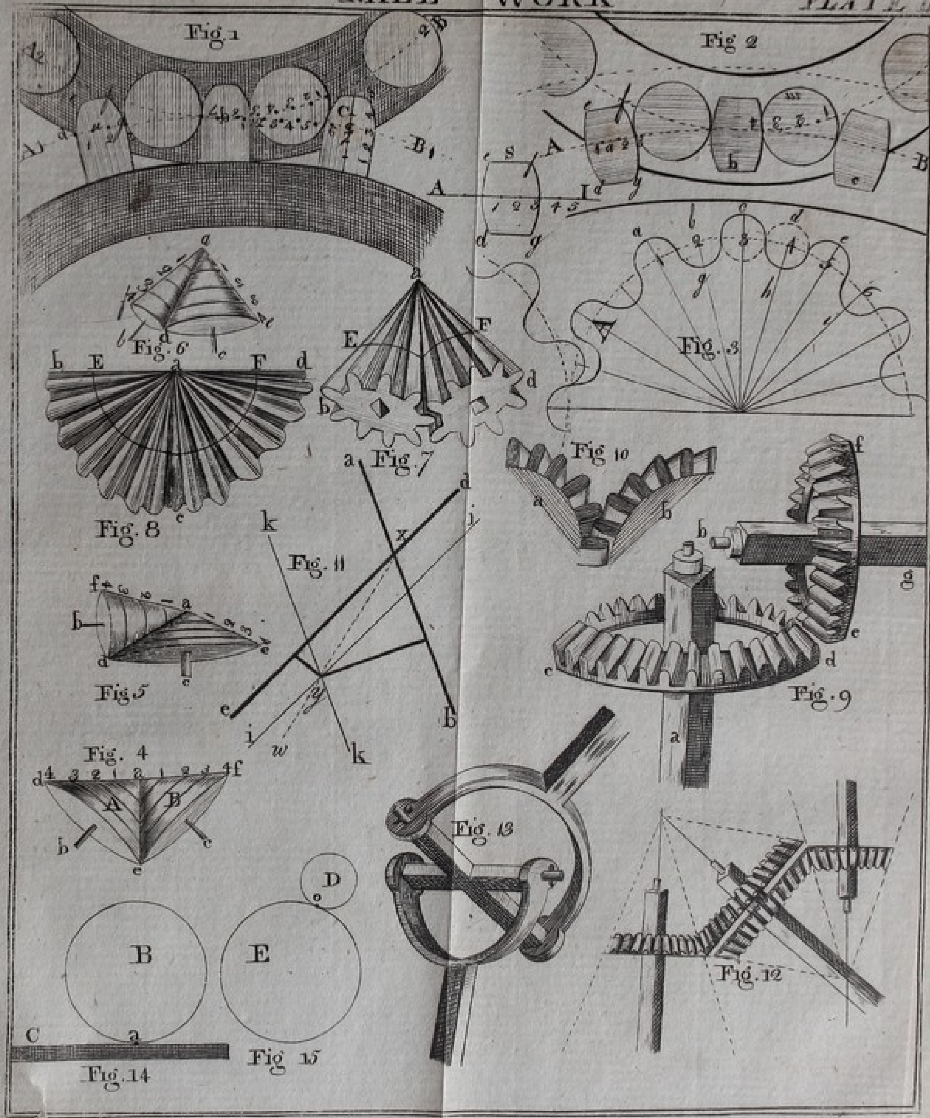
Difcoveries of Otto Guericke.

Otto Guericke, however, who was cotemporary with Mr. Boyle, improved the fcience much farther. He made ufe of a fulphur globe, whirled on an axis, much like our prefent glafs globes; by which means he excited a greater power of electricity than any of his predeceffors, and tried all their experiments to much more advantage. He difcovered the electric repulfion; and not only faw the electric light more clearly than Mr. Boyle, but heard the hiffing found with which it is emitted. He alfo made another remarkable difcovery, but which has fince been very generally overlooked; viz. that a feather, when repelled by an excited electric, always keeps the fame face towards the body which repells it, as the moon does to the earth.

Difcovery by Sir Ifaac Newton. Mr. Hawksbee's Improvements

The next difcovery of any moment was made by Sir Ifaac Newton; who obferved, that the electric attraction and repulfion penetrated through glafs. In the year 1709 a treatife was written on electricity by Mr. Hawkfbee; who not only far excelled all his predeceffors and cotemporaries, but alfo made fome difcoveries which well deferve the attention of the moft expert electricians at this day; he

MILL WORK PLATE II



he was the firſt that applied a glaſs globe to the machine, and he remarked various appearances of the electric light and the noiſe that accompanied it, together with a variety of phænomena relating to electric attraction and repulſion.

After his death, not only the uſe of glaſs globes, but even the ſtudy of electricity itſelf, ſeems to have been pretty generally laid aſide for ſome time. The reaſon of this was, that the recent diſcoveries of Sir Iſaac Newton, engroſſed the attention of philoſophers to ſuch a degree, that they had no leiſure for any other purſuits. However, after the death of that great man, electricity began to revive, and in 1729 a capital diſcovery was made by Mr. Stephen Grey, who (by his curious obſervations) found out the difference between electrics and conductors; who, with the aſſiſtance of Mr. Wheeler, contributed much to the advancement of electricity. Soon after, Mr. Du Fay accidentally diſcovered the difference between poſitive and negative electricity, by obſerving that a piece of leaf gold repelled by an excited glaſs tube, was again eagerly attracted to it, after it had touched ſome body which was not an electric; the ſame was alſo the caſe with roſin, ſealing wax, ſulphur, and a number of other ſubſtances.

Mr. Grey's diſcovery.

Mr. Du Fay's diſcovery.

It may be obſerved, that although the ſcience had, through the indefatigable attention of ſo many ingenious perſons, and by the diſcoveries that were daily produced, excited the curioſity of philoſophers, and engaged their attention; yet, as the cauſes of every thing, whether ſmall or great, are ſeldom much attended to, if their effects are not particularly ſtriking and ſingular; ſo electricity had till the year 1746 been ſtudied by none but philoſophers, until

that

Mr. Mufchenbroeks experimental difcovery.

Medical electricity firft applied.

that capital difcovery of the vaft accumulation of its power, in what is called the Leyden Phial, was accidentally made by Mr. Mufchenbroek in the year 1746, at which time the ftudy of electricity became general, and gave more furprize even to philofophers, than any other fcience whatever; from the time of this difcovery, electricity became the general fubject of converfation, and great numbers of people got their livelihood by going about and fhewing its curious phænomena. It was alfo applied medically, and feveral perfons found great benefit by it, particularly a paralytic perfon cured at Geneva, another of a violent pain in his head, alfo a woman of a diforder in her eyes at Bologna; fo that from this time we may date the introduction of electricity into the medical art. It is impoffible to enumerate all the happy effects which have been performed in curing various diforders incident to the human body by electrical applications.

The fcience of electricity has fince the above period been greatly improved by the indefatigable induftry of the celebrated philofophers, Dr. Franklin and Dr. Prieftley; but it would be endlefs to enumerate all the improvements that have been made by a great number of other gentlemen, who have each added fomething towards its advancement; but whoever would make himfelf acquainted with the particulars concerning thofe advances, fhould read over the elaborate hiftory of electricity compiled by the learned Dr. Prieftley, a work that will inform him of whatever had been done relative to the fubject till its publication.

Of

Of the Electric Fluid.

THE earth and all the bodies we are acquainted with, are ſuppoſed to contain a certain quantity of an exceedingly elaſtic and ſubtle fluid, which philoſophers have agreed to term electric. This certain quantity belonging to all bodies, may be called their natural ſhare; and ſo long as each body contains neither more nor leſs than this quantity, it ſeems to be wholly dormant, and produces no ſenſible effect; but the moment that the equilibrium is diſturbed, and any body becomes poſſeſſed of more or leſs than its natural quantity, very remarkable effects ariſe from it. The body is ſaid to be electrified, and is capable of exhibiting appearances, which are aſcribed to the power of electricity.

This equilibrium could never be diſturbed, or, if it was diſturbed, would be immediately reſtored, and therefore be inſenſible, but that ſome bodies do not admit the paſſage of this electric fluid through their pores, or along their ſurfaces, though others do. By this means, whenever any body has acquired an additional quantity of electric matter, and is every where ſurrounded with bodies through which it cannot paſs, it muſt remain overloaded; or, if it have loſt part of what naturally belonged to it, it muſt remain exhauſted; becauſe the ſurrounding bodies prevent any of the fluid from going to it, or coming out of it; and the body is then ſaid to be inſulated. Thoſe bodies, through which the electric fluid can paſs, are called conductors, and thoſe through which it cannot paſs are called non-conductors of electricity, and into theſe two kinds all bodies whatever are claſſed by electricians.

The beſt conductors of electricity, or thoſe which admit the electric fluid to paſs through them with the greateſt eaſe, are metals of all kinds. And the moſt perfect of the non-conducting claſs of bodies are, glaſs, roſin, ſealing-wax, ſulphur, bees-wax, and baked wood, among ſolids; and oils and air among fluids. But all ſubſtances become conductors when they are made very hot. They are alſo called electrics, and the conducting ſubſtances are called non-electrics.

The method of diſturbing the equilibrium of the electric fluid in bodies, or of making it paſs from one to another, is chiefly friction, or a ſlight rubbing of them one againſt another. In this caſe, the electric fluid will, in general, leave that ſubſtance which has the rougher ſurface, and paſs upon the other which is ſmoother; or it will leave that ſubſtance which is leſs perfect electric, and paſs upon the other which is the more perfect electric of the two. Thus, if I take a ſmooth glaſs tube (ſuch as is repreſented) and draw it through my hand, the effect of that friction is, that the electric matter leaves my hand, and paſſes upon the glaſs, where it will remain, as an addition to its natural quantity. For as neither the glaſs, nor the air which ſurrounds it, are conductors of electricity, this redundancy of the electric matter cannot poſſibly get away; but if my finger, a piece of metal, or any conducting ſubſtance, be preſented to any part of the glaſs, thus overloaded with the electri fluid, it will paſs immediately from that part into them; and if they be preſented to every part of the tube ſucceſſively, the whole of this redundant electricity will be diſcharged, and every thing will become juſt as it was before the operation. The glaſs, in this caſe, is ſaid to be excited; becauſe the friction

Plate III. Fig. 1.

ſeems

ſeems to excite, or call up the electric power which it had before, but which lay dormant in it.

In like manner, when the globe is whirled in the electrical machine, the friction of the glaſs againſt the rubber, makes the electric fluid, which was in the rubber, paſs upon the glaſs, from whence it is conveyed to the prime conductor, the points of which are preſented to every part of the globe in ſucceſſion. And, as the friction is continued, there will, by this means, be a conſtant ſupply of the electric matter to the prime conductor, though other bodies be preſented to it, and keep diſcharging it all the while, in viſible ſparks. The hand in the former of theſe caſes, and the rubber in the latter, which had parted with their ſhare of the electric fluid to the glaſs, againſt which they were rubbed, receive an immediate ſupply from the conducting ſubſtances in contact with them; and theſe are again ſupplied by the general maſs of the fluid that is lodged in the earth.

On the contrary, if I draw through my hand a ſtick of ſealing-wax, a piece of ſulphur, or a tube of rough glaſs, the effect of the friction is, that a quantity of electric matter naturally belonging to the ſulphur, &c. paſſes from it to my hand, and the ſulphur being ſurrounded by the air, which is a non-conductor, remains exhauſted, and is ready to take ſparks of electric fire from any bodies that are preſented to it. But it is impoſſible to diſtinguiſh by the eye which way the electric matter paſſes, its velocity is ſo extremely great. The ſulphur in this caſe, though deprived of its ſhare of electricity, is ſaid to be excited as well as the glaſs which was overloaded with it; becauſe though the ſtate they are in be the reverſe of one another, the effects

produced by them are, in many refpects, fimilar. The appearances which lead us to diftinguifh them, will be mentioned hereafter.

Of Electrical Attraction and Repulfion.

THE great laws of the electric fluid, and thofe on which all the phenomena of electricity depend, are, that it is, in a much higher degree than air, elaftic, and repulfive of itfelf; that two bodies, having both of them either more or lefs than their natural fhare of it, repel one another; but that, if one of them have more, and the other lefs than its fhare, they will attract one another.

Thus, if I hang a bundle of hairs or feathers upon the prime conductor, the moment I electrify them, by turning the wheel of the machine, they begin to fly from one another; fo that fome of them will ftand quite erect, in a beautiful manner, and they cannot be made to collapfe, and be brought into contact with one another, till I difcharge the conductor, by taking a fpark from it with a piece of metal, or fome other conducting fubftance. A large plumy feather, alfo grows beautifully turgid when it is electrified, expanding its fibres in all directions; and they collapfe when the electricity is taken off.

If I hold in my hand a bundle of threads, hairs, or feathers, and prefent them to the electrified conductor, the electric fluid, with which the conductor is overloaded, repels the electric fluid from thofe parts of the threads, &c. which are next to it, into the more diftant parts of thofe bodies, or into my hand, and fo into the ground; the con-

fequence

ſequence of which is, that the threads having leſs than their natural ſhare, do ſtrongly repel and avoid one another, and, at the ſame time, are all ſtrongly attracted by the conductor, which is in an oppoſite ſtate. If the conductor had been deprived of its natural ſhare of electricity, the bodies preſented to it would have had more than their natural ſhare; ſo that, ſtill, the ſame appearance of mutual repulſion, and of attraction by the conductor, would have taken place: and univerſally, all bodies that are brought within the influence of electrified bodies, whether they are ſo by having more or leſs than their natural ſhare of the electric fluid, become poſſeſſed of a contrary electricity. For the ſame reaſon, excited electrics of every kind attract all light bodies which are brought within the ſphere of their influence.

Electrical attraction and repulſion are exhibited in a very pleaſing manner, by means of a glaſs tube and a feather. When the tube is excited, by being drawn through the hand, or a rubber, the feather when brought near it, will be attracted and jump to the tube; then, after taking ſome time to get fully ſaturated with electric matter, (becauſe being a bad conductor, it can receive it but very ſlowly) it will ſuddenly jump from it, and fly towards the next conductor, upon which it may diſcharge the redundant electricity it has acquired. If no other body happen to be in the way, it will tend towards the ground; but if the electrified tube be held under it, it will ſtill be repelled, and driven into the middle of the room, where it may be kept ſuſpended, or be driven about in all directions, almoſt as long as a perſon pleaſes, if the air be dry. Experiment.

Other beautiful effects of electrical attraction and repulſion are ſhewn at the prime conductor belonging to the

Fig. 3. the machine. Suſpend a plate of metal from the conductor, which is ſupported by two pillars of glaſs, and muſt be ſuppoſed to be ſupplied with electricity from the globe and underneath it; at the diſtance of about three or four inches put another plate of the ſame ſize; upon the lower of theſe plates lay a feather, or a ſmall ſlip of light paper; and, as ſoon as the wheel begins to turn, the feather or the paper, will be attracted, and jump to the upper plate F; from which it will be immediately repelled, and fly to diſcharge itſelf upon the lower plate P, which is ſupported on the pedeſtal H G; after which it will be ready to be attracted and repelled again. Thus will the feather, or paper, fly from the one plate to the other alternately, and with inconceiveable rapidity if the electrification be pretty vigorous. When the pieces of paper are cut into the figures of men and women, they exhibit a kind of dance, which is extremely amuſing.

Electrical bells. Fig. 5. This experiment will be the more diverting, if it be accompanied with that of the electrical bells, which depends upon the ſame principle. Four bells, a, b, c, d, hang from braſs rods, communicated with the prime conductor, and another bell, e, fixed on a braſs pedeſtal A, reaching to the ground; and four ſmall braſs balls, ſuſpended by ſilken threads, hangs between a, b, c, d, and the bell e in the middle. The conſequence of this diſpoſition is, that the outermoſt bells, which hang from the prime conductor by braſs chains, are electrified, and attract the braſs balls which hang by ſilk; and the attraction being vigorous, they are made to ſtrike the bells with ſome force, and make them ring. Being then loaded with electricity, they are immediately repelled from theſe outermoſt bells, and fly to unload themſelves by ſtriking upon the middle bell,

which

which is insulated by the glass pillar B, upon the pedestal A; and from which the electric matter passes to the floor, by means of the brass pedestal A. The brass balls, which now may be called clappers to the bells, are then ready to be attracted by the outermost bells, as at first; and thus the ringing may be continued as long as it is agreeable. The amusement will be heightened, if the electrician now and then touch the prime conductor with a brass rod, or with his finger, for then the dancing and ringing will cease, and will not be renewed till his finger or the rod be removed. If he conceal this application of his finger, or the rod, with a little art, the figures will seem to dance, and the bells to ring, at the word of command.

Of the Electric Spark.

WHEN I present a piece of metal, or any other good conducting substance, to the overloaded prime conductor, the electric matter will pass with violence from the one to the other; an electric spark, with the appearance of fire, will be seen darting between them, and a report, which is usually compared to a snapping noise, will be heard, If the piece of metal that is presented to the prime conductor, be insulated, so that it cannot immediately lose what it receives, it will take only part of the charge from the prime conductor (the whole of the redundant electricity being divided between them, in proportion to their surfaces) and either of them will give a smaller spark to another body that is presented to them.

When any person stands upon the stool, with feet made of glass, or baked wood (such as is represented) and takes Fig. 7. in

in his hand a chain faſtened to the prime conductor; being then inſulated, he may be conſidered as part of the prime conductor, and any part of his body will exhibit all the ſame appearances which the prime conductor itſelf will do. Thus, if the finger of any perſon ſtanding upon the floor be preſented to him, a ſpark of fire will ſeem to iſſue from him, and both he and the perſon that receives it will feel a painful ſenſation, like a pricking; and the ſame ſnapping noiſe above-mentioned will be heard. Every part of his body will then attract light ſubſtances; and the bits of feathers, or the human figures above-mentioned, cut in paper, and laid on a plate, will perform the ſame dances that were mentioned before, if the palm of his hand be expanded over them. Alſo the hairs of his head, or of his wig, if they happen to be looſe, will repel one another, and many of them will ſtand upright. As theſe electric ſparks, which are attended with a ſenſation moderately painful, will be excited wherever he is touched, or wherever he touches any other perſon, this experiment will thereby furniſh very great diverſion.

Subſtances ſet on Fire by Electricity.

The electric ſpark has not only the appearance of fire, but is capable of actually ſetting fire to various ſubſtances that are eaſily inflamed; but the inflammation is probably produced by the rapid motion into which the parts of the ſubſtances are thrown, by the action of the electric matter upon them. Thus, if ſpirits of wine, be held in a ſpoon, and an electric ſpark be drawn from the ſpoon, ſo as to paſs through any part of the ſpirits, they will catch fire, and burn as if they had been lighted by a candle. The ſpoon in which the ſpirits are contained, may either be connected with the prime conductor, and the ſpark

ſpark drawn through them by a perſon ſtanding on the floor; or the ſpoon may be held by a perſon ſtanding on the floor, and the ſpark be drawn through them by a braſs rod, either connected immediately with the prime conductor, or held in the hand of a perſon ſtanding on the ſtool, in the manner mentioned above. If a candle be blown out, and an electric ſpark be immediately drawn through the ſmoke, it will often be lighted again; but it requires a pretty ſtrong ſpark, and ſome degree of dexterity and experience in the operator, to produce this effect with certainty. It will be more amuſing, and the effect will be as certain, if the ſpark be drawn through the ſpirits by the end of a perſon's finger.

Not only are the ſenſes of feeling, ſeeing, and hearing, affected by electricity, in the manner deſcribed above, but it is even ſenſible to the ſmell, and the taſte. If a pointed braſs rod be electrified, either by being faſtened to the prime conductor, or held in the hand of a perſon electrified, and another perſon ſtanding upon the floor, preſent his noſtrils within an inch or two of the point, he will feel a ſtrong and diſagreeable ſmell, like that of burning ſulphur; and if he receive the electric effluvia iſſuing from the point upon his tongue, he will perceive a taſte, which is manifeſtly acid.

The machine as repreſented fig. 2. was ſuch as my ingenious friend the Reverend Mr. Timothy Prieſtley uſed, on account of its ſimple conſtruction as not being liable to be out of order ſoon, having no wheel or ſtring either to make any noiſe or need alteration; it may be fixed firm on a table, and taken off in a moment, and the globe may be taken out with the greateſt eaſe, in order to be packed up. When the inſide of the globe is lined with his compoſition

hereafter mentioned, it will produce more fire, than with any other compofition which I know of.

The fpring S that is reprefented in the plate, is for thofe that care not for having the rubber infulated, but thofe that are more curious may have them made with the rubber well infulated, by a glafs pillar, that will hold the rubber to the back part of the globe, as reprefented, Plate IV. Fig. 1.

The con-ftruction of the electri-cal ma-chine.

Fig. 2. A is a piece of mahogany, 9 inches fquare, and 1 inch 1 quarter thick, in which a pedeftal B is fixed; C is an iron axle to which is fixed a brafs cap, and to which the globe G is firmly cemented, and runs in a brafs focket E, through the middle of the pedeftal B, and turned by the handle H.

R is the rubber which is made of a piece of wood cut to the curve of the globe, to which is fixed a leather covering, which being at a little diftance from the wood in the middle; it will yield to the preffure of the globe the better.

On this leather is another leather, which will take off by taking out a pin; on this the amalgam is rubbed, and being fo eafily taken off, is more readily brought into order than thofe which have only one leather, and that fixed to the rubber. To this outermoft leather, is fixed a piece of black filk, which reaches half round the globe, and greatly en-creafes the fire, fo that it will give fire well, if the rubber fcarce touch the globe; this machine will fuit any kind of a conductor, but I prefer paper globes covered with tin-foil, they

they being, in my opinion, the moſt compact, and retain the electrical effluvia better than any other ſhape.

Of the Influence of Points in Electricity.

THE more acutely pointed any bodies are, the more eaſily do they take or part with the electric matter. Thus, if a needle, or ſharp pointed wire, be faſtened to the prime conductor, it will retain but a ſmall degree of electricity, and conſequently, will give but a ſmall ſpark, when the finger or piece of a metal, is preſented to it. Alſo, if the needle, or ſharp pointed wire, be held in the hand of a perſon ſtanding upon the floor, and preſented to the conductor, it will, likewiſe, be found to retain but a ſmall degree of electricity. In the former of theſe caſes, while the needle was in contact with the prime conductor, the electric matter went off at the point, and was diſperſed in the air, or among the conducting particles which are always floating in the common atmoſphere. In the latter caſe, the needle, being preſented towards the conductor, received the electric matter from it at a conſiderable diſtance.

If theſe experiments be made in the dark, a flame will be ſeen at the point of the needle or wire; but the appearances of the fire will not be the ſame in both caſes, but conſiderably different; ſo that it may always be perceived by the eye, whether, according to the common theory, the point be receiving or giving out the electric matter.

If the ſharp pointed wire be giving out the electric matter, the flame will be large; the parts of which it conſiſts will be fewer; and, if the point be not very acute, a kind of

fnapping noife will be heard as the electric matter is iffuing out of it into the air: whereas, if the pointed wire be receiving the electric matter, the flame will be much fmaller, and more globular; the parts of which it confifts will be more in number, and the noife that is made will be a kind of hiffing; the flame iffuing from a body, on account of its oblong form, is called a pencil; and when the rays come to a point they project more equally from the center, and it is then called a ftar.

The reafon why pointed bodies tranfmit the electric fluid with fo much eafe, has not yet been thoroughly explained, but the effects of it are exceedingly remarkable. The capital ufe that has been made of this obfervation, has been, to draw the electric matter from the clouds, and thereby to prove, that lightening and electricity are the fame thing. For if a long rod, or pole, with a fharp pointed wire at one end of it, be fupported by electric fubftances, the point, projecting towards the clouds, will draw the electric matter from them, and become fenfibly charged with electricity; juft as it would have been from being connected with the prime conductor of an electrical machine. It will attract light bodies, fparks of electric matter may be drawn from it, and it will exhibit every other appearance of common electricity; as, on the other hand, by common electricity, we can produce, in miniature, all the known effects of lightening.

Several amufing experiments depend on this property of pointed bodies, to tranfmit the electric fluid. If a plate of
Fig. 6. tin be cut into the form of a ftar, and be fupported on its center D by a wire projecting from the prime conductor A B; as foon as the wheel of the machine is turned, and

this

this apparatus electrified, a flame will appear at the extremity of every angle of the star, which will be very beautiful; and if the star be made to turn swiftly on its center, an entire circle of fire will be seen in the dark. This experiment will be very surprising to persons unacquainted with electricity, if the operator, now and then privately touch the prime conductor, which may easily bemanaged, as it is performed in the dark, for, by this means, he may command the appearing or disappearing of the star, or circle of fire, at pleasure.

If two sharp pointed wires be bent, with the four ends at right angles, in the same plane, but pointing different ways, and be made to turn upon a center D; the moment it is electrified, a flame will be seen at the points a b c d; but what is most surprising in the experiment is, that the wire will, at the same time, begin to turn round, in the direction opposite to that to which the points are turned, as if some visible power acted upon the points and pushed against them; and, if the electrification be continued, the motion will presently become very rapid,

If the figures of horses, cut in paper, be fastened upon these wires, and they be so contrived, that the points shall be in their tails, the experiment will be very beautiful; the horses will seem to pursue one another, though without a possibility of any of them overtaking the rest; and this is called the electrical horse-race. It is possible to make several of these wires, each having a considerable number of points bent backwards, with horses, &c. fastened to each of them, and turning one above another; and then, some of them may be contrived to move faster than the others. They may also be made to move different ways. Electrical horse-race.

Pro-

Promiſcuous Experiments.

THE reader in the courſe of this work muſt obſerve in ſeveral of the experiments already deſcribed, the remarkable property, that points have, both of throwing off, and receiving ſilently the electric fluid; but hereafter I ſhall deſcribe ſome more curious experiments of this kind, by which the influence of points, in reſpect of electricity, may be better underſtood, and which may, in a more particular manner, demonſtrate the utility of metallic conductors to houſes, or piles of building, in order to preſerve them from the damage often occaſioned by a ſtroke of lightening, which is one of the greateſt benefits that mankind has received from the ſcience of electricity.

The Dancing Balls.

Experiment I. FIX a pointed wire upon the prime conductor, with the point outward; then take a glaſs tumbler, graſp it with your hands, and preſent its inſide ſurface to the point of the wire upon the prime conductor, while the machine is in motion; the glaſs in this manner will ſoon become charged; for its inſide ſurface acquires the electricity from the point, and its outſide loſes its natural quantity of electric fluid through the hands, which ſerve as a coating. This done, put a few pith balls upon the table, and cover them with this charged glaſs tumbler. The balls will immediately begin to leap up along the ſides of the glaſs, as repreſented, (Fig. 9.) and will continue their motion for a conſiderable time.

In this experiment the pith balls are attracted and repelled by the electric fluid ſuperinduced upon the inſide ſur-

face of the glaſs, which they gradually conduct to the table, or other conducting body upon which the glaſs is ſet; at the ſame time that the outward ſurface of the glaſs acquires the electric fluid from the contiguous air. This experiment may be made more diverting by having a glaſs cylinder three inches long, and the ſame in width, open at both ends, with a braſs plate fixed on its top; put any number of balls you pleaſe, and electrify the braſs cover, and the balls will dance with a very rapid motion, which will continue as long as the operator turns the machine.

To prove that Glaſs and other electrics become Conductors, when they are made very hot.

IN order to aſcertain the conducting quality of hot reſinous ſubſtances, oils, &c. bend a glaſs tube in the form of an arch C E F D, and tie a ſilk ſtring G C D to it, which ſerves to hold it by, when it is to be ſet near the fire; fill the middle part of this tube with roſin, ſealing-wax, &c. then introduce two wires A E, B F through its ends, ſo that they may touch the roſin, or penetrate a little way in it. This done, let a perſon hold the tube over a clear fire, ſo as to melt the roſin within it; at the ſame time, by connecting one of the wires A, or B with the outſide of a charged jar, and touching the other with the knob of the jar, endeavour to make the diſcharge through the roſin, and you will obſerve that, while the roſin is cold, no ſhocks can be tranſmitted through it; but it becomes a conductor, according as it melts, and when totally melted, then the ſhocks will paſs through it very freely. Experiment II. Fig. 10.

The

The Thunder House.

Experiment III. Fig. 11.

IS an inftrument reprefenting the fide of a houfe, either furnifhed with a metallic conductor, or not; by which both the bad effects of lightening ftriking upon a houfe not properly fecured, and the ufefulnefs of metallic conductors, may be clearly reprefented. A is a board about three quarters of an inch thick, and fhaped like the gable end of a houfe. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glafs pillar C D is alfo fixed in a hole about eight inches diftant from the bafis of the board A. A fmall hole I L M K about a quarter of an inch deep, and nearly one inch wide, is made in the board A, and is filled with a fquare piece of wood, nearly of the fame dimenfions. I mention, nearly of the fame dimenfions, becaufe it muft go fo eafily into the hole, that it may drop off, by the leaft fhaking of the inftrument. A wire L K is faftened diagonally to this fquare piece of wood. Another wire I H of the fame thicknefs, having a brafs ball H, fcrewed on its pointed extremity, is faftened upon the board A; fo alfo the wire M N, which is fhaped in a ring at O. From the upper extremity of the glafs pillar C D, a crooked wire proceeds, having a fpring focket F, through which a double knobbed wire flips perpendicularly, the lower knob G of which falls juft above the knob H. The glafs pillar D C muft not be made very faft into the bottom board; but it muft be fixed fo as it may be pretty eafily moved round its own axis, by which means the brafs ball G may be brought nearer or farther from the ball H, without touching the part E F G. Now, when the fquare piece of wood L M I K (which may reprefent the fhutter

of

of a window or the like) is fixed into the hole, ſo that the wire L K ſtands in the dotted repreſentation I M, then the metallic communication from H to O is complete, and the inſtrument repreſents a houſe furniſhed with a proper metallic conductor; but if the ſquare piece of wood L M I K is fixed ſo that the wire L K ſtands in the direction L K, as repreſented in the figure, then the metallic conductor H O, from the top of the houſe to its bottom, is interrupted at I M, in which caſe the houſe is not properly ſecured.

Fix the piece of wood L M I K, ſo that its wire may be as repreſented in the figure, in which caſe the metallic conductor H O is diſcontinued. Let the ball G be fixed at about half an inch perpendicular diſtance from the ball H, then, by turning the glaſs pillar D C, remove the former ball from the latter; by a wire or chain, connect the wire E F with the wire Q of the jar P, and let another wire or chain, faſtened to the hook O, touch the outſide coating of the jar. Connect the wire Q with the prime conductor, and charge the jar; then, by turning the glaſs pillar D C, let the ball G come gradually near the ball H, and when they are arrived ſufficiently near one another, you will obſerve, that the jar explodes, and the piece of wood L M I K is puſhed out of the hole to a conſiderable diſtance from the thunder houſe. Now the ball G, in this experiment, repreſents an electrified cloud, which when it is arrived ſufficiently near the top of the houſe A, the electricity ſtrikes it, and as this houſe is not ſecured with a proper conductor, the exploſion breaks part of it, *i. e.* knocks off the piece of wood I M.

Repeat the experiment with only this variation, viz. that this piece of wood I M is ſituated ſo that the wire L K may ſtand in the ſituation I M, in which caſe the conductor H O is not diſcontinued; and you will obſerve, that the exploſion will have no effect upon the piece of wood L M; this remaining in the hole unmoved; which ſhews the uſefulneſs of the metallic conductor.

Further, unſcrew the braſs ball H from the wire H I, ſo that this may remain pointed, and with only this difference, in the apparatus repeatboth the above experiments; and you will find that the piece of wood I M is in neither caſe moved from its place, nor any exploſion will be heard.

Of the Electrical Battery.

Fig. 12. A Number of coated jars connected together in ſuch manner that their whole force may be united, and act like one jar, conſtitutes what is called an electrical battery. This battery is the moſt formidable, and entertaining part of an electrical apparatus, and by its uſe many wonderful effects are produced.

If a battery is required of no very great power, as containing about eight or nine ſquare feet of coated glaſs, I ſhould recommend to make uſe of common pint, or half pint phials, ſuch as apothecaries uſe. They may be eaſily coated with tin-foil, on the outſide, and braſs-filings on the inſide, they occupy a ſmall ſpace, and on account of their thinneſs, hold a very good charge. But when a large battery is required, then theſe phials cannot be uſed, for they break

break very eafily, and for that purpofe cylindrical glafs jars of about fifteen inches high, and four or five inches in diameter are the moft convenient.

When glafs plates or jars, having a fufficiently large opening, are to be coated, the beft method is to coat them with tin-foil on both fides, which may be fixed upon the glafs with pafte made of wheat flour; but in cafe the jars have not an aperture large enough to admit the tin-foil, and an inftrument to adapt it to the furface of the glafs, then, brafs-filings, fuch as are fold by the pin-makers, may be advantageoufly ufed, and they may be ftuck with gum-water, bees-wax, &c. Care muft be taken that the coatings do not come very near the mouth of the jar, for that will caufe the jar to difcharge itfelf. If the coating is about two inches below the top, it will in general do very well; but there are fome kinds of glafs, efpecially tinged glafs, that when coated and charged, have the property of difcharging themfelves more eafily than others, even when the coating is five or fix inches below the edge. There is another fort of glafs like that of which Florence flafks are made, which, on account of fome unvitrified particles in its fubftance, is not capable of holding the leaft charge; on thefe accounts therefore, whenever a great number of jars are to be chofen for a large battery, it is adivifeable to try fome of them firft, fo that their quality and power may be afcertained.

A battery compofed of twelve jars coated in the infide and outfide with tin-foil, which alltogether contain about twelve feet of coated glafs. About the middle of each of thefe jars is a cork that fuftains a wire, which at the top is faftened round, or foldered to the wire E, knobed at each

 end;

end; which connects the inside coatings of three jars; and by four wires such as F F, the inside coatings of all the twelve jars may be connected together. Each of the wires F, has a ring at one end, through which one of the wires E passes, and the other end has a brass knob. If the whole force of the battery is not required, one, two or three rows of jars may be used at pleasure; for as each of the wires F F is moveable round the wire E, which passes through its ring, and rests upon the next wire E, it may be easily removed from that, and turned upon the contrary wire E; and thus the communication between one row of jars and another may be discontinued at pleasure. *See the figure.*

The square box that contains these jars is of wood, lined at the bottom with tin-foil, and has two handles on two opposite sides, by which it may be easily removed. In one side of the box is a hole, through which an iron hook passes, which communicates with the metallic lining of the box, and consequently with the outside coating of all the jars. To this hook is fastened a wire, the other end of which is connected with the discharging rod.

Fig. 4. The discharging rod consists of a glass handle A, and two curved wires B B, which move by a joint C, fixed to the brass cap of the glass handle A. The wires B B are pointed, and the points enter the knobs D D, to which they are screwed, and may be unscrewed from them at pleasure. By this construction we have the opportunity of using the balls or the points, as occasion requires; and as the wires are moveable by the joint C, they may be adapted to smaller or larger jars at pleasure.

The

The battery, reprefented in the plate, is a fmall one in comparifon to thofe now frequently ufed, and much too weak for the purpofe of fome experiments. But I thought it fufficient to give an idea of its conftruction; and when a large battery is to be conftructed, I would recommend rather to make two, three, or more fmall ones as reprefented in the plate, than a fingle large battery, which is heavy, and, on feveral accounts, inconvenient. The force of feveral fmall batteries may be eafily united by a wire or chain, and thus they be made to act in every refpect like a large one. The beft conftruction of a battery is to have a wire from every jar, connected with a ball at the top, in form of a wire cage.

The force of accumulated electricity, great as it appears by the experiments performed with a fingle coated jar, is very fmall when compared with that which is produced by a number of jars connected together; and if the effects of a fingle jar are furprifing, the prodigious force of a large battery is certainly aftonifhing. To obferve that the metals, even the moft purified platina, which refifts the greateft efforts of chemic fire, are actually, and almoft inftantaneoufly rendered red-hot, and fufed; to fee animals deftroyed, and to hear the loud report of a large electric battery, are things that always produce a kind of terror in the mind of an attentive obferver. Experiments of this kind fhould be conducted with great caution, and the operator ought to be attentive not only to the bufinefs in hand, but alfo to the perfons who may happen to be near him, prohibiting their touching, or even coming too near any part of the apparatus; for if a miftake in performing other experiments may be difagreeable, thofe in the difcharge of a large battery may be attended with worfe confequences.

When

When a battery is to be charged, inftead of a large prime conductor, a fmall one is much more convenient; for in this cafe, the diffipation of the electricity is not fo confiderable. The quadrant electrometer, which fhews the height of the charge in the battery, may be fixed either upon the prime conductor, or upon the battery, in which cafe, it fhould be placed upon a rod, proceeding from the wires of the jars, and if the battery be very large, it fhould be elevated two or three feet above them.

The index of the electrometer in charging a large battery will feldom rife fo high as 90°, becaufe the machine cannot charge a battery fo high in proportion as a fingle jar. Its limit is often about 60° or 70°, more or lefs in proportion to the fize of the battery, and the force of the machine.

The Spider feemingly animated by Electricity.

Experiment IV. Fig. 14. AN electric jar, having a wire C D E, faftened on its outfide, which is bended fo as to have its knob E, as high as the knob A. B is a fpider made of cork with a few fhort threads run through it, to reprefent its legs. This fpider is faftened at the end of a filk thread, proceeding from the ceiling of the room, or from any other fupport, fo that the fpider may hang mid-way between the two knobs A E, when the jar is not charged. Let the place of the jar upon the table be marked; then charge the jar by bringing its knob A, in contact with the prime conductor, and replace it in its marked place. The fpider will now begin to move from knob to knob, and continue this motion for a confiderable time, fometimes for feveral hours.

The

The inside of the jar being charged positively, the spider is attracted by the knob A, which communicates to it a small quantity of electricity; the spider then becoming possessed of the same electricity with the knob A, is repelled by it, and runs to the knob E, where it discharges its electricity, and is then again attracted by the knob A, and so on. In this manner the jar is gradually discharged, and when the discharge is nearly compleated the spider finishes its motion.

The Spiral Tube.

AN instrument composed of two glass tubes C D, one within another, and closed with two knobbed brass caps A, and B. The innermost of these tubes has a spiral row of small round pieces of tin-foil, stuck upon its outside surface, and laying at about one thirteenth of an inch from each other. If this instrument be held by one of its extremities, and its other extremity be presented to the prime conductor, every spark that it receives from the prime conductor, will cause small sparks to appear between all the round pieces of tin-foil stuck upon the innermost tube, which in the dark affords a pleasing spectacle, the instrument appearing encompassed by a spiral line of fire. Experiment V. Fig. 18.

The small round pieces of tin-foil are sometimes stuck upon a flat piece of glass A B C D, so as to represent curve lines, flowers, letters, &c. and they are illuminated after the same manner as the spiral tube; *i. e.* by holding the extremity C or B in the hand, and presenting the other extremity to the prime conductor when the machine is in motion. They may also be fixed in any other position by having connecting wires. Fig. 19.

To

To shew that the Electric Fluid prefers a short Passage through the Air, to a long one through good Conductors.

Experiment VI. Fig. 16. BEND a wire about five feet long, at the ends of which fix a piece of glass G, to keep the parts A B at a proper distance, so that they may slide within half an inch of one another if required; then connect the chains belonging to the sliding wires with the hook of the battery, and the discharging rod, and send the charge of a battery through it. On making the explosion, a spark will be seen between A and B, which shews that the electric fluid chuses rather a short passage through the air, than a long one through the wire. The charge, however, does not pass entirely through A and B, but part of it goes also through the wire, which may be proved by putting a slender wire between A and B; for on making the discharge, with only this addition in the apparatus, the small wire will be hardly made red-hot, whereas if the large wire A D B be cut in D, so as to discontinue the circuit A D B, the small wire will be melted, and even exploded by the same shock that before made it scarcely red-hot. In this manner the conducting power of different metals may be tried, using metallic circuits of the same length and thickness, and observing the difference of the passage through the air in each.

To swell Clay, and break small Tubes with the Electric Explosion.

Experiment VII. Fig [illegible]. ROLL up a piece of soft tobacco-pipe-clay in a small cylinder C D, and insert in it two wires A B, so that their ends within the clay may be about a fifth part of an inch from

from one another. If a ſhock be ſent through this clay, by connecting one of the wires A, or B with the outſide of a charged jar, and the other with the inſide, it will be inflated by the ſhock, *i. e.* by the ſpark that paſſes between the two wires, and after the exploſion will appear, as repreſented Fig. 23. If the ſhock ſent through it is too ſtrong, and the clay not very moiſt, it will be broken by the exploſion, and its fragment ſcattered in every direction. Fig. 23.

To make this experiment with a little variation, take a piece of the tube of a tobacco-pipe, about one inch long, and fill its bore with moiſt clay, then inſert in it two wires, as in the above rolled clay, and ſend a ſhock through it. This tube will not fail to burſt by the force of the exploſion, and its fragments will be ſcattered about to a great diſtance.

If inſtead of clay, the above-mentioned tube of the tobacco-pipe, or a glaſs tube (which will anſwer as well) be filled with any other ſubſtance, either electric or non-electric inferior to metal, on making the diſcharge, it will be broken in pieces with nearly the ſame force.

An Electrometer.

WHICH conſiſts of a lined thread, having at each end a ſmall cork or pith ball. This electrometer is ſuſpended by the middle of the thread on any conductor proper for the purpoſe, and ſerves to ſhew the kind and quantity of its electricity, by applying a ſtick of ſealing wax excited, or, an excited ſmooth glaſs tube to the balls, which will recede or collapſe when the above wax or tube are applied alternately; by this means it will ſhew whether the conductor Fig. 13.

be charged positively or negatively; for if it be charged positively by applying the excited glass the balls will recede still further asunder, and on applying the excited wax they collapse together.

The Universal Discharger.

Fig. 8. WHICH is of extensive use, and is composed of the following parts: A is a flat board fifteen inches long, four inches broad, and one thick, or thereabouts, which forms the basis of the instrument. B B are two glass pillars cemented in two holes upon the board A, and furnished at the top with brass caps, each of which has a turning joint, and supports a spring tube, through which, the wire D C slides: each of these caps is composed of three pieces of brass, connected so, that the wire D C, besides its sliding through the socket, has two other motions, viz. an horizontal and vertical one. Each of the wires D C, D C is furnished with an open ring at one end, and at the other end has a brass ball D, which, by a short spring socket, is slipt upon its pointed extremity, and it may be removed from it at pleasure. E is a strong circular piece of wood five inches in diameter, having, on its surface, a slip of ivory inlaid, and furnished with a strong cylindrical foot, which fits the cavity of the socket F, which is fastened in the middle of the bottom board and has a screw G, which serves to fasten the foot of the circular board E at any required height.

To prove that the electric Spark displaces and rarefies the Air.

Experiment VIII. Fig. 24. THE electrical air thermometer, being very useful to observe the effects of the electric explosion upon

air

air. The body of this thermometer confifts of a glafs tube A B, about ten inches long, and nearly two inches diameter; and clofed air-tight at both ends by two brafs caps. Through a hole in the upper cap, a fmall tube H A, opens at both ends, is introduced in fome water, at the bottom B of the large tube. Through the middle of each of the brafs caps, a wire F G E I is introduced, having a brafs knob within the glafs tube, and by fliding through the caps, they may be fet at any diftance from one another. This inftrument is, by a brafs ring C, faftened to the pillar of the wooden ftand C D, that fupports it. When the air within the tube A B is rarefied, it will prefs upon the water at the bottom of the tube, which will confequently rife in the cavity of the fmall tube; and as this water rifes higher or lower, fo it fhews the greater or lefs rareaction of the air within the tube A B, which has no communication with the external air.

If the water, when this inftrument is to be ufed, is all at the bottom of the large tube, *i. e.* none of it is in the cavity of the fmall tube; it will be proper to blow with the mouth into the fmall tube, and thus caufe the water to rife a little in it, where, for better regulation, a mark may be fixed.

Bring the knobs G I of the wires I E, F G into contact, with one another, then connect the ring E, or F, with one fide of the charged jar, and the other ring with the other fide, by which operation a fhock will be made to pafs through the wires I G, I E, *i. e.* between the knobs G I. In this cafe you will obferve, that the water in the fmall tube, is not at all moved from the mark; which fhews that the paffage of the electric fluid through conductors fufficiently large, occafions no rarefaction, nor difplaces the air about them.

represented in fig. 20. But if the phial is held by the brass cap, and its bottom be touched by the prime conductor, then the point of the wire on its inside, will appear illuminated with a star, when charging, and with a pencil when discharging. If it be presented to a prime conductor electrified negatively, all these appearances, both in charging and discharging, will be reversed.

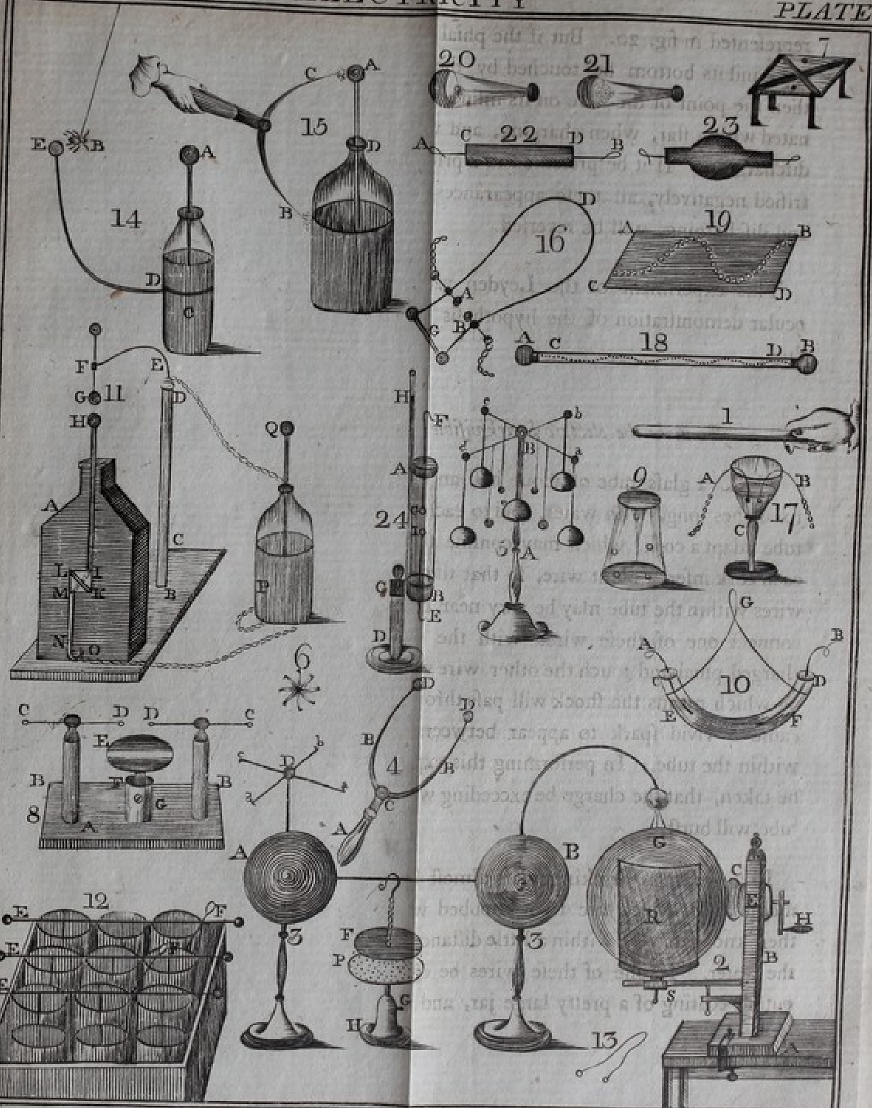
This experiment of the Leyden vacuum, exhibits an ocular demonstration of the hypothesis of a single electric fluid.

To make the electric Spark visible in Water.

Experiment X. FILL a glass tube of about half an inch diameter, and six inches long, with water, and to each extremities of the tube adapt a cork, which may confine the water; through each cork insert a blunt wire, so that the extremities of the wires within the tube may be very near one another; lastly connect one of these wires with the coating of a small charged phial and touch the other wire with the knob of it; by which means the shock will pass through the wires, and cause a vivid spark to appear between their extremities within the tube. In performing this experiment care must be taken, that the charge be exceeding weak, otherwise the tube will burst.

Fig. 17. In a common drinking glass almost full of water, immerge A B, which are two knobbed wires so bent, that their knobs may be within a little distance of one another in the water. If one of these wires be connected with the outside coating of a pretty large jar, and the other wire be touched

ELECTRICITY PLATE III



touched with the knob of it; the explosion which must pass through the water from the knob of one of the wires to that of the other, will disperse the water, and break the glass with a surprising violence. This experiment is very dangerous if not conducted with great caution.

The Powder House.

Is an ingenous contrivance, and well adapted to the purpose; the front is fitted up like the thunder-house; it is generally made 7 or 8 inches long, and nearly the same height to the top of the roof; the side, and that half of the roof next the eye is omitted in the figure, that the inside may be more conveniently seen. The sides, back, and front of the house are joined to the bottom by hinges; the roof is divided into two parts, which are also fastened by hinges to the sides; the building is kept together by a ridge fixed half way on one side of the roof, so that when the building is put together, the other half of the ridge laps over the other half of the roof, and holds it together. Within the house, there is a brass tube $1\frac{1}{2}$ inch long, and $\frac{5}{8}$ of an inch in diameter screwed upon a pedestal of wood; into the side of this brass tube is screwed a wire, which goes through $\frac{1}{8}$ of an inch or better; the other end, by means of a chain, has a communication to the hook D; at the other side of the tube a piece of ivory one inch long is screwed, with a small hole for the wire to slide into. Plate IV. Fig. 3.

To use this apparatus, fill the brass tube A with gunpowder, and ram the wire B a small way into the ivory tube; then connect the hook C with the bottom of a large jar or battery; and when the jar, &c. is charged, form

form a communication from the hook D to the top of the jar, &c. the difcharge will then take place, and the explofion of the gun-powder will throw afunder the roof; and the fides, the fore-front, and the back-front will then fall down.

The Pyramid.

Fig. 4. As reprefented fig. 4. is defigned to fhew the fame experiments as the thunder-houfe, and is ufed in the fame manner. When the piece A is thrown out by the difcharge, the upper part of the pyramid falls down; it is ufually made to reprefent a ftone fteeple, and is compofed of feveral pieces, by which means, when the difcharge is made there appears greater devaftation.

The Luminous Word.

This experiment is exactly on the fame principle as fig. 18 and 19, plate III. and the word is formed by the
Fig. 5. fmall feparations made in the tin-foil; if they were cut a little round at every divifion the fpark by that means would appear more vivid, as it paffed along the windings.

It may be obferved in making thefe experiments, that the longer any word is, and the oftener the tin-foil is cut, the more powerful the machine muft be in order to convey the fpark from one end to the other; becaufe every time the paffage is interrupted by cutting, the fpace is increafed; and in long conveyances the fpace will amount to more than the machine will be able

to

to overcome. Therefore the ſhorter the illuminations are, the more pleaſing they will appear.

To ſhew how a Jar charges and diſcharges.

Coat a jar as repreſented fig. 6, by paſting ſmall pieces of tin-foil, at a little diſtance from each other, round its exterior ſurface. As this jar is charging, ſmall ſparks will paſs from one piece of tin-foil to another, in a variety of directions; the ſeparation of the tin-foil is the means of making the paſſage of the fluid, from the outſide of the jar to the table, viſible. Diſcharge this jar, by bringing a pointed wire gradually near the braſs ball, and the uncoated part of the glaſs, between the pieces of tin-foil will be pleaſantly illuminated, and make a crackling noiſe; but if the jar is diſcharged ſuddenly, the whole outſide ſurface will appear illuminated. The glaſs muſt be very dry to produce theſe appearances to the greateſt advantage. Fig. 6.

How to make inflammable Air that will take Fire by the electric Spark.

Procure two bottles as repreſented, A D, fig. 8, in the bottle D, put about 2 or 3 ounces of iron filings, to which put ſome oil of vitriol, mixed with four times its quantity of water, fill the bottle A with water, and fix the bended glaſs pipe C air-tight into the bottle D, and the other end a little way up the neck of the bottle A, and in a ſhort time the mixture will boil, and emit a fluid, which will paſs through the bended tube C into the bottle A, and

will at laſt fill it; expelling the water into the baſon B The bottle A is then expeditiouſly corked up for uſe.

The electrical Piſtol.

Fig. 9. Is repreſented by a, b, c, d, e, fig. 9; c, a, is made of thin braſs; to the mouth a, b, a cork is fitted; and a perforated pice of braſs e, ſcrews on the bottom of the piſto at c, having a glaſs tube with a wire cemented into it, bended over the glaſs tube, ſo as to reach within $\frac{1}{8}$ of an inch of the braſs; when the piſtol is to be charged uncork the inflammable air bottle, likewiſe the piſtol, and place the mouth of the piſtol upon the top of the bottle, and the common air which is within the piſtol will deſcend while the other aſcends; keep the piſtol in this ſituation a few ſeconds, according to the ſtrength of the inflamable air, then expeditiouſly cork both the bottle and piſtol, and it is charged. To diſcharge it fill a ſmall jar or a hollow handle, and apply it to the little knob of the wire e, it will then explode, and drive out the cork to a conſiderable diſtance, making a report as loud as a piſtol filled with gunpowder.

The Conſtruction of a ſimple Orrery put into Motion by Electricity.

Fig. 1. Plate V. THIS orrery is for ſhewing the earth's motion round its axis in twenty-four hours, the age of the moon from change to change, and all her various phaſes during that time. A is the horizontal board or ſtand of this machine, and B is the great wheel, with eighteen floats or wings for the electric ſtream to act upon, and turn the wheel according

e left till it , expelling

bottle A is then expediti

according to the order of the letters a b c d. On the axis of this wheel is a trundle C, of eight ſtaves, for turning the wheel F, of thirty-two teeth, on whoſe axis is a trundle G, of eight ſtaves, for turning the wheel H, of fifty-nine teeth, which will go once round in the time the great wheel A goes 29½. A little 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 twenty-four hours, in the time that the earth D turns round. And an ivory ball I is placed on the top of the axis of the wheel H, half black, half white, to repreſent the moon; below which, on the ſame axis, is an index K, which goes round a ſmall plate k divided into 29½ equal parts, for the days of the moon's age from change to change. So that, in the time the great wheel A, the earth D, and hour-index E, make 29½ revolutions, the moon I and her index K make only one; 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.

Having ſet the orrery near the prime conductor, place a crooked wire from the conductor, 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 the moveable work: by which means, the earth D will be turned round its axis, from weſt by ſouth, to eaſt; and, in ſuch turn of the earth, the index E will go round all the twenty-four hours on the dial plate e. In the time the earth and index turns 29½ times round, the moon I will turn once Experiment XI.

 round

round her axis, ſhewing all her various phaſes; and the index K will go over all the 29½ days of the moon's age on the plate k.

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

Fig. 2. A MODEL of a common mill for grinding corn. A is a water-wheel, B the cog-wheel on its axis, C the trundle turned by that wheel, and D the running mill-ſtone on the top of the axis of the trundle. It may eaſily be contrived and turned alſo by electricity, if inſtead of the round plate D for the mill-ſtone, there be a horizontal wheel on the axis of the trundle C with ſpur cogs, which will turn two trundles placed on its oppoſite ſides; and on the top of each of theſe trundles' axis, may be a round plate repreſenting a mill-ſtone; ſo that this model has all the working parts of a double water-mill, turning two mill-ſtones.

Experiment XII. Set the mill 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. 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.

Another Electrical Orrery ſhewing the Motions of the Sun, Earth, and Moon.

Fig. 3. THE ſun and earth go round the common center of gravity between them in a ſolar year, and the earth and moon go round the common center of gravity between them in a lunar

lunar month. Thefe motions are reprefented by an electricalexperiment as follows:

The ball S reprefents the fun, E the earth, and M the moon, connected by wires a c and b d: a is the center of gravity between the fun and earth, and b is the center of gravity between the earth and moon. Thefe three balls, and their connecting wires, are hung and fupported on the fharp point of a wire A, which is ftuck upright in the prime conductor B of the electrical machine; the earth and moon hanging upon the fharp point of the wire c a e, in which wire is a pointed fhort pin, fticking out horizontally at c; and there is juft fuch another pin at d, fticking out in the fame manner, in the wire that connects the earth and the moon.

When the globe of the electrical machine is turned, the above-mentioned balls and wires are electrified: and the electrical fire, flying off horizontally from the points c and d, caufe S and E to move round their common center of gravity a; and E and M to move round their common center of gravity b. And as E and M are light when compared with S and E, there is much lefs friction on the point b than upon the point a; fo that E and M will make many more revolutions about the point b than S and E make about the point a. The weights of the balls may be adjufted fo, that E and M may go twelve times round b in the time that S and E go only once round a. It makes a good amufing experiment in electricity; but it is fo far from proving that the motions of the planets in the heavens are owing to a like caufe, that it plainly proves they are not. For the real fun and planets are not connected by wires or bars of metal; and confequently there can be no fuch metallic points as c and

Experiment XIII.

and d between them. And without ſuch points, the electric fluid would never cauſe them to move: for, take away theſe points in the above-mentioned experiment, and the balls will continue at reſt, let them be ever ſo ſtrongly electrified.

The electrified Capillary Syphon.

LET a ſmall bucket of metal, full of water, be ſuſpended from the prime conductor, and put in it a glaſs ſyphon of ſo narrow extremity, as the water will juſt drop from it. If in this diſpoſition of the apparatus the winch of the machine be turned, the water, which, when not electrified, only dropt from the extremity of the ſyphon, will now run in a full ſtream, which will even be ſubdivided into other ſmaller ſtreams; and if the experiment be made in the dark, it will be beautifully illuminated, and like a fountain with ſtreams of fire; which may be made to ſtop apparently by the word of command by touching the prime conductor.

Fig. 6.

The Quadrant Electrometer.

THE only inſtrument, that can, with propriety, be called an electrometer, that is, ſuch as meaſures the preciſe degree to which any body is electrified, is as follows: A is a very light rod, that turns on the center of a ſemicircle B, ſo as always to keep pretty near its graduated limb: at the extremity of the rod is a cork ball C. D is the pillar that ſupports the rod, and may be either fixed to the prime conductor, or ſet into the braſs knob of a jar or battery, or be ſet on

Fig. 4.

on a ſtand to ſupport itſelf. The whole inſtrument may be made of wood or ivory, but is found moſt perfect when the pillar and rod, or index, are of box, made very ſmooth with emery paper: the ball of cork, and the ſemicircle ivory, as the diviſions on that are more legible than on wood.

The moment this inſtrument begins to be electrified, the rod is repelled by the pillar, and conſequently begins to move over the edge of the ſemicircle, and ſhews, to the greateſt preciſion, the degree to which the prime conductor is electrified; or how high any jar or battery is charged. As the materials of which this inſtrument is made are very imperfect conductors, it will very rarely diſſipate any of the electricity of the prime conductor, &c. with which it is connected: but if it be found, by a trial in the dark, that any part of it collects the electric matter, it muſt be placed before the fire to dry off the damp, particularly from the index: it ſhould nor, however, be much heated, for then it will not receive the electricity ready enough, and the motion of the index will not anſwer with ſufficient accuracy, to the degree of electricity in the body with which it is in contact: but this inconvenience may be eaſily remedied by moiſtening the pillar and the index; for the ſemicircle can never be too dry.

It is evident, from the conſtruction of this inſtrument, that the force of different exploſions may be aſcertained by it, before the diſcharge, with the greateſt accuracy. If a jar be charged with poſitive electricity, and you want to know the preciſe time, while you are attempting to charge it negatively, that it becomes diſcharged, watch the moment the index comes to the perpendicular ſtation, which may be obſerved without the leaſt danger of a miſtake, and

you

you will then find there is not the leaſt ſpark left in the jar. If you continue the operation, the index will begin to advance again; and thereby ſhew the exact quantity of the oppoſite electricity the jar has acquired.

A very uſeful Inſtrument to cure the Tooth-ach.

Fig. 5. THE inſtrument A is a flat ſquare piece of box-wood, about an inch broad, and a quarter of an inch thick: two longitudinal holes are made quite through it, near its oppoſite edges, through which the braſs wires a b c and d e f are put while they are ſtraight; then fixed with ſealing wax, and bent as in the figure, ſo as to receive the tooth and gum between their points c and f, which muſt not be made too ſharp, for fear of hurting the gum. When it is uſed, two chains g and h muſt be hooked to the other ends of the wires, 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 jar, and cauſe an aſſiſtant to hold the chain h, hanging down from his hand; the chains not touching one another, and both of them clear of the table. Then having charged the jar, deſire the aſſiſtant to ſtrike the prime conductor with the looſe end of the chain h; this will diſcharge the jar, and give the perſon a ſhock, which will be felt only in the tooth and gum that is taken in between the wires at c and f.

Practical

Practical Rules concerning the Use of the electrical Apparatus and the performing of Experiments.

IT often happens that young electricians are at a loſs to aſſign the reaſon, why ſome experiments do not ſucceed with them, as deſcribed in the treatiſes on electricity. Sometimes they are in poſſeſſion of very good inſtruments, but by reaſon of ſome circumſtance or other, unattended to, they are quite uſeleſs in their hands. This, indeed can be remedied by nothing but practice, and it is by long uſe, that the electrician, as well as the practitioner in any art or ſcience, becomes ſo good an operator, as to uſe his inſtruments to the beſt advantage. A few rules are however very neceſſary to guide him in his operations; and although theſe alone are inſufficient to make a perſon a complete practical electrician, yet, when accompanied with the actual management of the apparatus, they facilitate the uſe of it, and render the performance of the experiments more accurate and expeditious.

The firſt thing that the young electrician ſhould obſerve, is, the preſervation and care of his inſtruments. The electrical machine, the coated jars, and in ſhort every part of the electrical apparatus, ſhould be kept clean, and as free as poſſible from duſt, and moiſture.

When the weather is clear, and the air dry, eſpecially in clear and froſty weather, the electrical machine will always work well. But when the weather is very hot, the machine is not ſo powerful: nor in damp weather, except it

be brought into a warm room, and the cylinder, the ſtands, and the jars, &c. be made thoroughly dry.

Before the machine is uſed, the cylinder ſhould be firſt wiped very clean with a ſoft linen cloth, that is dry, clean, and warm; and afterwards with a clean hot flannel, or an old ſilk handkerchief; this done, apply a little amalgam and turn the winch, and it will ſoon be perceived that the electric fluid will come like a wind from the cylinder to the knuckle, and, if the motion be a little continued, ſparks, and crackling will ſoon follow. This indicates that the machine is in good order, and the electrician may proceed to perform his experiments. But, if, when the winch is turned for ſome time, no wind is felt upon the knuckle, then the fault is, very likely, in the rubber, and to remedy that, uſe the following directions: by unſcrewing the ſcrews on the back of the rubber, remove it from its glaſs pillar, and keep it a little near the fire, ſo that its ſilk part may be dried; take now a piece of dry mutton ſuet, or a little tallow from the candle, and juſt paſs it over the leather of the rubber, and then the machine cannot fail but be fit for uſe.

Sometimes the machine will not work well becauſe the rubber is not ſufficiently ſupplied with electric fluid; which happens when the table, upon which the machine ſtands, and to which the chain of the rubber is connected, is very dry, and conſequently in a bad conducting ſtate. Even the floor and the walls of the room are, in very dry weather, bad conductors, and they cannot ſupply the rubber ſufficiently. In this caſe the beſt expedient is, to connect the chain of the rubber by means of a long wire, with ſome moiſt ground, or with the iron work of a water-pump; by which

which means the rubber will be ſupplied with as much electric fluid as is required.

When a ſufficient quantity of amalgam has been accumulated upon the leather of the rubber, and the machine does not work very well, then, inſtead of putting more amalgam, it will be ſufficient to take the rubber off, and to ſcrape a little off that, which is already upon the leather.

It will be often obſerved, that the globe or cylinder, after being uſed ſome time, contracts ſome black ſpots, occaſioned by the amalgam, or ſome foulneſs of the rubber, which grow continually larger, and greatly obſtruct its electric power. Theſe ſpots muſt be carefully taken off, and the cylinder muſt be frequently wiped in order to prevent its contracting them.

In charging electric jars in general, it muſt be obſerved, that every machine will not charge them equally high. That machine, whoſe electric power is the ſtrongeſt, will always charge the jars higheſt. If the coated jars, before they are uſed, be made a little warm, they will receive, and hold the charge the better.

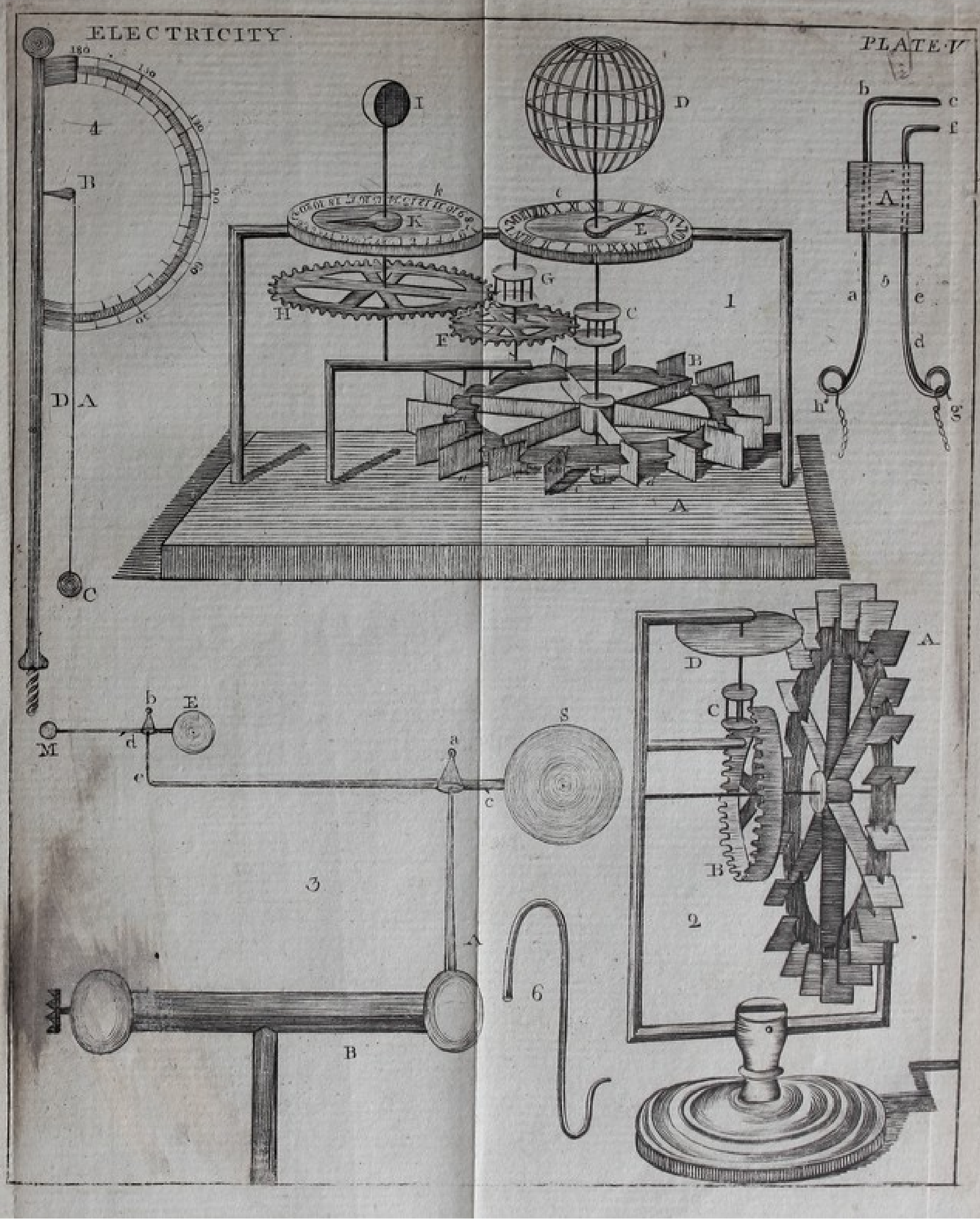
If ſeveral jars are connected together, among which there is one, that is apt to diſcharge itſelf very ſoon, then the other jars will alſo be ſoon diſcharged with that; although they may be capable of holding a very great charge by themſelves. When electric jars are to be diſcharged, the electrician muſt be cautious leſt, by ſome circumſtance not adverted to, the ſhock ſhould paſs through any part of his body; for an unexpected ſhock, though not very ſtrong, may occaſion ſeveral diſagreeable accidents. In making the diſcharge, care muſt be taken that the diſcharging rod be

not placed on the thinneft part of the glafs, for that may caufe the burfting of the jar.

When a large battery is difcharged, jars will be often found broken in it, which burft at the time of the difcharge. To remedy this inconvenience take this method, which is, never to difcharge the battery through a good conductor, except the circuit be at leaft five feet long. Mr. Nairne fays that, ever fince he made ufe of this precaution, he has difcharged a very large battery near a hundred times without ever breaking a fingle jar, whereas before he was continually breaking them. But here it muft be confidered that the length of the circuit weakens the force of the fhock proportionably; the higheft degree of which is in many experiments required.

It is advifeable when a jar, and efpecially a battery has been difcharged, not to touch its wires with the hand, before the difcharging rod be applied to its fides a fecond, and even a third of time; as there generally remains a refiduum of the charge; this refiduum is occafioned by the electricity, that, when the jar is charging, fpreads itfelf over the uncoated part of the glafs near the coating, which will not be difcharged at firft, but gradually returns to the coating after the firft difcharge, which is fometimes very confiderable.

When any experiment is to be performed, which requires but a fmall part of the apparatus, the remaining part of it fhould be placed at a diftance from the machine, the prime conductor, and even from the table, if that is not very large. Candles, particularly, fhould be placed at a confiderable


ELECTRICITY
PLATE V
180
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B

able diſtance from the prime conductor, for the effluvia of their flames carry off much of the electric fluid.

Laſtly, the young electrician ſhould be cautioned not to depend on firſt appearances in electricity. A new phenomenon may juſtly excite his curioſity: it is laudable to remark it, and to purſue the hint; but at the ſame time even the doubtful aſſertion of a new fact ſhould never be made, till after a number of ſimilar and concurring experiments. Electricity is a ſcience that often deceives the ſenſes, and the moſt experienced electrician frequently finds himſelf miſtaken in things, which perhaps he may have before conſidered as the moſt certain.

In many electrical experiments, it is very convenient to have a method of determining, whether a ſmall degree of electricity be poſitive or negative; and in uſing large batteries, it is a matter of conſequence to know how the charge advances, and of what ſtrength it is. Mr. Canton's balls are extremely uſeful for both theſe purpoſes. They are made of the pith of elder turned perfectly globular, and ſuſpended from the conductor, by fine threads. Plate VI. Fig. 1.

To underſtand the uſe of them, ſuppoſe a jar or battery ſtands upon the table, and I want to know whether the inſide be charged poſitively or negatively. In order to this, I preſent the balls, and they are immediately attracted by the wire, and diverge from one another. This is common to both electricities, and the greater the diſtance to which the balls ſeparate, and the farther they repel one another the higher is the charge. To determine of what kind it is, I rub a ſmall piece of glaſs (which I carry about me for the purpoſe) againſt my hand or coat, which I know will excite

cite it poſitively, and then preſent it to the balls in their diverging ſtate. If it makes the balls converge and conſequently avoid the glaſs, it ſhews that they are electrified poſitively, as well as the glaſs. On the contrary, if it increaſe their divergency, and attract them, it ſhews their electricity to be of a kind oppoſite to that of the glaſs, that is, negative. And it muſt be remembered, that the electricity of the balls (which do not touch, or receive any electricity from the wires of the jar or battery) is always contrary to that with which they are charged; for all bodies placed within the influence of electrified bodies, are affected with the contrary electricity.

In order to aſcertain the kind of an exceeding ſmall degree of electricity, it will be convenient to have a very light body, as a piece of downy feather hanging by a ſilken thread. This light body, when it is once electrified, either poſitively or negatively, will retain its virtue a long time, with very little loſs. If then any body (the electricity of which is unknown), be brought to it, the feather will be repelled by it, if it be of the ſame kind with its own, and attracted if it be the contrary to it. The ſilk, by which it is ſuſpended, ſhould be a ſingle thread, as it comes from the worm, or at leaſt, a very few of thoſe threads, and the whole ſhould be as light as poſſible.

The Electrophorus.

IT conſiſts of two plates A and B made of a circular form, from ſix to eighteen inches diameter or upwards. The upper plate is generally made of braſs, but a tin plate with a wire turned in upon its edge will anſwer exceeding well.

well. At the center of this plate there is a ſocket, o, in which a glaſs handle I (nine or ten inches long) is fixed. A thin board covered with tin-foil, and ſuſpended by ſilken ſtrings will anſwer well, when the electrophorus is wanted of a large diameter.

The under plate may be made of glaſs, ſealing wax, or of the following compoſition, viz. Four parts roſin, three parts pitch, three parts ſhel-lac, two parts venice-turpentine, melted together over a gentle fire; it may be poured and ſpread upon a thin lin cloth about ¼ of an inch thick; the lin cloth muſt be ſtretched upon a hoop, and made as tight as poſſible; if the ſurface be a little rough it will be no worſe.

The manner of uſing this machine is as follows; rub the coated ſide of the under plate A with new fine flannel, or a hare or cat's ſkin; and when it is excited as much as poſſible, ſet it upon a table, and place the upper plate upon it, and put your finger upon the upper plate; then take your finger off and take hold of the top of the glaſs handle I, and apply it to the knob of a coated jar: repeat this operation for 30 or 40 times and the jar will become charged.

Mr. Cavallo mentions one of the above kind which he made, with which he charged a coated phial ſeveral times, (by once exciting) ſo ſtrong as to pierce a hole through a card at every diſcharge.

When a glaſs is coated with ſealing wax, after it is excited and laid with the waxed ſide downward, and the glaſs uppermoſt, then on making the uſual experiment of putting the

the metal plate on it, and taking the ſpark, &c. it will be attended with contrary electricity to what it had before.

Medical Electricity.

BEFORE we conclude the ſubject, it will be neceſſary to give ſome rules, in order to explain a few practical experiments of applying medical electricity: and firſt, it ſhould be attentively obſerved, to apply the ſmalleſt force of electricity, which may be ſufficient to remove, or alleviate any diſorder; the chief difficulty conſiſts in diſtinguiſhing the proper ſtrength of the electric power that is required for a given diſorder. The ſex and condition of the patient muſt be duly conſidered; and, in regard to this point, it is impoſſible to give any exact and invariable rules; the circumſtances being of ſuch a nature and ſo various, that long experience, and a ſtrict attention to every particular phenomenon, are the only means by which proper inſtructions may be received. The ſureſt rule that can be given relating to this particular, is to begin with the moſt gentle treatment; at leaſt ſuch, that conſidering the conſtitution of the patient, may be thought rather weak than ſtrong. When this gentle treatment has been found ineffectual for a few days, which is denoted by the diſeaſe not abating, and the application of electricity not cauſing any material alteration, then the operator may gradually increaſe the force of electricity, until he finds the proper degree of it.

In judging of caſes proper to be electrified, experience ſhews, that in general, all kinds of obſtructions, whether of motion, of circulation, or of ſecretion, are very often removed or alleviated by electricicity. The ſame may alſo

alſo be ſaid of nervous diſorders; both which include a great variety of diſeaſes. The application of electricity has alſo been found very beneficial in diſeaſes of a long ſtanding. It has likewiſe been found a powerful remedy in muſcular contractions. But when any limb of the body is deprived of motion, it muſt be obſerved, that the privation of motion is not always originated by a contraction of the muſcles; but that it is often occaſioned by a relaxation; thus for inſtance, if the hand is bent inwardly, and the patient has no power of ſtraightening it, the cauſe of it may be a weakneſs of the outward muſcles, as well as a contraction of the inward ones. In ſuch caſes it is often difficult, even for good anatomiſts to diſcover the real cauſe, but the ſureſt method is to electrify, not only thoſe muſcles which are ſuppoſed to be contracted, but alſo their antagoniſts; for to electrify a ſound muſcle is by no means hurtful.

Rheumatic diſorders, even of long ſtanding, are relieved, and generally quite cured, by only drawing the electric fluid with a point from the part, or by drawing ſparks from the conductor; the operation ſhould be continued for about four or five minutes, repeating it once or twice every day. When ſtrong ſhocks are adminiſtered, their greateſt number ſhould not exceed a dozen or fourteen, except when they are to be given to the whole body in different directions.

The inſtruments which, beſides the electrical machine and its prime conductor, are neceſſary for the adminiſtration of medical electricity, may be reduced to three, viz. an electric jar, with Mr. Lane's electrometer; an inſulated

chair, or an insulated stool, upon which a common chair may be occasionally set, and the directors.

Fig. 4. Represents the electric jar, with Mr. Lane's electrometer, and the manner in which the shocks are sent through any part of the body. The surface of the jar, which is coated with tinfoil, should be about four inches in diameter, and six inches high, which is equal to about seventy-three square inches. The brass wire, which passes through the covering of the jar, and touches the inside coating, has a brass ball F, to which the electrometer F D E is fastened: and proceeding a little farther up, terminates in another brass ball B, which should be so high as to touch the prime conductor A, which is supposed to stand before the electrical machine. The electrometer consists in a glass stick F, D, cemented to two brass caps F and D; from the latter of which a strong perpendicular brass wire proceeds, the extremity of which comes as high as the center of the ball B, and is furnished with an horizontal spring socket, through which the wire C E, having the brass ball C at one end, and the open ring E at the other, may be slided backwards and forwards, so as to set the brass ball C at any required distance from the ball B. This distance, at most, need not be greater than half an inch; hence the electrometer may be made very small. Sometimes small divisions are marked upon the wire C E, which serve to set the balls B and C at a given distance from one another with more readiness and precision. Now, suppose that the jar is set contiguous to the prime conductor, that is, with the ball B touching the conductor; that the ball C be set at one tenth of an inch distant from the ball B; and that, by means of a chain, a conducting communication be formed from E to the outside coating of the jar, by a chain x. In

this

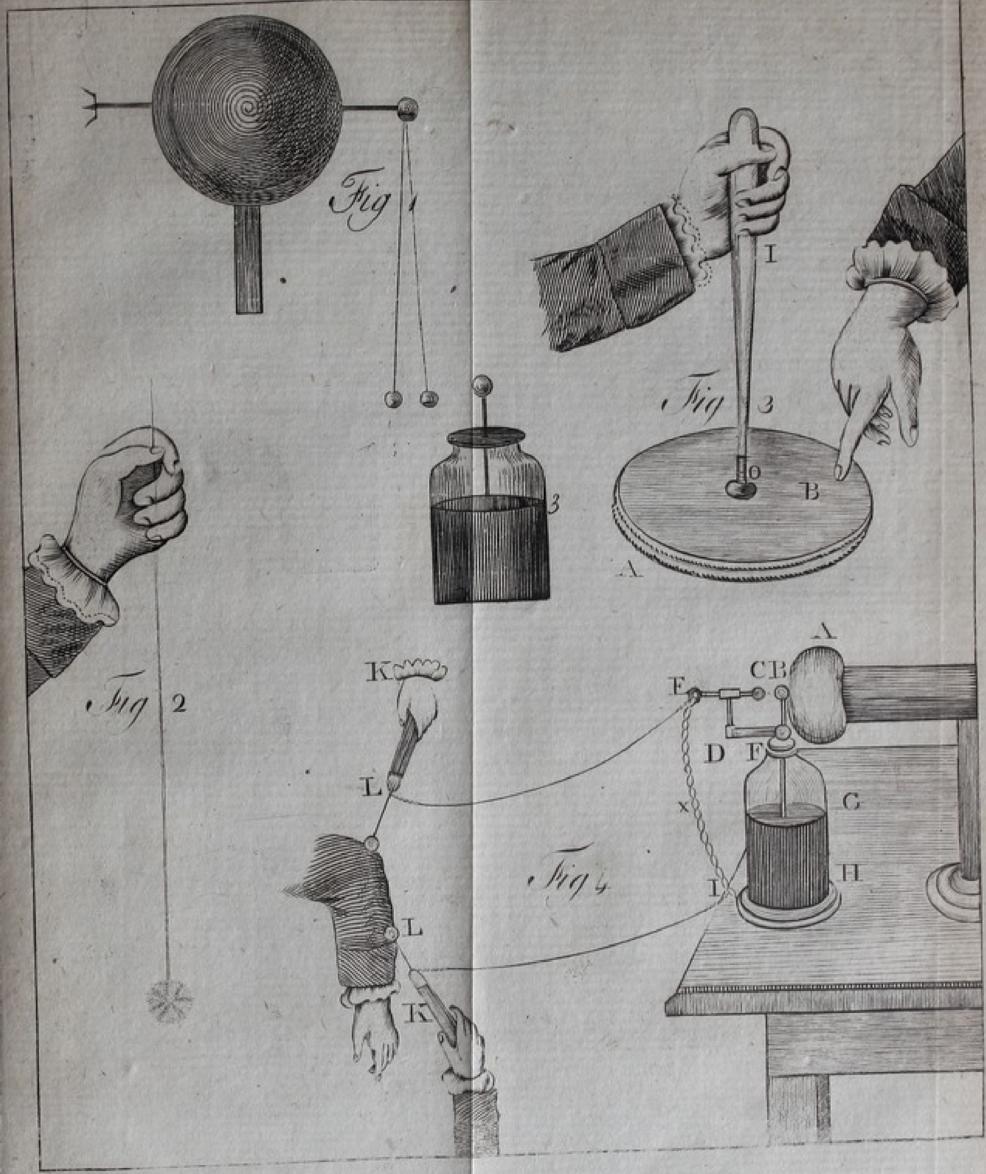
th scase, if the electrical machine be put in motion, the jar will be charged; and when the charge is so high as that the electric fluid accumulated within the jar can leap from the ball B to C, which we have supposed to be one tenth of an inch asunder, the discharge will happen, and a spark appear between the said balls, and the shock passes through the chain x; for the part F D of the electrometer being of glass, generally covered with sealing-wax, is impervious to electricity, consequently the electric fluid has no other way through which it can pass from the inside to the outside of the glass jar. When the shocks are to be given with this apparatus to any particular part of the body, for instance, to the arm, then instead of the chain x, which must now be taken away, two slender and pliable wires, E L, I L, are to be fastened, one to the open ring E of the electrometer, and to the brass hook I of the stand H I, which communicates with the outside coating of the jar. If the jar has not the stand H I, the extremity I of the wire I L may be simply rested under, or may be tied round it. In short, it must be put in contact with the outside coating of the jar, in any convenient manner. The other extremities of the said wires are fastened each to the brass wires L, and L of the directors K L, K L. Each of those instruments, justly called directors, consists of a knobbed brass wire L, which by means of a brass cap is cemented to the glass handle K. The operator, holding them by the extremity of the glass handle, brings their balls into contact with the extremities of that part of the body of the patient through which he desires to send the shock. The management and convenience of this apparatus are easily comprehended by inspecting the figure; for when the machine is in motion, and the apparatus, &c. is situated as in the figure, the discharge of the jar must be evidently made through that part of the patient's

arm, which lies between the knobs of the directors; and the operator, whilſt an aſſiſtant keeps the machine in motion, has nothing more to do, but to hold the knobs of the directors to the extremities of the arm, or to any other part of the body that is required to be thus electrified; always taking care that the two wires E L, I L, do not touch each other, becauſe in that caſe the ſhock will not paſs through that part of the body which is required to be electrified. Thus any number of ſhocks, preciſely of the ſame ſtrength, may be given, without altering any part of the apparatus, or having any farther trouble; and when the ſtrength of the ſhocks is required to be diminiſhed or increaſed, it is only neceſſary to diminiſh or augment the diſtance between the balls B C, which is done by ſlipping the wire C E forwards or backwards through the ſpring ſocket that holds it.

It is almoſt needleſs to mention, that when ſhocks are adminiſtered, it is immaterial whether the patient ſtands upon the ground, upon the inſulating ſtool, or in any other ſituation whatever. Neither is it always neceſſary to remove the cloathes from the part that is to be electrified, in order to let the knobs of the directors touch the ſkin; for, except the coverings be too many and too thick, in which caſe part of them at leaſt ſhould be removed, the ſhocks will go through them very eaſily, eſpecially if the knobs of the directors be preſſed a little upon the part.

ELECTRICITY

PLATE VI



Of the Technical Terms used by Writers on the Subject of Electricity.

BATTERY, *electrical*, a number of jars combined together, fo that they may be all charged and difcharged at the fame time. The form of one is exhibited. Fig. 12. Plate III.

Charging, throwing an additional quantity of electric matter upon one fide of a plate of glafs, or a jar, while the other fide is exhaufted in the fame proportion. All other electric fubftances are capable of being charged as well as glafs.

Circuit, electric, thofe conducting fubftances which are made ufe of to form a communication between the two coatings of a charged jar or battery, &c. and through which the electric matter muft pafs, when the equilibrium between the two fides is reftored by the difcharge.

Coatings, plates of metal, or other conducting fubftances, laid upon plates of glafs, or other electrics, whereby the additional quantity of electric matter, called *the charge*, may be the more eafily and uniformly conveyed to them, or difcharged from them.

Conductor, prime, a piece of metal furnifhed with points, to receive electric matter from the globe, after it has been excited by friction. It muft always be infulated, or cut off from a communication with the earth by means of electric fubftances, fuch as *glafs*, *baked wood*, &c. Whenever *the conductor*

conductor is mentioned, the prime conductor muſt alſo be underſtood.

Conductors, or *conducting ſubſtances*; thoſe bodies through which the electric matter may be tranſmitted. They are alſo called non-electrics, becauſe no electric powers can be excited in them by friction.

Diſcharging, reſtoring the equilibrium of the electric fluid, after it has been diſturbed by charging. It is affected by forming a communication between the overloaded and the exhauſted ſide of a glaſs jar, battery, &c. by means of conducting ſubſtances, through which the overplus or charge may paſs from the one to the other. When the diſcharge is conſiderable, it is often called an *exploſion*.

Diſcharging rod, a braſs rod, with a knob at each end, very convenient either for taking ſparks from the prime conductor, or for diſcharging jars or batteries. It is ſometimes bent into a ſemicircular form, in order to bring one of the knobs to the outſide, and the other to the wire, communicating with the inſide of a charged jar, in order to diſcharge it, by receiving the exploſion on the knob.

Electric matter, that ſubtle fluid which is ſuppoſed to be the cauſe of all thoſe appearances which are termed electric. It is ſometimes called *electric fire*, and ſometimes *ether*.

Electrics, thoſe bodies in which electric powers of attraction, repulſion &c. may be excited by friction. They are are alſo called *non-conductors*, becauſe the electric matter cannot paſs through them.

Elec-

Electrometers, inftruments to meafure the degree of electrification; (that is the quantity of electric matter thrown upon any body) or the force of an electrical explofion.

Excitation, the act of exciting or calling forth electric powers from electric fubftances, by means of friction, and other methods.

Infulating, placing bodies where they are not in contact with any conducting fubftance; as by fufpending them in the air by filken ftrings, putting them on glafs ftands, &c. fo that the electricity they may be charged with cannot be conveyed to the earth.

Negative electricity, a lefs quantity of the electric matter than is natural to any body.

Pencil, the appearance of electric light iffuing from the point of a body electrified pofitively.

Pofitive electricity, a quantity of electric matter thrown upon any body, above its natural fhare.

Rubber or cufhion, a piece of leather, or any other fubftance againft which the glafs globe, or other electric body whirled in the machine, is rubbed, in order to excite them.

Shock, electric, the convulfion given to the animal mufcles by the paffage of the electric matter through them, efpecially in the difcharging of a jar or battery.

Star,

Star, the appearance of electric light from the point of a body electrified negatively.

Wire of a phial, a jar, or battery, the wire or metal rod which goes into the phial, and which touches the inside coating. This wire is therefore often put for the inside coating.

Two Methods to make Amalgam.

FIRST take spelter four ounces, and dissolve it in an iron ladle over a fire, let it cool a little, but not so as to become quite stiff; add to it, while in that state, six ounces of mercury, and stir them well up together; then turn it out of the ladle upon a smooth stone, and grind it with a muller till it becomes like fine tough paste, which, put into a box, and it is ready for use. If it should become too hard, grind it again with a little more mercury; the addition of a little tallow may be occasionally added.

The Second Method.

TAKE of tin one pound; flowers of sulphur seven ounces; sal ammoniac, and purified quicksilver, of each half a pound.

Melt the tin by itself, add to it the quicksilver, and when the mixture is grown cold reduce it into powder: mix this with the sulphur and sal ammoniac, and sublimate it in a matrass: the mosaic gold will be found under the sublimated matter, with some dross at the bottom: this is thought as powerful an amalgam as the former.

A Com-

A Compoſition for lining the inſide of Globes or Cylinders.

TAKE four parts of Venice turpentine, one part of roſin, and one of bees-wax, boil the whole over a gentle fire for two hours, and it is fit for uſe. When a globe or cylinder is to be lined, it muſt be put into an oven, with a ſufficient quantity of the compoſition, broken, and put in the inſide, and when it is melted, it muſt be turned round every way, in order to ſpread it all over equally. This lining has been found to increaſe the electric power amazingly. Mr. Prieſtley uſed linſeed oil and roſin in the ſame manner as above directed, the proportion was equal parts of each, boiled very well together.

A Varniſh for all the Parts of the Machine which are inſulated.

TAKE ſpirits of wine, highly rectified, and in it, diſſolve the beſt ſealing-wax to a tolerable ſtiff conſiſtence, with which, varniſh over all your glaſs pillars, to keep off the moiſture they attract from damp air.

PNEUMATICS.

PNEUMATICS, is that branch of natural philosophy which treats of the nature, weight, pressure, and elasticity of the air, and the effects rising therefrom.

Of the Properties of the Air.

THE air is that thin transparent fluid in which we live and breathe. It encompasses the whole earth to a considerable height; and, together with the clouds and vapours that float in it, it is called the *atmosphere.* The air is justly reckoned among the number of fluids, because it has all the properties by which a fluid is distinguished. For, it yields to the least force impressed, its parts are easily moved among one another, it presses according to its perpendicular height, and its pressure is every way equal.

That the air is a fluid, consisting of such particles as have no cohesion betwixt them, but easily glide over one another, and yield to the slightest impression, appears from that ease and freedom with which animals breathe in it, and move

move through it without any difficulty or fenfible refiftance.

But it differs from all other fluids, in the four following particulars. 1. It can be compreffed into a much lefs fpace then what it naturally poffeffeth. 2. It cannot be congealed or fixed, as other fluids may. 3. It is of a different denfity in every part, upward from the earth's furface; decreafing in its weight, bulk for bulk, the higher it rifes; and therefore muft alfo decreafe in denfity. 4. It is of an elaftic or fpringy nature, and the force of its fpring is equal to its weight.

That air is a body, is evident from its excluding all other bodies out of the fpace it poffeffes: for, if a glafs jar be plunged with its mouth downward into a veffel of water, there will but very little water get into the jar, becaufe the air of which it is full keeps the water out.

As air is a body, it muft needs have gravity or weight; and that it is weighty, is demonftrated by experiment. For, let the air be taken out of a veffel by means of the air pump, then, having weighed the veffel, let in the air again, and upon weighing it when refilled with air, it will be found confiderably heavier. Thus, a bottle that holds a wine quart, being emptied of air and weighed, is found to be about 16 grains lighter than when the air is let into it again; which fhews that a quart of air weighs 16 grains. But a quart of water weighs 14621 grains; this divided by 16 quotes 914 in round numbers; which fhews, that water is 914 times as heavy as air near the furface of the earth.

As the air riſes above the earth's ſurface, it grows rarer, and conſequently lighter, bulk for bulk. For ſince it is of an elaſtic nature, and its lowermoſt parts are preſſed with the weight of all that is above them, it is plain that the air muſt be more denſe, or compact at the earth's ſurface, than at any height above it; and gradually rarer the higher up. For the denſity of the air is always as the force that compreſſeth it: and therefore, the air toward the upper part of the atmoſphere being leſs preſſed than that which is near the earth, will expand itſelf, and thereby become thinner than at the earth's ſurface.

Dr. Cotes has demonſtrated, that if altitudes in the air be taken in arithmetical proportion, the rarety of the air will be in geometrical proportion. For inſtance,

At the Altitude of	Miles above the ſurface of the earth, the air is	times thinner and lighter than at the earth's ſurface.
7	4	
14	16	
21	64	
28	256	
35	1024	
42	4096	
49	16384	
56	65536	
63	262144	
70	1048576	
77	4194304	
84	16777216	
91	67108864	
98	268435456	
105	1073741824	
112	4294967296	
119	17179869184	
126	68719476736	
133	274877906944	
140	1099511627776	

And

And hence it is eaſy to prove by calculation, that a cubic inch of ſuch air as we breathe would be ſo much rarefied at the altitude of 500 miles, that it would fill a ſphere equal in diameter to the orbit of Saturn.

The weight or preſſure of the air is exactly determined by the following experiment.

Take a glaſs tube about three feet long, and open at one end; fill it with quickſilver, and, putting your finger upon the open end, turn that end downward and immerſe it into a ſmall veſſel of quickſilver, without letting in any air: then take away your finger, and the quickſilver will remain ſuſpended in the tube 29½ inches above its ſurface in the veſſel; ſometimes more and at other times leſs, as the weight of the air is varied by winds and other cauſes. That the quickſilver is kept up in the tube by the preſſure is evident; for, if the baſon and tube be put under a glaſs, and the air be then taken out of the glaſs, all the quickſilver in the tube will fall down into the baſon, and if the air be let in again, the quickſilver will riſe to the ſame height as before. Therefore the air's preſſure on the ſurface of the earth, is equal to the weight of 29½ inches depth of quickſilver all over the earth's ſurface, at a mean rate.

A ſquare column of quickſilver, 29½ inches high, and one inch thick, weighs juſt 15 pounds, which is equal to the preſſure of the air upon every ſquare inch of the earth's ſurface; and 144 times as much, or 2160 pounds, upon every ſquare foot contains 144 ſquare inches. At this rate a middle ſized man, whoſe ſurface may be about 14 ſquare feet, ſuſtains a preſſure of 30240 pounds, when the air is of

a mean

a mean gravity: a preſſure which would be inſupportable, and even fatal to us, were it not equal on every part, and counterbalanced by the ſpring of the air within us, which is diffuſed through the whole body, and re-acts with an equal force againſt the outward preſſure.

Now, ſince the earth's ſurface contains 200,000,000 ſquare miles, and every ſquare mile 27,876,400 ſquare feet, there muſt be 5,575,680,000,000,000 ſquare feet on the earth's ſurface; which multiplied by 2160 pounds (the preſſure on each ſquare foot) gives 12,043,468,800,000,000,000 pounds for the preſſure, or weight of the whole atmoſphere.

When the end of a pipe is immerſed in water, and the air is taken out of the pipe, the water will riſe in it to the height of 33 feet above the ſurface of the water in which it is immerſed; but will go no higher: for it is found, that a common pump will draw water no higher than 33 feet above the ſurface of the well; and unleſs the bucket goes within that diſtance from the well, the water will never get above it. Now, as it is the preſſure of the atmoſphere on the ſurface of the water in the well that cauſes the water to aſcend in the pump, and follow the piſton or bucket, when the air above it is lifted up; it is evident, that a column of water 33 feet high, is equal in weight to a column of quickſilver of the ſame diameter, $29\frac{1}{2}$ inches high; and to as thick a column of air, reaching from the earth's ſurface to the top of the atmoſphere.

In ſerene calm weather, the air has weight enough to ſupport a column 31 inches high; but in tempeſtuous ſtormy weather, not above 28 inches. The quickſilver thus

thus ſupported in a glaſs tube, is found to be a nice counterbalance to the weight or preſſure of the air, and to ſhew its alterations at different times. And being now generally uſed to denote the change, in the weight of the air, and of the weather conſequent upon them, it is called the *barometer* or weather glaſs. (See the conſtruction and uſe of the barometer in the Miſcellaneous Articles.)

The preſſure of the air being equal on all ſides of a body expoſed to it, the ſofteſt bodies ſuſtain this preſſure without ſuffering any change in their figure; and ſo do the moſt brittle bodies without being broke.

The air is rarefied, or made to ſwell with heat, and of this property, *wind* is a neceſſary conſequence. For, when any part of the air is heated by the ſun, or otherwiſe, it will ſwell and thereby affect the adjacent air; and ſo by various degrees of heat in different places, there will ariſe various winds.

When the air is much heated, it will aſcend towards the upper part of the atmoſphere, and the adjacent air will ruſh in to ſupply its place; and therefore, there will be a ſtream or current of air from all parts towards the place where the heat is. And hence we ſee the reaſon why the air ruſhes with ſuch force into any place where a great fire is made. And alſo, why ſmoke is carried up a chimney, and why the air ruſhes in at the key hole of the door, or any ſmall chink, when there is a fire in the room. So we may take it in general, that the air will preſs towards that part of the world where it is moſt heated.

Upon

Upon this principle, we can eafily account for the *trade winds*, which blow conftantly from eaft to weft about the equator. For, when the fun fhines perpendicularly on any part of the earth, it will heat the air very much in that part, which air will therefore rife upward, and when the fun withdraws, the adjacent air will rufh in to fill its place; and confequently will caufe a ftream or current of air from all parts towards that which is moft heated by the fun. But as the fun, with refpect to the earth, moves from eaft to weft, the common courfe of the air will be that way too; continually preffing after the fun: and therefore, at the equator where the fun fhines ftrongly, there will be a continual wind from the eaft; but on the north fide, it will incline a little to the north, and on the fouth fide to the fouth.

This general courfe of wind about the equator, is changed in feveral places, and upon feveral accounts; as 1. By exhalations that rife out of the earth at certain times, and from certain places; in earthquakes, and volcanoes. 2. By the falling of great quantities of rain, caufing thereby a fudden condenfation or contraction of the air. 3. By burning fands, that often retain the folar heat to a degree incredible to thofe who have not felt it, caufing a more than ordinary rarefaction of the the air contiguous to them. 4. By high mountains, which alter the direction of the winds in ftriking againft them. 5. By the declination of the fun towards the north or fouth, heating the air on the north or fouth fide the equator.

To thefe and fuch like caufes are owing. 1. The irregularity or uncertainty of winds in climates diftant from the equator, as in moft parts of Europe. 2. Thofe periodical winds

winds called *monſoons*, which in the Indian ſeas blow half a year one way, and half a year another. 3. Thoſe winds which on the coaſt of Guinea, and on the weſtern coaſts of America, blow always from weſt to eaſt. 4. The ſea breezes, which in hot countries, blow generally from ſea to land, in the day time; and the land breezes, which blow in the night; and, in ſhort, all thoſe ſtorms, hurricanes, whirlwinds, and irregularities, which happen at different times and places. The Monſoons

All common air is impregnated with a certain kind of vivifying ſpirit or quality, which is neceſſary to continue the lives of animals: and this, in a gallon of air, is ſufficient for one man during the ſpace of a minute, and not much longer. The vivifying ſpirit air.

This ſpirit in air is deſtroyed in paſſing through the lungs of animals: and hence it is, that an animal dies ſoon after being put under a veſſel which admits no freſh air to come to it. This ſpirit is alſo in the air which is in water; for fiſh die when they are excluded from freſh air, as in a pond that is cloſely frozen over. And the little eggs of inſects ſtopped up in a glaſs do not produce their young, though aſſiſted by a kindly warmth. The ſeeds alſo of plants mixed with good earth, and incloſed in a glaſs will not grow.

This enlivening quality in air, is alſo deſtroyed by the air's paſſing through fire; particularly charcoal fire or the flame of ſulphur. Hence ſmoaking chimnies muſt be very unwholeſome, eſpecially if the rooms they are in be ſmall and cloſe.

Air is alfo vitiated, by remaining clofely pent up in any place fcr a confiderable time; or perhaps, by being mixed with malignant fteams and particles flowing from the neighbouring bodies: or laftly, by the corruption of the vivifying fpirit; as in the holds of fhips, in oil cifterns, or wine cellars, which have been fhut for a confiderable time. The air in any of them is fometimes fo much vitiated, as to be immediate death to any animal that comes into it.

Damps. Air that has loft its vivifying fpirit is called damp, not only becaufe it is filled with humid or moift vapours, but becaufe it deadens fire, extinguifhes flame, and deftroys life. The dreadful effects of damps are fufficiently known to fuch as work in mines.

If part of the vivifying fpirit in air in any country begins to putrify, the inhabitants of that country will be fubject to an epidemical difeafe, which will continue until the putrefaction is over. And as the putrifying fpirit occafions this difeafe, fo if the difeafed body contributes towards the putrifying of the air, then the difeafe will not only be epidemical, but peftilential and contagious.

The atmofphere is the common receptacle of all the effluvia or vapours arifing from different bodies; of the fteams and fmoke of things burnt or melted; the fogs or vapours proceeding from damp watery places; and of the effluvia proceeding from fulphureous, nitrous, acid, and alkaline bodies. In fhort, whatever may be called volatile, rifes in air to greater or lefs heights, according to its fpecific gravity.

When

When the effluvia which arife from acid and alkaline bodies meet each other in the air, there will be a ftrong conflict or fermentation between them; which will fometimes be fo great, as to produce a fire; then if the effluvia be combuftible, the fire will run from one part to another, juft as the inflammable matter happens to lie. Fermentations.

Any one may be convinced of this, by mixing an acid and an alkaline fluid together, as Glauber's fpirit of nitre and oil of cloves, upon the doing of which, a fudden ferment, with a fine flame, will arife; and if the ingredients be very pure and ftrong, there will be a fudden explofion.

Whoever confiders the effects of fermentation, cannot be at a lofs to account for the dreadful effects of thunder and lightning: for the effluvia of fulphureous and nitrous bodies, and others that may rife into the atmofphere, will ferment with each other, and take fire very often of themfelves; fometimes by the affiftance of the fun's heat. Thunder and lightning.

If the inflammable matter be thin and light, it will rife to the upper part of the atmofphere, where it will flafh without doing any harm: but if it be denfe, it will lie nearer the furface of the earth, where taking fire, it will explode with a furprizing force: and by its heat rarefy and drive away the air, kill men and cattle, fplit trees, walls, rocks, &c. and be accompanied with terrible claps of thunder.

The heat of lightning appears to be quite different from that of other fires; for it has been known to run through wood, leather, cloth, &c. without hurting them, while it

has broken and melted iron, ſteel, ſilver, gold, and other hard bodies. Thus it has melted or burnt aſunder a ſword, without hurting the ſcabbard; and money in a man's pocket, without hurting his cloaths; the reaſon of this ſeems to be, that the particles of that fire are ſo fine, as to paſs through ſoft, looſe bodies, without diſſolving them; whilſt they ſpend their whole force upon the hard ones.

It is remarkable, that knives and forks which have been ſtruck with lightning have a very ſtrong magnetical virtue for ſeveral years after: and I have heard that lightning ſtriking upon the mariner's compaſs, will ſometimes turn it round; and often make it ſtand the contrary way; or with the north pole towards the ſouth.

Fire damps. Much of the ſame kind with lightning are thoſe exploſions, called fulminating or fire damps, which ſometimes happen in mines; and are occaſioned by ſulphureous and nitrous, or rather oleaginous particles, riſing from the mine, and mixing with the air, where they will take fire by the lights the workmen are obliged to make uſe of. The fire being kindled will run from one part of the mine to another, like a train of gunpowder, as the combuſtible matter happens to lie; and as the elaſticity of the air is increaſed by that heat, *that* in the mine will conſequently ſwell very much, and ſo, for want of room, will explode with a greater or leſs degree of force, according to the denſity of the combuſtible vapours. It is ſometimes ſo ſtrong, as to blow up the mine; and at other times ſo weak, that when it has taken fire at the flame of a candle, it is eaſily blown out.

Air that will take fire at the flame of a candle, may be produced thus. Having exhauſted a receiver of the air-

pump,

pump, let the air run into it through the flame of the oil of turpentine; then remove the cover of the receiver, and holding a candle to that air, it will take fire, and burn quicker or ſlower, according to the denſity of the oleaginous vapour.

When ſuch combuſtible matter, as is above-mentioned, kindles in the bowels of the earth, where there is little or no vent, it produces earthquakes, and violent ſtorms or hurricanes of wind when it breaks forth in the air. Earthquakes.

An artificial earthquake may be made thus. Take 10 or 15 pounds of ſulphur, and as much of the filings of iron, and knead them with common water into the conſiſtency of a paſte; this being buried in the ground, will, in 8 or 10 hours time, burſt out into flames, and cauſe the earth to tremble all around to a conſiderable diſtance.

From this experiment we have a very natural account of the fires of Mount Ætna, Veſuvius, and other volcanoes, they being probably ſet on fire at firſt by the mixture of ſuch metalline and ſulphureous particles.

The air-pump being conſtructed the ſame way as the water-pump, whoever underſtands the one, will be at no loſs to underſtand the other. Plate VII. Fig. 1.

Having put a wet leather on the plate L L of the air-pump, place the glaſs receiver M upon the leather, ſo that the hole i, in the plate may be within the glaſs. Then, turning the handle F backward and forward, the air will be pumped out of the receiver; which will then be held down to the plate by the preſſure of the external air, or atmoſ-

phere.

phere. For, as the handle F, (Fig. 2.) is turned backwards, it raiſes the piſton d e in the barrel B K, by means of the wheel E and rack D d: and, as the piſton is leathered ſo tight as to fit the barrel exactly, no air can get between the piſton and barrel; and therefore all the air above d in the barrel is lifted up towards B, and a vacuum is made in in the barrel from b to e; upon which, part of the air in the receiver M (Fig. 1.) by its ſpring, ruſhes through the hole i, in the braſs plate L L along the pipe G C G (which communicates with both barrels in the hollow trunk I H K Fig. 2.) and puſhing up the valve b, enters into the vacant place b e of the barrel B K. For, wherever the reſiſtance or preſſure is taken off, the air will run to that place, if it can find a paſſage. Then, if the handle F be turned forward, the piſton d e will be depreſſed in the barrel; and, as the air which had got into the barrel cannot be puſhed back through the valve b, it will aſcend through a hole in the piſton, and eſcape through a valve at d; and be hindered by that valve from returning into the barrel, when the piſton is again raiſed. At the next raiſing of the piſton, a vacuum is again made in the ſame manner as before, between b and e; upon which, more of the air that was left in the receiver M, gets out thence by its ſpring, and runs into the barrel B K, through the valve B. The ſame thing is to be underſtood with regard to the other barrel A I; and as the handle F is turned backwards and forwards, it alternately raiſes and depreſſes the piſtons in their barrels; always raiſing one while it depreſſes the other. And, as there is a vacuum made in each barrel when its piſton is raiſed, the particles of air in the receiver M puſh out another by their ſpring or elaſticity, through the hole i, and pipe G G into the barrels; until at laſt the air in the receiver comes to be ſo much dilated, and its ſpring ſo far weakened,

weakened, that it can no longer get through the valves; and then uo more can be taken out. Hence, there is no ſuch thing as making a perfect vacuum in the receiver; for the quantity of air taken out at any one ſtroke, will always be as the denſity thereof in the receiver, and therefore it is impoſſible to take it all out, becauſe, ſuppoſing the receiver and barrels of equal capacity, there will be always as much left as was taken out at the laſt turn of the handle.

There is a cock k below the pump plate, which being turned, lets the air into the receiver again; and then the receiver becomes looſe and may be taken off the plate. The barrels are fixed to the frame E e e by two ſcrew nuts f f, which preſs down the top piece E upon the barrels: and the hollow trunk H (in Fig. 2.) is covered by a box, as G H (in Fig. 1.)

There is a glaſs tube l m m m n open at both ends, and about 34 inches long; the upper end communicating with the hole in the pump-plate, and the lower end immerſed in quickſilver at n in the veſſel N. To this tube is fitted a wooden ruler m m, called the gauge, which is divided into inches and parts of an inch, from the bottom at n (where it is even with the ſurface of the quickſilver) and continued up to the top, a little below l, to 30 or 31 inches.

As the air is pumped out of the receiver M, it is likewiſe pumped out of the glaſs tube l m n, becauſe that tube opens into the receiver through the pump plate; and as the tube is gradually emptied of air, the quickſilver in the veſſel N is forced up into the tube by the preſſure of the atmoſphere. And if the receiver could be perfectly exhauſted of air, the quickſilver would ſtand as high in the tube

tube as it does at that time in the barometer: for it is supported by the same power or weight of the atmosphere in both.

The quantity of air exhausted out of the receiver on each turn of the handle, is always proportionable to the ascent of the quickfilver on that turn; and the quantity of air remaining in the receiver, is proportionable to the defect of the height of the quickfilver in the gauge, from what it is at that time in the barometer.

I shall now give an account of the experiments made with the air pump; shewing the resistance, weight, and elasticity of the air.

Exp. I. Fig. 3. To shew the resistance of the air. There is a little machine, consisting of two mills, a and b, which are of equal weights, independent of each other, and turn equally free on their axles in the frame. Each mill has four thin arms or sails fixed into the axis: those of the mill a have their planes at right angles to its axis, and those of b have their planes parallel to it. Therefore, as the mill a turns round in common air, it is but little resisted thereby, because its sails cut the air with their thin edges: but the mill b is much resisted, because the broad side of its sails move against the air when it turns round. In each axle is a fine pin near the middle of the frame, which goes quite through the axle, and stands out a little on each side of it: under these pins, the slider a may be made to bear, and so hinder the mills from going, when the strong spring C is set on bend against the opposite ends of the pins.

Having

Having ſet this machine upon the pump plate L L (fig. 1.) draw up the ſlider d to the pins on one ſide, and ſet the ſpring C at bend upon the oppoſite ends of the pins: then puſh down the ſlider d, and the ſpring acting equally ſtrong upon each mill, will ſet them both a going with equal forces and velocities; but the mill a, will run much longer than the mill b, becauſe the air makes much leſs reſiſtance againſt the edges of its ſails, than againſt the ſides of the ſails of b.

Draw up the ſlider again, and ſet the ſpring upon the pins as before; then cover the machine with the receiver M upon the pump-plate, and having exhauſted the receiver of air, puſh down the wire P P (through the collar of leathers in the neck g) upon the ſlider; which will diſengage it from the pins, and allow the mills to turn round by the impulſe of the ſpring: and as there is no air in the receiver to make any ſenſible reſiſtance againſt them, they will both move a conſiderable time longer than they did in the open air; and the moment that one ſtops the other will do ſo too. This ſhews that air reſiſts bodies in motion, and that equal bodies meet with different degrees of reſiſtance, according as they preſent greater or leſs ſurfaces to the air, in the planes of their motions. Fig. 1.

Take off the receiver M, and the mills; and having put the guinea a and feather b upon the braſs flap c, turn up the flap and ſhut it into the notch d. Then, putting a wet leather over the top of the tall receiver A B, (it being open both at top and bottom) cover it with the plate C, from which the guinea and feather tongs e d will then hang within the receiver. This done, pump the air out of the receiver; Experiment II. Fig. 4.

and then draw up the wire f a little, which by a ſquare piece on its lower end will open the tongs e d; and the flap falling down as at c̄, the guinea and feather will deſcend with equal velocities in the receiver; and both will fall upon the pump-plate at the ſame inſtant.

In this experiment the obſervers ought not to look at the top, but at the bottom of the receiver; in order to ſee the guinea and feather fall upon the plate: otherwiſe, on account of the quickneſs of their motion, they will eſcape the ſight of the beholders.

To ſhew the Weight of the Air.

Experiment III. HAVING fitted a braſs cap, with a valve tied over it, to the mouth of a thin bottle or Florence flaſk, whoſe contents are exactly known, ſcrew the neck of this cap into the hole i of the pump-plate: then, having exhauſted the air out of the flaſk, and taken it off the pump, let it be ſuſpended at one end of a balance, and nicely counterpoiſed by weights in the ſcale at the other end: this done, raiſe up the valve with a pin, and the air will ruſh into the flaſk with an audible noiſe: during which time, the flaſk will deſcend, and pull down that end of the beam. When the noiſe is over put as many grains into the ſcale at the other end, as will reſtore the equilibrium; and they will ſhew exactly the weight of the quantity of air that has got into the flaſk, and filled it. If the flaſk holds an exact quart, it will be found, that 16 grains will reſtore the equipoiſe of the balance, when the quickſilver ſtands at 29½ inches in the barometer; which ſhews, that when the air is at a mean rate of denſity, a quart of it weighs 16 grains: it weighs more when the

the quickfilver ftands higher; and lefs when it ftands lower.

Place the fmall receiver O (fig. 1.) over the hole i in the pump-plate, and upon exhaufting the air, the receiver will be fixed down to the plate by the preffure of the air on its outfide, which is left to act alone, without any air in the receiver to act againft it: and this preffure will be equal to as many times 15 pounds, as there are fquare inches in that part of the plate which the receiver covers; which will hold down the receiver fo faft, that it cannot be got off, until the air be let into it by turning the cock k: and then it becomes loofe. Experiment IV.

Set the little glafs A B (which is open at both ends) over the hole i upon the pump-plate L L, and put your hand clofe upon the top of it at B: then, upon exhaufting the air out of the glafs, you will find your hand preffed down with a great weight upon it: fo that you can hardly releafe it, until the air be readmitted into the glafs by turning the cock k; which air, by acting as ftrongly upward againft the hand as the external air acted in preffing it downward, will releafe the hand from its confinement. Experiment V. Fig. 5.

Having tied a piece of wet bladder b over the open top of the glafs A (which is alfo open at bottom) fet it to dry, and then the bladder will be tight like a drum. Then place the open plate A upon the pump-plate, over the hole i, and begin to exhauft the air out of the glafs. As the air is exhaufting, its fpring in the glafs will be weakened, and give way to the preffure of the outward air on the bladder, which, as it is preffed down, will put on a fpherical con- Experiment VI. Fig. 6.

cave figure, which will grow deeper and deeper, until the ſtrength of the bladder be overcome by the weight of the air; and then it will break with a report as loud as that of a gun. If a flat piece of glaſs be laid upon the top of this receiver, and joined to it by a flat ring of wet leather between them, upon pumping the air out of the receiver, the preſſure of the outward airs upon the flat glaſs will break it all to pieces.

Experiment VII. Plate VIII. Fig. 1.

Pour ſome quickſilver into the jar D, and ſet it on the pump-plate near the hole i; then ſet on the tall open receiver A B, ſo as to be over the jar and hole; and cover the receiver with the braſs plate C. Screw the open glaſs tube f g, which has a braſs top on it at h, into the ſyringe H, and putting the tube through a hole in the middle of the plate, ſo as to immerſe the lower end of the tube e into the quickſilver at D, ſcrew the end h of the ſyringe into the plate. This done, draw up the piſton in the ſyringe by the ring I, which will make a vacuum in the ſyringe below the piſton: and as the upper end of the tube opens into the ſyringe, the air will be dilated in the tube, becauſe part of it, by its ſpring, gets up into the ſyringe; and the ſpring of the undilated air in the receiver acting upon the ſurface of the quickſilver in the jar, will force part of it up into the tube: for the quickſilver will follow the piſton in the ſyringe, in the ſame way, and for the ſame reaſon, that water follows the piſton of a common pump, when it is raiſed in the pump-barrel; and this, according to ſome is done by ſuction. But to refute that erroneous notion, let the air be pumped out of the receiver A B, and then all the quickſilver in the tube will fall down by its own weight into the jar; and cannot be raiſed one hair's breadth in the tube by working the ſyringe; which ſhews that ſuction had

no

no hand in raiſing the quickſilver; and to prove that it is done by preſſure, let the air into the receiver by the cock k (fig. 1.) and its action upon the ſurface of the quickſilver in the jar will raiſe it up into the tube, although the piſton of the ſyringe continues motionleſs. If the tube be about 32 or 33 inches high the quickſilver will riſe in it very near as high as it ſtands at that time in the barometer. And, if the ſyringe has a ſmall hole, as m, near the top of it, and the piſton be drawn up above that hole, the air will ruſh through the hole into the ſyringe and tube, and the quickſilver will immediately fall down into the jar. If this part of the apparatus be air-tight, the quickſilver may be pumped up into the tube to the ſame height that it ſtands in the barometer; but it will go no higher, becauſe then the weight of the column in the tube is the ſame as the weight of a column of air of the ſame thickneſs with the quickſilver, and reaching from the earth to the top of the atmoſphere.

Having placed the jar A, with ſome quickſilver in it, on the pump-plate as in the laſt experiment, cover it with the receiver B, then puſh the open end of the glaſs tube d e through the collar of leathers in the braſs neck C which it fits ſo as to be air-tight) almoſt down to the quickſilver in the jar. Then exhauſt the air out of the receiver, and it will alſo come out of the tube, becauſe the tube is cloſe at top. When the gauge m m ſhews that the receiver is well exhauſted, puſh the tube, ſo as to immerſe its lower end into the quickſilver in the jar. Now, although the tube be exhauſted of air, none of the quickſilver will riſe into it, becauſe there is no air left in the receiver to preſs upon its ſurface in the jar. But let the air into the receiver by the cock k, and the quickſilver will immediately riſe in the

Experiment VIII, Fig. 2.

the

the tube; and ſtand as high in it, as it was pumped up in the laſt experiment.

Both theſe experiments ſhew that the quickſilver is ſupported in the barometer by the preſſure of the air on its ſurface in the box, in which the open end of the tube is placed. And that the more denſe and heavy the air is, the higher the quickſilver riſes; and on the contrary, the thinner and lighter the air is, the more will the quickſilver fall. For if the handle F be turned ever ſo little, it takes ſome air out of the receiver, by raiſing one or other of the piſtons in its barrel; and conſequently, that which remains in the quickſilver is ſo much the rarer, and has ſo much the leſs ſpring and weight; and thereupon the quickſilver falls a little in the tube: but upon turning the cock, and re-admitting the air into the receiver, it becomes as weighty as before, and the quickſilver riſes again to the ſame height. Thus we ſee the reaſon why the quickſilver in the barometer falls before rain or ſnow, and riſes before fair weather; for in the former caſe the air is too thin and light to bear up the vapours, and in the latter too denſe and heavy to let them fall.

It is to be noted, that, in all mercurial experiments with the air pump, a ſhort pipe muſt be ſcrewed into the hole i, ſo as to riſe about an inch above the plate, to prevent the quickſilver from getting into the air pipe and barrels, in caſe any of it ſhould be accidentally ſpilt over the jar; for if it once gets into the pipes or barrels, it ſpoils them, by looſening the ſolder, and corroding the braſs.

Take

Take the tube out of the receiver, and put one end of a bit of dry hazel branch, about an inch long, tight into the hole, and the other end tight into a hole quite through the bottom of a ſmall wooden cup: then, pour ſome quickſilver into the cup, and exhauſt the receiver of air, and the preſſure of the outward air, on the ſurface of the quickſilver, will force it through the pores of the hazel, from whence it will deſcend in a beautiful ſhower, into a glaſs cup placed under the receiver to catch it. Experiment IX.

Put a wire through the collar of leathers on the top of the receiver, and fix a bit of dry wood on the end of the wire within the receiver; then exhauſt the air, and puſh the wire down, ſo as to immerſe the wood into a jar of quickſilver on the pump plate; this done, let in the air, and upon taking the wood out of the jar, and ſplitting it, its pores will be found full of quickſilver, which the force of the air, upon being let into the quickſilver, drove into the wood. Experiment X.

Join the two braſs hemiſpherical cups A and B together, with a wet leather between them, having a hole in the middle of it; then ſcrew the end D of the pipe C D into the plate of the pump at i, and turn the cock E, ſo as the pipe may be open all the way into the cavity of the hemiſpheres: then exhauſt the air out of them, and turn the cock a quarter round, which will ſhut the pipe C D, and keep out the air. This done, unſcrew the pipe at D from the pump, and ſcrew the piece F h upon it at D; and let two ſtrong men try to pull the hemiſpheres aſunder by the rings g and h which they will find hard to do; for if the diameter of the hemiſpheres be four inches, they will be preſſed together by the external air with a force equal to 190 pounds: and to ſhew that it is the preſſure of the air that keeps them together, Experiment XI. Plate VII. Fig. 7.

gether, hang them by either of the wings upon the hook P of the wire in the receiver M, (Fig. 1) and upon exhaufting the air out of the receiver, they will fall afunder of themfelves.

Experiment XII.

Place a fmall receiver O (Fig 1) near the hole i on the pump plate, and cover both it and the hole with the receiver M; and turn the wire fo by the top P, that its hook may take hold of the little receiver by a ring at its top, allowing that receiver to ftand with its own weight on the plate. Then, upon working the pump, the air will come out of both receivers; but the large one M, will be forcibly held down to the pump by the preffure of the external air; whilft the fmall one O, having no air to prefs upon it, will continue loofe, and may be drawn up and let down at pleafure by the wire P P. But, upon letting it quite down to the plate, and admitting the air into the receiver M, by the cock k, the air will prefs fo ftrongly upon the fmall receiver O, as to fix it down to the plate; and, at the fame time, by counterbalancing the outward preffure on the large receiver M, it will become loofe. This experiment evidently fhews, that the receivers are held down by preffure, and not by fuction, for the internal receiver continued loofe while the operator was pumping, and the external one was held down; but the former became faft immediately by letting in the air upon it.

Plate VIII. Fig. 3. Experiment XIII.

Screw the end A of the brafs pipe A B F into the pump plate, and turn the cock e until the pipe be open; then put a wet leather upon the plate c d, which is fixed on the pipe, and cover it with the tall receiver G H, which is clofe at top: then exhauft the air out of the receiver, and turn the cock e

to

to keep it out; which done, unſcrew the pipe from the pump, and ſet its end A into a baſon of water, and turn the cock c to open the pipe; on which, as there is no air in the receiver, the preſſure of the atmoſphere on the water in the baſon, will drive the water forcibly through the pipe, and make it play up in a jet to the top of the receiver.

Set the ſquare phial A upon the pump plate, and having covered it with the wire cage B, put a cloſe receiver over it and exhauſt the air out of the receiver; in doing which, the air will alſo make its way out of the phial, through a ſmall hole in its neck under the valve b. When the air is exhauſted, turn the cock below the plate, to re-admit the air into the receiver; and as it cannot get into the phial again, becauſe of the valve, the phial will be broke into ſome thouſands of pieces by the preſſure of the air upon it. Had the phial been of a round form, it would have ſuſtained this preſſure like an arch, without breaking; but as its ſides are flat, it cannot. Plate VII. Fig. 8. Experiment XIV.

To ſhew the elaſticity or ſpring of the air. Tie up a very ſmall quantity of air in a bladder, and put it under the receiver; then exhauſt the air out of the receiver: and the ſmall quantity which is confined in the bladder (having nothing to act againſt it) will expand itſelf ſo by the force of its ſpring, as to fill the bladder as full as it could be blown of common air. But upon letting the air into the receiver again, it will overpower the air in the bladder, and preſs its ſides almoſt cloſe together. Experiment XV. Fig. 11.

If the bladder ſo tied up be put into a wooden box, and have 20 or 30 pounds weight of lead put upon it in the box, and the box be covered with a cloſe receiver; upon exhauſt- Experiment XVI.

ing the air out of the receiver, that air which is confined in the bladder will expand itſelf ſo as to raiſe up all the lead by the force of its ſpring.

Plate VIII. Fig. 3. Exp. 17. Screw the pipe A B into the pump plate, place the tall receiver G H upon the plate c d, as in the 13th experiment, and exhauſt the air out of the receiver; then turn the cock e to keep out the air, unſcrew the pipe from the pump, and ſcrew it into the mouth of the copper veſſel C C (Fig. 4) the veſſel having been firſt about half filled with water. Then open the cock e (Fig. 3) and the ſpring of the air which is confined in the copper veſſel, will force the water up through the pipe A B in a jet into the exhauſted receiver, as ſtrongly as it did by its preſſure on the ſurface of the water in a baſon in the thirteenth experiment.

Exp. 18. If a fowl, cat, rat, mouſe, or bird, be put under a receiver, and the air be exhauſted, the animal will be at firſt oppreſſed as with a great weight, then grow convulſed, and at laſt expire in all the agonies of a moſt bitter and cruel death. But as this experiment is too ſhocking to every ſpectator who has the leaſt degree of humanity, we ſubſtitute a machine called the *lungs-glaſs* in place of the animal.

Exp. 19. If a butterfly be ſuſpended in a receiver, by a fine thread tied to one of its horns, it will fly about in the receiver, as long as the receiver continues full of air; but if the air be exhauſted, though the animal will not die, and will continue to flutter its wings, it cannot remove itſelf from the place where it hangs in the middle of the receiver, until the air be let in again, and then the animal will fly about as before.

Pour

Pour ſome quickſilver into the ſmall bottle A, and ſcrew the braſs collar c of the tube B C into the braſs neck b of the bottle, and the lower end of the tube will be immerſed into the quickſilver, ſo that the air above the quickſilver in the bottle will be confined there, becauſe it cannot get about the joining, nor can it be drawn out through the quickſilver into the tube. This tube is alſo open at top, and is to be covered with the receiver G and large tube E F, which tube is fixed by braſs collars to the receiver, and is cloſe at the top. This preparation being made, exhauſt the air both out of the receiver and its tube; and the air will by the ſame means be exhauſted out of the inner tube B C, through its open top at C; and as the receiver and tubes are exhauſting, the air that is confined in the glaſs bottle A will preſs ſo by its ſpring upon the ſurface of the quickſilver, as to force it up in the inner tube as high as it was raiſed in the tenth experiment by the preſſure of the atmoſphere: which demonſtrates that the ſpring of the air is equivalent to its weight. Exp. 20. Fig. 5.

Put a cork into the ſquare phial A, and fix it in with wax or cement; put the phial upon the pump-plate with the wire cage B over it, and cover the cage with a cloſe receiver; then exhauſt the air out of the receiver, and the air that was corked up in the phial will break the phial outwards by the force of its ſpring, becauſe there is no air left on the outſide of the phial to act againſt the air within it. Exp. 21. Plate VII. Fig. 8.

Put a ſhrivelled apple under a cloſe receiver and exhauſt the air; then the ſpring of the air within the apple will plump it out, ſo as to cauſe all the wrinkles to diſappear; but upon letting the air into the receiver again, to preſs upon the apple, it will inſtantly return to its former decayed and ſhrivelled ſtate. Exp. 22.

Take

Exp. 23. Take a freſh egg, and cut off a little of the ſhell and film from its ſmalleſt end, then put the egg under a receiver, and pump out the air; upon which all the contents of the egg will be forced out into the receiver, by the expanſion of a ſmall bubble of air contained in the great end, between the ſhell and film.

Exp. 24. Put ſome warm beer into a glaſs, and having ſet it on the pump, cover it with a cloſe receiver, and then exhauſt the air. Whilſt this is doing, and thereby the preſſure more and more taken off from the beer in the glaſs, the air therein will expand itſelf, and riſe up in innumerable bubbles to the ſurface of the beer: and from thence it will be taken away with the other air in the receiver. When the receiver is nearly exhauſted, the air in the beer, which could not diſentangle itſelf quick enough to get off with the reſt, will now expand itſelf ſo, as to cauſe the beer to have all the appearance of boiling; and the greateſt part of it will go over the glaſs.

Exp. 25. Put ſome warm water into a glaſs, and put a bit of dry wainſcot or other wood into the water; then cover the glaſs with a cloſe receiver, and exhauſt the air, upon which the air in the wood having liberty to expand itſelf, will come out plentifully, and make all the water to bubble about the wood, eſpecially about the ends becauſe the pores lie lengthways. A cubic inch of dry wainſcot has ſo much air in it, that it will continue bubbling for near half an hour together.

Miſcellaneous Experiments.

SCREW the ſyringe H (fig. 1.) to a piece of lead that weighs one pound at leaſt; and, holding the lead in one hand, pull up the piſton in the ſyringe with the other; then, quitting hold of the lead, the air will puſh it upward, and drive back the ſyringe upon the piſton. The reaſon of this is, that the drawing up of the piſton makes a vacuum in the ſyringe, and the air, which preſſes every way equally, having nothing to reſiſt its preſſure upward, the lead is thereby preſſed upward, contrary to its natural tendency by gravity. If the ſyringe, ſo loaded, be hung in a receiver, and the air be exhauſted, the ſyringe and lead will deſcend upon the piſton-rod by their natural gravity; and, upon admitting the air into the receiver, they will be driven upward again, until the piſton be at the very bottom of the ſyringe. Exp. 26. Plate VIII.

Let a large piece of cork be ſuſpended by a thread at one end of a balance, and counterpoiſed by a leaden weight, ſuſpended in the ſame manner, at the other. Let this balance be hung to the inſide of the top of a large receiver; which being ſet on the pump, and the air exhauſted, the cork will preponderate, and ſhew itſelf to be heavier than the lead; but upon letting in the air again, the equilibrium will be reſtored. The reaſon of this is, that ſince the air is a fluid, and all bodies loſe as much of their abſolute weight in it, as is equal to the weight of their bulk of the fluid, the cork being the larger body, loſes more of its real weight than the lead does; and therefore muſt in fact be heavier, to balance it under the diſadvantage of loſing ſome of its weight, Exp. 27.

weight, which disadvantage being taken off by removing the air, the bodies then gravitate according to their real quantities of matter, and the cork which balanced the lead in air, shews itself to be heavier when in vacuo.

Exp. 28. Set a lighted candle upon the pump, and cover it with a tall receiver. If the receiver holds a gallon, the candle will burn a minute; and then, after having gradually decayed from the first instant, it will go out; which shews that a constant supply of fresh air is necessary to feed flame; and so it also is for animal life. For a bird kept under a close receiver will soon die, although no air be pumped out; and it is found that, in the diving bell, a gallon of air is sufficient only for one minute for a man to breathe in.

The moment when the candle goes out, the smoke will be seen to ascend to the top of the receiver, and there it will form a sort of cloud; but, upon exhausting the air, the smoke will fall down to the bottom of the receiver, and leave it as clear at the top as it was before it was set upon the pump. This shews that smoke does not ascend on account of its being positively light, but because it is lighter than air; and its falling to the bottom when the air is taken away, shews that it is not destitute of weight. So most sorts of wood ascend or swim in water; and yet there are none who doubt of the wood's having gravity or weight.

Exp. 29. Set a receiver which is open at top, upon the air pump, and cover it with a brass plate, and wet leather; and having exhausted it of air, let the air in again at top through an iron pipe, making it pass through a charcoal flame at the end of the pipe; and when the receiver is full of that air, lift up the cover, and let down a mouse or bird into the receiver, and

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the burnt air will immediately kill it. If a candle be let down into that air, it will go out directly; but by letting it down gently, it will purify the air ſo far as it goes; and ſo by letting it down more and more, the flame will drive out the bad air, and good air will get in.

Set a bell upon a cuſhion on the pump plate, and cover it with a receiver; then ſhake the pump to make the clapper ſtrike againſt the bell, and the ſound will be very well heard: but, exhauſt the receiver of air, and then, if the clapper be made to ſtrike ever ſo hard againſt the bell, it will make no ſound at all; which ſhews that air is abſolutely neceſſary for the propagation of ſound. Exp. 30.

Let a candle be placed on one ſide of a receiver, and viewed through the receiver at ſome diſtance; then, as ſoon as the air begins to be exhauſted, the receiver will be filled with vapours, which riſe from the wet leather, by the ſpring of the air in it; and the light of the candle being refracted through that medium of vapours, will have the appearance of circles of various colours, of a faint reſemblance to thoſe of the rain-bow. Exp. 31.

The air-pump was invented by *Otho Gueriche* of *Madgeburg*, but was much improved by Mr. *Boyle*, to whom we are indebted for our greateſt part of the knowledge of the wonderful properties of the air, demonſtrated in the above experiments.

The elaſtic air which is contained in many bodies, and is kept in them by the weight of the atmoſphere, may be got out of them either by boiling, or by the air pump, as ſhewn in

in the 24th experiment: but the fixed air, which is by much the greater quantity, cannot be got out but by diſtillation, fermentation, or putrefaction.

If fixed air did not come out of bodies with difficulty, and ſpend ſome time in extricating itſelf from them, it would tear them to pieces. Trees would be rent by the change of air, from a fixed to an elaſtic ſtate, and animals would be burſt in pieces by the exploſion of air in their food.

Dr. *Hales* found by experiment, that the air in apples is ſo much condenſed, that if it were let out into the common air, it would fill a ſpace 48 times as great as the bulk of the apples themſelves; ſo that its preſſure outwards was equal to 11776 lb. and, in a cubic inch of oak, to 19860 lb. againſt its ſides. So that if the air was let looſe at once in theſe ſubſtances, they would tear every thing to pieces about them with a force ſuperior to that of gun-powder. Hence, in eating apples, it is well that they part with the air by degrees, as they are chewed, and foment in the ſtomach, otherwiſe an apple would be immediate death to him who eats it.

The mixing of ſome ſubſtances with others will releaſe the air from them, all of a ſudden, which may be attended with very great danger. Of this we have a remarkable inſtance in an experiment made by Dr. Slare; who having put half a dram of oil of caraway-ſeeds into one glaſs, and a dram of compound ſpirit of nitre in another, covered them both on the air pump with a receiver 6 inches wide, and 8 inches deep, and then exhauſted the air, and continued pumping until all that could poſſibly be got both out of the receiver and out of the two fluids, was extricated: then, by a parti-

cular

cular contrivance from the top of the receiver, he mixed the fluids together; upon which they produced ſuch a prodigious quantity of air, as inſtantly blew up the receiver, although it was preſſed down by the atmoſphere with upwards of 400 pound weight. Obſerve in the 27th experiment, the cork muſt be covered all over with a piece of thin wet bladder glued to it, and not uſed until it be thoroughly dry.

The Conſtruction and Uſe of the Barometer or Weather Glaſs.

THIS inſtrument is uſeful for meaſuring the weight of the atmoſphere, and in fortelling the changes of the weather, and alſo for meaſuring the height of mountains, &c. Fig. 2.

The common barometer conſiſts of a glaſs tube hermetically ſealed at one end, and filled with quickſilver, and defecated and purged of its air. The finger being then placed on the open end, in immediate contact with the mercury, ſo as not to admit the leaſt particle of air, the tube is inverted, and the lower end plunged into a baſon of the ſame prepared mercury. (See Miſcellaneous Articles) then, upon removing the finger, the mercury in the tube will join that in the baſon, and the mercurial column in the tube will ſubſide to the height of twenty-nine or thirty inches, according to the ſtate of the atmoſphere at that time, (See the ſcale.) This Fig. 6. is the principle upon which all barometers are conſtructed.

In the beginning of the laſt century, philoſophers were of opinion, that the aſcent of water in pumps was owing to the abhorrence of a vacuum; and, that by means of ſuction, fluids might be raiſed to any height whatever. But *Galilæo*,

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Galilæo's discovery. who flouriſhed about that time, diſcovered that water would not aſcend in a pump unleſs the ſucker reached within thirty-three feet of its ſurface in the well. From hence he concluded, that not the power of ſuction, but the preſſure of the atmoſphere was the cauſe of the aſcent of water in pumps: that a column of water thirty-three feet high was a counterpoiſe to one of air of an equal baſe, whoſe height extended to the top of the atmoſphere; and that for this reaſon the water would not follow the ſucker any farther. From this TORRICELLI, *Galilæo*'s diſciple, took the hint; and conſidered, that if a column of water of about thirty-three in height was equal in weight to one of air having the ſame baſe, a column of mercury no longer than about twenty-nine inches and a half would be ſo too, becauſe, mercury being about fourteen times heavier than water, a column of mercury muſt be fourteen times ſhorter than one of water equally heavy. Accordingly, having filled a glaſs tube with mercury, and inverted it into a baſon of the ſame, he found the mercury in the tube to deſcend till it ſtood about twenty-nine inches and a half above the ſurface of that in the baſon.

Torricellian Experiment.

It was, however, ſome time after the Torricellian experiment had been made, and even after it had been univerſally agreed that the ſuſpenſion of the mercury was owing to the weight of the atmoſphere, before it was diſcovered that this preſſure of the air was different at different times, though the tube was kept in the ſame place. But the variations of altitude in the mercurial columns were too obvious to remain long unobſerved: and accordingly philoſophers ſoon became careful enough to mark them. When this was done; it was impoſſible to avoid obſerving alſo, that the changes in the height of the mercury were accom-

panied,

panied, or very quickly ſucceeded, by changes in the weather. Hence, the inſtrument obtained the name of the weather-glaſs, and was generally made uſe of with a view to the foreknowledge of the weather. In this character, its principal phenomena are as follow:

1. The riſing of the mercury preſſages, in general, fair weather; and its falling, foul weather, as rain, ſnow, high winds, and ſtorms. 2. In very hot weather, the falling of the mercury foreſhews thunder. 3. In winter, the riſing preſſages froſt; and in froſty weather, if the mercury falls three or four diviſions, there will certainly follow a thaw. But in a continued froſt, if the mercury riſes, it will certainly ſnow. 4. When foul weather happens ſoon after the falling of the mercury, expect but little of it; and, on the contrary, expect but little fair weather when it proves fair ſhortly after the mercury has riſen. 5. In foul weather, when the mercury riſes much and high, and ſo continues for two or three days before the foul weather is quite over, then expect a continuance of fair weather to follow. 6. In fair weather, when the mercury falls much and low, and thus continues for two or three days before the rain comes; then expect a great deal of wet, and probably high winds. 7. The unſettled motion of the mercury denotes uncertain and changeable weather. 8. You are not ſo ſtrictly to obſerve the words engraved on the plates (though in general it will agree with them) as the mercury's riſing and falling. For if it ſtands at much rain, and then riſes up to changeable, it preſages fair weather; though not to continue ſo long as if the mercury had riſen higher: and ſo, on the contrary, if the mercury ſtood at fair, and falls

Preliminary rules to judge of the weather.

Note.

falls to changeable, it preſages foul weather; though not ſo much of it as if it had ſunk lower.

From theſe obſervations it appears, that it is not ſo much the height of the mercury in the tube, that indicates the weather as the motion of it up and down: wherefore, in order to paſs a right judgment of what weather is to be expected, we ought to know whether the mercury is actually riſing or falling; to which end the following rules are of uſe.

1. If the ſurface of the mercury is convex, ſtanding higher in the middle of the tube than at the ſides, it is generally a ſign that the mercury is then riſing. 2. If the ſurface is concave, it is then ſinking; and, 3. If it is plain, the mercury is ſtationary, or rather, if it is a little convex; for mercury being put into a glaſs tube, eſpecially a ſmall one, will naturally have its ſurface a little convex, becauſe the particles of mercury attract one another more forcibly than they are attracted by glaſs. 4. If the glaſs is ſmall, ſhake the tube; and if the air is grown heavier, the mercury will riſe about half the tenth of an inch higher than it ſtood before: if it is grown lighter it will ſink as much. This proceeds from the mercury's ſticking to the ſides of the tube, which prevents the free motion of it till it is diſengaged by the ſhock: and therefore, when an obſervation is to be made by ſuch a tube, it ought always to be ſhaken firſt; for ſometimes the mercury will not vary of its own accord, till the weather it ought to have indicated is preſent.

Here we muſt obſerve, that the above-mentioned phenomena are peculiar to places lying at a conſiderable diſtance

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from the equator; for in the torrid zone, the mercury in the barometer, ſeldom either riſes or falls much. In Jamaica, it is obſerved by Sir *William Beeſton*, that the mercury in the morning, conſtantly ſtood at one degree below changeable, and at noon, ſunk to one degree above rain; ſo that the whole ſcale of variation there was only three tenths of an inch. At St. Helena, too, where Dr. *Halley* made his obſervations, he found the mercury to remain moſtly ſtationary whatever weather happened. Of theſe phenomena, their cauſes, and why the barometer indicates an approaching change of weather, the Doctor gives us the following account:

Dr. Halley's rules and obſervations.

1. In calm weather, when the air is inclined to rain, the mercury is commonly low. 2. In ſerene, good, and ſettled weather, the mercury is generally high. 3. Upon very great winds, though they be not accompanied with rain, the mercury ſinks loweſt of all, with relation to the point of the compaſs the wind blows upon. 4. The greateſt heights of the mercury are found upon eaſterly or north-eaſterly winds. 5. In calm froſty weather the mercury generally ſtands high. 6. After very great ſtorms of wind, when the mercury has been very low, it generally riſes again very faſt. 7. The more northerly places have greater alterations of the barometer than the more ſoutherly. 8. Within the tropics, and near them, thoſe accounts we have had from others, and the obſervations made at St. Helena, make very little or no variation of the height of the mercury in all weathers.

Hence, I conceive, that the principal cauſe of the riſe and fall of the mercury is from the variable winds which are

found

found in the temperate zone, and whofe great inconftancy, here in England, is notorious.

A fecond caufe is, the uncertain exhalation and precipitation of the vapours lodging in the air, whereby it comes to be at one time much more crowded than at another, and confequently heavier; but this latter depends in a great meafure upon the former. Now, from thefe principles, I fhall endeavour to explicate the feveral phenomena of the barometer, taking them in the fame order I have laid them down. Thus.

1. The mercury's being low inclines it to rain, becaufe the air being light, the vapours are no longer fupported thereby, being become fpecifically heavier than the medium wherein they floated; fo that they defcend towards the earth, and, in their fall, meeting with other aqueous particles, they incorporate together, and form little drops of rain: but the mercury's being at one time lower than another, is the effect of two contrary winds blowing from the place where the barometer ftands; whereby the air of that place is carried both ways from it and confequently the incumbent cylinder of air is diminifhed, and accordingly the mercury finks: as, for inftance, if in the German ocean it fhould blow a gale of wefterly wind, and, at the fame time, an eafterly wind in the Irifh fea; or, if in France it fhould blow a northerly wind, and in Scotland a foutherly; it muft be granted, that that part of the atmofphere impendant over England would thereby be exhaufted and attenuated, and the mercury would fubfide, and the vapours which before floated in thefe parts of the air of equal gravity with themfelves would fink to the earth.

2. The

2. The greater height of the barometer is occaſioned by two contrary winds blowing towards the place of obſervation, whereby the air of other places is brought thither and accumulated; ſo that the incumbent cylinder of air being increaſed both in height and weight, the mercury preſſed thereby muſt needs ſtand high, as long as the winds continue ſo to blow; and then the air being ſpecifically heavier, the vapours are better kept ſuſpended, ſo that they have no inclination to precipitate, and fall down in drops, which is the reaſon of the ſerene good weather which attends the greater heights of the mercury.

3. The mercury ſinks the loweſt of all by the very rapid motion of the air in ſtorms of winds. For the tract or region of the earth's ſurface, wherein the winds rage, not extending all round the globe; that ſtagnant air which is left behind, as likewiſe that on the ſides, cannot come in ſo faſt as to ſupply the evacuation made by ſo ſwift a current; ſo that the air muſt neceſſarily be attenuated, when and where the ſaid winds continue to blow; and that more or leſs according to their violence: add to which that the horizontal motion of the air being ſo quick, may in all probability take off ſome part of the perpendicular preſſure thereof; and the great agitation of its particles is the reaſon why the vapours are diſſipated, and do not condenſe into drops ſo as to form rain, otherwiſe the natural conſequence of the air's rarefaction.

4. The mercury ſtands higheſt upon the eaſterly and north-eaſterly wind; becauſe in the great Atlantic ocean, on this ſide the thirty-fifth degree of north latitude, the winds are almoſt always weſterly or ſouth-weſterly; ſo that whenever here the wind comes up at eaſt and north-eaſt, it is

is ſure to be checked by a contrary gale as ſoon as it reaches the ocean; wherefore, according to our ſecond remark, the air muſt needs be heaped over this iſland, and conſequently, the mercury muſt ſtand high, as often as theſe winds blow. This holds true in this country: but is not a general rule for others, where the winds are under different circumſtances: and I have ſometimes ſeen the mercury here ſo low as twenty-nine inches upon an eaſterly wind; but then it blew exceeding hard, and ſo comes to be accounted for by what was obſerved in the third remark.

5. In calm froſty weather the mercury generally ſtands high; becauſe (as I conceive) it ſeldom freezes, but when the winds come out of the northern and north-eaſtern quarters: or at leaſt, unleſs thoſe winds blow at no great diſtance off. For the north parts of Germany, Denmark, Sweden, Norway and all that tract, from whence north-eaſtern winds come, are ſubject to almoſt continual froſt all the winter: and thereby the lower air is very much condenſed, and in that ſtate is brought hitherward by thoſe winds, and, being accumulated by the oppoſition of the weſterly wind blowing in the ocean, the mercury muſt needs be preſſed to a more than ordinary height; and as a concurring cauſe, the ſhrinking of the lower parts of the air into leſſer room by cold, muſt needs cauſe a deſcent of the upper parts of the atmoſphere, to reduce the cavity made by this contraction to an equilibrium.

6. After great ſtorms, when the mercury has been very low, it generally riſes again very faſt: I once obſerved it to riſe one inch and an half in leſs than ſix hours, after a long continued ſtorm of ſouth-weſt wind. The reaſon is, becauſe the air being very much rarefied by the great evacuations

tions which ſuch continued ſtorms make thereof, the neighbouring air runs in the more ſwifty to bring it to an equilibrium; as we ſee water runs the faſter for having a greater declivity.

7. The variations are greater in the more northerly places, as at Stockholm greater than at Paris (compared by *M. Paſchall*) becauſe the more northerly parts have uſually greater ſtorms of wind than the more ſoutherly, whereby the mercury ſhould ſink lower in that extreme; and then the northerly winds bringing in the more denſe and ponderous air from the neighbourhood of the pole, and that again being checked by a ſoutherly wind at no great diſtance, and ſo heaped, muſt of neceſſity make the mercury in ſuch caſe ſtand higher in the other extreme.

8. Laſtly, this remark, that there is little or no variation near the equinoctial, does, above all others, confirm the hypotheſis of the variable winds being the cauſe of theſe variations of the height of the mercury; for in the places above-named, there is always an eaſy gale of wind blowing nearly upon the ſame point, viz. E. N. E. at Barbadoes, and E. S. E. at St. Helena, ſo that their being no contrary currents of air to exhauſt or accumulate it, the atmoſphere continues much in the ſame ſtate: however, upon hurricanes, the moſt violent of ſtorms, the mercury has been obſerved very low; but this is but once in two or three years, and it ſoon recovers its ſettled ſtate, about 29½ inches.

To fill the Barometer Tube.

IN order to fill a barometer tube to the greateſt perfection, it will be neceſſary to obſerve the following rules. 1. That the tube be at leaſt one fourth of an inch bore; but one third of an inch is better. 2. That the tube ought to be new, and clean within when filled. In order to this, the tube ſhould be hermetically ſealed at both ends, at the glaſs-houſe when made; one end of which may be cut off with a file when you uſe it. 3. The diameter of the ciſtern that holds the mercury, in which the tube is immerſed, ſhould be as large as conveniently may be, that the mercury therein may have nearly at all times the ſame altitude; otherways the index will not be true. 4. The mercury muſt be pure, and free from any mixture of tin, lead, or other metal. 5. It ought to be purged from air entirely, as it may be by boiling it, and filling the tube with it, while boiling hot, nearly. 6. The tube muſt be heated hot when filled, to avoid breaking by the boiling mercury. 7. It ſhould be rubbed very hard, to excite the electric virtue, which will expel the particles of air from the ſurface within.

Fig. 7. Then take the tube, fig. 7. and nearly fill the ball with mercury, after which, place the thumb of your right hand upon the end A, and the fore-finger of your left upon the end B, holding it downwards, and ſhaking it endways, the mercury will run into the tube until it be quite filled; you may then turn it as in the figure, and the mercury will ſink in the tube to B, which will be 29½ inches from the ſurface of the mercury in the ball at A, if the preſſure of the atmoſphere at that time be at changeable, as at fig. 6.

N. B. If

N. B. If any air bubbles ſhould happen to be left in the tube after it is filled, you muſt invert it, and place your thumb and fore-finger as before, and gently knock the end B with your finger underneath it, upon a table, while all the air bubbles have riſen into the ball, then it is perfect; but this operation is never neceſſary but when the bore of the tube is too ſmall.

The Diagonal Barometer.

A B C, fig. 8, is a tube ſealed at C, immerſed in mercury at A; this tube is perpendicular from A to B, where the ſcale of variation begins; from thence it is bent into C B. This part B C proceeds to the higheſt limit in the ſcale of variation, viz. I C; and conſequently while the mercury riſes from C to I in the common barometer, it will move in this from B to C, and ſo the ſcale will by this means be enlarged in the proportion of B C to I C. Fig. 8.

However, this form being ſubject to a great degree of friction, on account of the obliquity in the part B C, which inclination, making the quickſilver frequently divide into ſeveral parts, requires the trouble of filling the tubes anew too often.

The Horizontal Rectangular Barometer.

CONSISTS of a tube A C D F, fig. 9, ſealed on the upper end A, and bent to a right-angle at D, whence it has the name of the horizontal rectangular barometer. The mercury ſtands in both legs from E to C. The ſcale of Fig. 9.

variation from D to P, is here made of a larger part, and then it is evident in moving three inches from A to C, it will move through fo many times three inches in the fmall leg D F, as the bore of D F is lefs than the bore of A C, whence the motion of the mercury at E muft be extremely fenfible. This form is liable to the like exceptions as remarked in that of fig. 8, and befides a great degree of friction; and the frequent breaking off of the mercury in the leg E, the part D F being a very fmall bore, the free motion of the mercury therein muft be impeded by the attraction of cohefion.

The Wheel Barometer.

Fig. 10. A, fig. 10, reprefents the quickfilver in a glafs tube, having a large round head or ball, and turned up at bottom B, upon the furface of the mercury in the recurved leg, there is then placed a fhort glafs tube loaded with mercury, with a ftring going over a pulley, and is balanced by another weight hanging freely in the air. As the furface at A is very large, and that at B very fmall, the motion of the quickfilver, and confequently of the ball A, will at bottom be very confiderable; but as the weight moves up and down, it turns the pulley, and that a hand or index, by the divifions of a large graduated circle, the minuteft variations of the air are plainly fhewn, if the inftrument be accurately made, and the friction of the feveral parts be inconfiderable.

For refining mercury, &c. fit for the above ufe, fee the Mifcellaneous Articles.

The Air Gun.

THIS pneumatical inftrument is an ingenious contrivance, which will drive a bullet with great violence, by means of condenfed air, forced into an iron ball, by a condenfor, (reprefented Fig. 11.) At the end a of this inftru- Fig. 11.
ment, is a male fcrew, on which, the hollow ball b is fcrewed in order to be filled with condenfed air. In the infide of this ball is a valve to hinder the air after it is injected from making its efcape, until it be forced open by a pin, againft which the hammer of the lock ftrikes; (as at a Fig 12) which then lets out as much air as will drive a ball with confiderable force to a great diftance.

When you condenfe the air in the ball; place your feet on the iron crofs h h to which the pifton rod d e is fixed; then lift up the barrel c a by the handles i i until the pifton at e be brought between o and c; the barrel a c will then be filled with air through the hole o from o to a. Then thruft down the barrel a c by the handles i i until the pifton e join with the neck of the iron ball at a; the air being thus condenfed between o and a will force open the valve in the ball, and when the handles i i are lifted up again, the valve will clofe and keep in the air: fo by rapidly continuing the ftrokes up and down, the ball will prefently be filled; after which unfcrew the ball off the condenfer, and fcrew it upon another male fcrew which is connected with the barrel and goes through the ftock of the gun as reprefented at b Fig. 12. I have frequently injected 12dwts. of air into a ball $3\frac{1}{4}$ inches diameter, with which I difcharged 15 bullets with confiderable force.

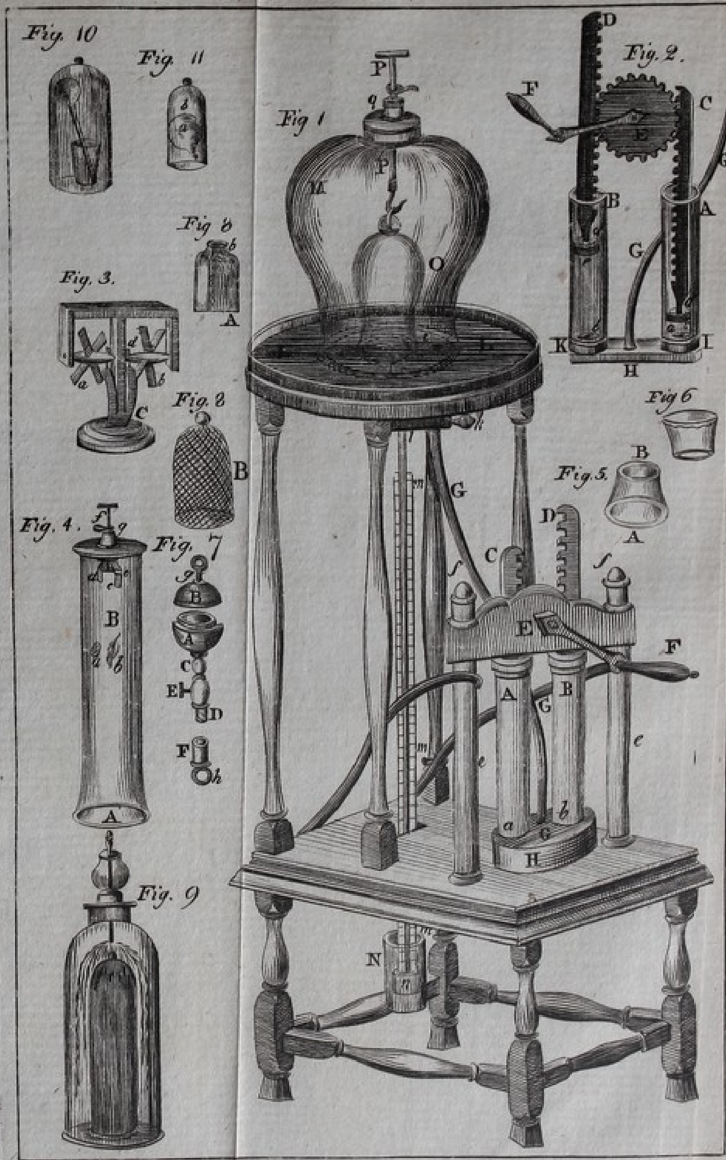
There

There are many contrivancs in conſtructing air guns; ſome have a ſmall barrel contained within a large one, and the ſpace between the two barrels ſerves for the reception of condenſed air. In theſe ſort a valve is fixed at a Fig. 12, with a condenſor fixed to the barrel at a and continued through the butt end to c, as a c Fig. 11, where the piſton rod may be always left in; and when uſed an iron pin one foot long, may be put through the hole d. Place your feet on the pin, and the whole gun ſerves inſtead of the handles i i Fig. 11. to condenſe the air in the barrel.

The magazine air gun differs from the common one, only by having a ſerpentine barrel which contains 10 or 12 balls; theſe are brought into the ſhooting barrel ſucceſſively, by means of a lever, and they may be diſcharged ſo faſt as to be nearly of the ſame uſe with ſo many different guns.

HYDRAU-

PNEUMATICS PLATE. VII.



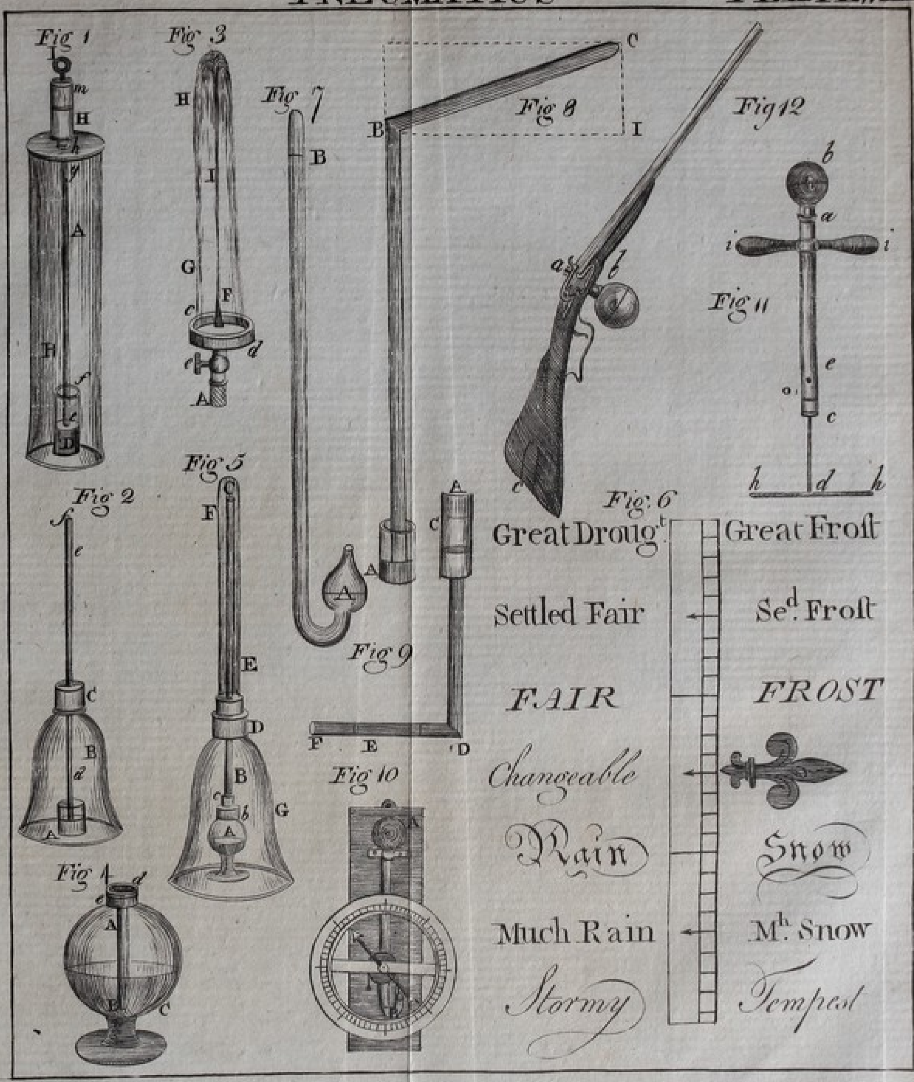


Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 7
Fig 8
Fig 9
Fig 10
Fig 11
Fig 12
Fig: 6
Great Droug^t
Great Frost
Settled Fair
Se^d Frost
FAIR
FROST
Changeable
Rain
Snow
Much Rain
M^h Snow
Stormy
Tempest

HYDRAULICS,

AND

HYDROSTATICS.

DEFINITIONS.

1. HYDRAULICS is the ſcience of fluids, particularly of water, with a ſpecial attention to artificial water-works; and to the laws and motion of fluid bodies.

HYDROSTATICS explain the equilibrium of fluids, or the gravitation of fluids at reſt; and upon removing that equilibrium, motion enſues: and here Hydraulics commence.

Hydraulics therefore, ſuppoſes *Hydroſtatics*, which induces me to begin this treatiſe with Hydroſtatics.

2. A *Syphon* is a bended tube, as repreſented Plate IX. Fig. 4.

3. A *valve* is a ſort of flap or cover, fixed to a pipe or other body, which by opening one way only, ſuffers the water to paſs, but not to return.

4. A

4. A *Piſton* is a ſmall cylinder faſtened to the end of a rod, and fitted to the bore of a pipe or hollow cylinder, and frequently contains a valve.

5. The *Hydrometer* is an inſtrument conſtructed to find the ſpecific gravities of fluids, as Fig. 2.

6. The *Hydroſtatic balance* is contrived to ſhew the ſpecific gravities of fluids, and of ſolids, by weighing them in fluids.

APHORISMS.

1. WATER is a ſcentleſs, tranſparent, colourleſs fluid, with which a certain degree of cold turns to ice.

Note. Though fludity is commonly regarded as an eſſential property of water, yet many philoſophers, particularly *Boyle* and *Boerhaave*, conſider it as an adventitious circumſtance, produced by a certain degree of heat, and aſſert its natural ſtate to be that of a chryſtalline, as when in ice.

2. Water is one of the conſiſtent parts of all bodies: this is proved by diſtillation, for the dryeſt woods, earths, bones, and ſtones pulveriſed, conſtantly yield a certain quantity of water.

3. All fluids except air are incompreſſible.

4. Though water is leſs tranſparent than air, it is more penetrative, as it will pervade bodies that air will not: this is evident from its paſſing through the pores of a bladder.

5. Water

5. Water diſſolves ſome bodies, as ſalts, and conglutinates others, as bricks, ſtones, bones, &c.

6. Water in its natural ſtate contains the three other elements, fire, earth, and air.

We have already ſaid that water owes its fluidity to heat, and it is evident from many experiments with the air pump, that it contains no ſmall quantity of air; and the ſediment that is found in all water, except that which is diſtilled, always contains a quantity of earth. From the laſt element it is ſuppoſed that plants derive all the nouriſhment they receive by means of water.

7. The water, in ſeveral tubes that communicate with each other, will ſtand at the ſame height in all of them, whether they be ſmall or great, perpendicular or oblique.

8. The ſurface of water contained in a veſſel will always be even, and parallel to the horizon: but in large bodies of water, as the ſea, or great lakes, the ſurface will not be plain, but ſpherical, as making a part of the terraqueous globe.

9. In a veſſel of water the preſſure of the upper parts on the lower, is in proportion to the depth; and is the ſame at the ſame depth, whatever be the diameter of the veſſel.

10. The preſſure of a fluid upward is equal to its preſſure downward, at any given depth.

11. The bottom and ſides of a veſſel are preſſed by the fluid it contains, in proportion to its height, without any regard to the quantity.

12. If fluids of different gravities be contained in the ſame veſſel, the heavieſt will be at bottom, the lighteſt at top, and the reſt in proportion to their ſpecific gravities.

13. A body that is heavier than an equal quantity of a fluid, will ſink in that fluid; if it be lighter, it will ſwim at the top; but if it be of the ſame gravity, it will neither ſink nor ſwim, but remain ſuſpended in any part of that fluid.

14. A ſolid immerſed in a fluid is preſſed by that fluid on all ſides, in proportion to the height of the fluid above the ſolid. Bodies very deeply immerged may be conſidered as equally preſſed on all ſides.

15. Every ſolid immerſed in a fluid, loſes ſo much of its weight, as is equal to the weight of a quantity of that fluid of the ſame dimenſion with the ſolid.

16 The fluid acquires the weight the ſolid loſes.

Of Fluidity.

Sir Iſaac Newton's definition of a fluid is, *That it is a body yielding to any force impreſſed, and which has its parts very eaſily moved one among another.*

It muſt here be remarked, that this definition ſuppoſes the motion ſpoken of, produced by a partial preſſure; for in the caſe of an incompreſſible fluid, it is demonſtrated by Dr. *Keil*, that under a total or an equal preſſure, it would be impoſſible the yielding body ſhould move.

The

The original and conftituent parts of fluids are by the moderns conceived to be, particles fmall, fmooth, hard, and fpherical; according to which opinion, every particle is of itfelf a folid, or a fixed body; and when confidered fingly, is no fluid, but becomes fo only by being joined with other particles of the fame kind.

'Tis probable that the particles of fluids are exceeding fmall, becaufe their texture has never yet been difcovered by the fineft microfcope; we judge them to be fmooth, becaufe they are found eafily to glide one over another; hard and impenetrable, becaufe no fluid we are acquainted with, the air excepted, is capable of compreffion: we conceive them to be fpherical, that they may only touch in fome points of their furfaces; and fo not only may be the more eafily moved, but alfo form interftices or vacancies between them, which may be proved.

Were fluids not compounded of primary particles, formed as above, but made up of one homogeneous fubftance, without confiftence equally denfe; there would be no difference in their fpecific gravity, and all fluids would be of the fame weight, bulk for bulk, which is contrary to experience.

That fluids have vacuities, will appear upon mixing falt with water, a certain quantity whereof will be diffolved, and thereby imbibed, without enlarging the dimenfions. A fluid's becoming more buoyant, is a certain proof that its fpecific gravity is increafed, and of confequence, that many of its vacuities are thereby filled; after which it may ftill receive a certain quantity of other diffoluble bodies, the particles whereof are adapted to the vacancies remaining,

without adding any thing to its bulk, though the abſolute weight of the whole fluid be thereby increaſed. This might be demonſtrated by weighing a phial of rain water, critically, with a nice balance: pour this water into a cup, and add ſalt to it: refund of the clear liquor, what will again fill the phial; an increaſe of weight will be found under the ſame dimenſions, from a repletion, as has been ſaid, of the vacuities of the freſh water with ſaline particles.

And as fluids have vacuities, or are not perfectly denſe; it is alſo probable, that they are compounded of ſmall ſpheres of different diameters, whoſe interſtices may be ſucceſſively filled with apt materials for that purpoſe: and the ſmaller theſe interſtices are, the greater will the gravity of the fluid always be.

For inſtance: ſuppoſe a barrel be filled with bullets in the moſt compact manner, a great many ſmall ſhot may afterwards be placed in the interſtices of thoſe balls; the vacuities of the ſhot may then be repleniſhed with a certain quantity of ſea ſand; the interſtices of the ſand may again be filled with water; and thus may the weight of the barrel be greatly augmented, without increaſing the general quantity: now this being true with regard to ſolids, is applicable alſo to fluids. For inſtance, river-water will diſſolve a a certain quantity of ſalt; after which it will receive a certain quantity of ſugar, and after that a certain quantity of allum, and perhaps other diſſoluble bodies, and not increaſe its firſt dimenſions.

Was all ſpace abſolutely full of matter, this matter muſt either be fluid or fixed. Was it fixed, there could poſſibly

be

be no motion therein, as is plain both from reafon and experience; it muft therefore be fluid. But a fluid without vacuities will be denfer, and confequently heavier, than all fluids; and if denfer, all bodies will emerge, and fwim therein, by hydroftatical laws, nor could there be fuch a thing as gravity. But as gravity cannot be denied, all fpace therefore cannot be filled, even with a fluid.

Borelli has demonftrated, that the conftituent parts of fluids are not fluid, but confiftent bodies; and that the elements of all bodies are perfectly firm and hard. The incompreffibility of water, proved by the Florentine experiment, is a fufficient evidence alfo, that each primary particle or fpeckle thereof is a perfect and impenetrable folid.

This famous experiment was firft attempted by the great Lord Verulam, who inclofed a quantity of water in lead, and found that it inclined rather to make its way through the pores of the metal, than be reduced to lefs compafs by any force that could be applied. At Florence this experiment was afterwards made more accurately with a globe of filver: this being filled with water and well clofed, was gently preffed, upon which a fmall quantity of water iffued from the globe in form of dew.

Sir Ifaac Newton and others have attempted it fince with globes made of gold and other metals, and with equal fuccefs. Mr. Canton has obferved in fome experiments made by him, that the different ftate of the air makes water to be compreffed at fome times more than at others: but though naturally it may be thus affected, we cannot by any artificial method comprefs it, for as foon as the cold is over, it will return to its former bulk.

The

The Hydrostatic Balance.

THOUGH the hydrometer is the moſt convenient inſtrument for meaſuring the ſpecific weights of fluids, yet for a meaſure of the ſpecific gravity of all ſubſtances, we muſt have recourſe to the hydroſtatic balance: which is conſtructed in various forms; but we ſhall content ourſelves here with deſcribing that which appears of all others the moſt accurate.

Plate IX. Fig. 1. V C G (Plate IX. fig. 1.) is the ſtand or pillar of this hydroſtatic balance, which is to be fixed in a table, From the top A, hangs, by two ſilk ſtrings, the horizontal bar B B, from which is ſuſpended by a ring i, the fine beam of a balance b: which is prevented from deſcending too low on either ſide by the gently ſpringing piece l x y z, fixed on the ſupport M. The harneſs is annulated at o, to ſhow diſtinctly the perpendicular poſition of the examen, by the ſmall pointed index fixed above it.

The ſtrings by which the balance is ſuſpended, paſſing over two pullies, one on each ſide of the piece at A, go down to the bottom on the other ſide, and are hung over the hook at v; which hook, by means of a ſcrew P, is moveable, about one inch and one quarter, backward and forward, and therefore the balance may be raiſed or depreſſed ſo much. But if a greater elevation or depreſſion be required, the ſliding piece S, which carries the ſcrew P, is readily moved to any part of the ſquare braſs rod V K, and fixed by means of a ſcrew.

The

The motion of the balance being thus adjufted, the reft of the apparatus is as follow. H H is a fmall board, fixed upon the piece D, under the fcales d and e, and is moveable up and down in a long flit in the pillar above C, and faftened at any part by a fcrew behind. From the point in the middle of the bottom of each fcale hangs, by a fine hook, a brafs wire a d and a c; thefe pafs through two holes m m, in the table. To the wire a d is fufpended a curious cylindric wire r s, perforated at each end for that purpofe: this wire r s is covered with paper, graduated by equal divifions, and is about five inches long.

In the corner of the board at E, is fixed a brafs tube, on which a round wire h l is fo adapted as to move neither too tight nor too free, by its flat head I. Upon the lower part of this moves another tube Q, which has fufficient friction to make it remain in any pofition required: to this is fixed an index T, moving horizontally when the wire h l is turned about, and therefore may be eafily fet to the graduated wire r s. To the lower end of the wire r s hangs a weight L, and to that a wire p n, with a fmall brafs ball g, about $\frac{1}{4}$ of an inch diameter. On the other fide, to the wire a c, hangs a large glafs bubble R, by a horfe hair.

Let us firft fuppofe the weight L taken away, and the wire p n fufpended by S; and on the other fide, let the bubble R be taken away, and the weight F fufpended at c, in its room. This weight F we fuppofe to be fufficient to keep the feveral parts hanging to the other fcale in equilibrium; at the fame time that the middle point of the wire p n is at the furface of the water in the veffel N. The wire p n is to be of fuch a fize, that the length of one inch fhall weigh four grains.

Now

Now it is evident, ſince braſs is eight times heavier than water, that for every inch the wire ſinks in the water it will become half a grain lighter, and half a grain heavier for every inch it riſes out of the water: conſequently by ſinking two inches below the middle point, or riſing two inches above it, the wire will become one grain lighter or heavier. Therefore, if when the middle point is at the ſurface of the water in equilibrium, the index T be ſet to the middle point a, of the graduated wire r s, and the diſtance on each ſide a r and a s contains a hundred equal parts; then, if in weighing bodies the weight is required to the hundredth part of a grain, it may be eaſily had by proceeding in the following manner.

Let the body to be weighed be placed in the ſcale d. Put the weight X in the ſcale e, and let this be ſo determined that one grain more ſhall be too much, and one grain leſs too little. Then the balance being moved gently up or down, by the ſcrew P, till the equilibrium be nicely ſhewn at o; if the index T be at the middle point a of the wire r s, it ſhews that the weights put into the ſcale e, are juſt equal to the weight of the body. By this method we find the abſolute weight of the body: the relative weight is found by weighing it hydroſtatically in water, as follows.

Inſtead of putting the body into the ſcale e, as before, let it hang with the weight F, at the hook c, by a horſe hair, as at R, ſuppoſing the veſſel O of water were away. The equilibrium being then made, the index T ſtanding between a and r, at the thirty-ſixth diviſion, ſhews the weight of the body put in, to be 1095,36 grains. As it thus hangs let it be immerſed in the water of the veſſel O, and it will become much lighter: the ſcale e will deſcend till the beam

of

of the balance reſt on the ſupport x. Then ſuppoſe 100 grains put in the ſcale d, reſtore the equilibrium preciſely, ſo that the index T ſtand at the thirty-ſixth diviſion above a; it is evident that the weight of an equal bulk of water would, in this caſe, be exactly a hundred grains.

After a like manner this balance may be applied to find the ſpecific gravities of fluids, as is eaſy to conceive from what has been ſaid.

The Hydrometer.

THIS is the moſt eligible of all inſtruments for finding the ſpecific gravity of fluids only, as well for eaſe as expedition.

The globe of the hydrometer ſhould be made of copper, for ivory imbibes ſpirituous liquors, and thereby alters their gravity, and glaſs requires an attention that is incompatible with expedition. The moſt ſimple hydrometer conſiſts of a copper ball B b, to which is ſoldered a braſs wire A B, one quarter of an inch thick. The upper part of this wire being filed flat, is marked *proof*, at m, fig. 3, becauſe it ſinks exactly to that mark in proof ſpirits. There are two other marks at A and B, fig. 2, to ſhew whether the liquor be 1-tenth above, or below proof, according as the hydrometer ſinks to A, or emerges to B, when a braſs weight as C or K, is ſcrewed to its bottom c. There are other weights to ſcrew on, which ſhew the ſpecific gravity of different fluids, quite down to common water.

Plate IX. Fig. 2. and 3.

The round part of the wire above the ball, may be marked fo as to reprefent river water when it finks to R W, fig. 3, the weight which anfwers to that water being then fcrewed on; and when put into fpring water, mineral water, fea water, and water of falt fprings, it will gradually rife to the marks S P, M I, S E, S A; on the contrary, when it is put into Briftol water, rain water, port wine, and mountain wine, it will fucceffively fink to the marks b r, r a, p o, m o. Inftruments of this kind are fometimes called areometers.

There is another fort of hydrometer that is calculated to afcertain the fpecific gravity of fluids to the greateft precifion poffible, and which confifts of a large hollow ball B,
Fig. 4. fig. 4, with a fmaller bolt b fcrewed on to its bottom, partly filled with mercury, or fmall fhot, in order to render it but little fpecifically lighter than water. The larger ball has alfo a fhort neck at C, into which is fcrewed the graduated brafs wire A C, which, by a fmall weight at A, caufes the body of the inftrument to defcend in the fluid with part of the ftem.

When this inftrument is fwimming in the liquor contained in the jar I L M K, the part of the fluid difplaced by it, will be equal in bulk to the part of the inftrument under water, and equal in weight to the whole inftrument. Now, fuppofe the weight of the whole to be four thoufand grains, it is evident we can by this means compare the different dimenfions of 4000 grains of feveral forts of fluids. For if the weight at A be fuch, as will caufe the ball to fink in rain water, till its furface come to the middle point of the ftem 20, and after that, if it be immerfed in common fpring water, and the furface be obferved to ftand

at

at one tenth of an inch below the middle point 20, it is apparent that the ſame weight of each water differs only in bulk, by the magnitude of one tenth of an inch in the ſtem.

Now, ſuppoſe the ſtem to be ten inches long and weigh 100 grains, then every tenth of an inch will weigh one grain; and as the ſtem is of braſs, which is about eight times heavier than water, the ſame bulk of water will be equal to 1-8th of a grain, and conſequently to the 1-8th of 1-4 thouſandth part, that is, 1-32 thouſandth part of the whole bulk. This inſtrument is capable of ſtill greater preciſion, by making the ſtem or neck conſiſt of a flat thin ſlip of braſs, inſtead of one that is cylindrical: for by this means we increaſe the ſurface, which is the moſt requiſite circumſtance, and diminiſh the ſolidity, which neceſſarily renders the inſtrument ſtill more accurate.

To adapt this inſtrument to all purpoſes, there ſhould be two ſtems to ſcrew on and off, in a ſmall hole at a. One ſtem ſhould be a ſmooth thin ſlip of braſs, or rather ſteel, like a watch ſpring ſet ſtraight, ſimilar to that we have juſt mentioned, on one ſide of which is to be the ſeveral marks or diviſions to which it will ſink in different ſorts of water; as rain, river, ſpring, ſea, and ſalt ſpring waters, &c. and on the other ſide you may mark the diviſions to which it ſinks in various lighter fluids, as hot Bath water, Briſtol water, Lincomb water, Cheltenham water, port wine, mountain, madeira, and other ſorts of wines. But here the weight at A on the top, muſt be a little leſs than before, when it was uſed for heavier waters.

But in trying the ſtrength of the ſpirituous liquors a common cylindric ſtem will do beſt, becauſe of its ſtrength and ſteadineſs: and this ought to be ſo contrived, that when immerſed in what is called proof ſpirit, the ſurface of the ſpirit may be upon the middle point 20; which is eaſily done by duly adjuſting the ſmall weight A, on the top, and making the ſtem of ſuch a length, that when immerſed in water, it may juſt cover the ball and riſe to a; but when immerſed in pure ſpirit, it may riſe to the top A. Then by dividing the upper and lower parts A 20, and a 20, into ten equal parts each, when the inſtrument is immerſed in any ſort of ſpirituous liquor, it will immediately ſhew how much it is above or below proof.

Proof ſpirit conſiſts of half water, and half pure ſpirit, that is ſuch as when poured on gunpowder, and ſet on fire, will burn all away; and permits the powder to take fire and flaſh, as in open air. But if the ſpirit be not ſo highly rectified, there will remain ſome water, which will make the powder wet, and unfit to take fire. Proof ſpirit of any kind weighs ſeven pounds twelve ounces per gallon.

The common method of ſhaking the ſpirits in a phial, and raiſing a head of bubbles, to judge by their manner of riſing or breaking, whether the ſpirit be proof or near it, is very fallacious. There is no way ſo certain, and at the ſame time ſo eaſy and expeditious, as this by the hydrometer: which will infallibly demonſtrate the difference of bulks, and conſequently the ſpecific gravities in equal weights of ſpirits, to the thirty, forty, or fifty thouſandth part of the whole, which is a degree of accuracy no one can wiſh to exceed.

My

My friend Mr. Dicas of Liverpool has obtained his Majesty's letters patent for the compleatest hydrometer I have yet seen.

On the Syphon.

IF a small syphon, whose legs are of equal length, be filled with water, and turned downward, the fluid will not run off, but remain suspended therein, so long as it is held exactly level: but when an inclination to either leg is given, whereby one in effect is made shorter than the other, the water will shoot out by the longer leg.

The air is a fluid whose density near the surface of the earth is experimentally found to be to that of water, at a medium, as 1 to 850; so that 850 gallons of air, near the earth weigh as much as one gallon of water. Now, according to the nature of all other fluid bodies, the air presses the surface of all things exposed to it every way equally. When therefore the legs of the syphon, equal in length, are turned down, the weight of the atmosphere above being kept off by the machine, the under air, bearing against and repressing the water, endeavouring to fall out of either of them, with equal force, keeps it in suspence, and prevents its motion. But when by inclining it to either side, we in effect shorten one of its legs, and prolong the other, an advantage is given to the weightier fluid to preponderate or over-weigh; the water then begins to descend, and by its continuity brings away the whole.

And to observe how small an inclination will serve this purpose, one need only take a couple of jars full of water, and

and hang a fmall fyphon, whofe legs are of equal length, upon the edge of one; the external leg whereof will, from the floping of the jar, naturally incline a little, and the fyphon will foon begin to act, by the attraction of cohefion before-mentioned; then taking it on the edge of the other jar, the like will immediately happen: and thus reciprocally may the effect be produced, as often and as fuddenly as you pleafe.

And hence the reafon why in practice the legs of the fyphon are ufually made of unequal lengths; and why the fhorter leg is put into the liquor, and the fluid decanted by the other, will in part appear.

Fig. 5. It is evident from what has been faid, that the two legs of the fyphon being of equal length in the plane A B, are there equally repreffed by the atmofphere; and was the crane filled with liquor only to that height, and held level, no motion of the fluid would follow, till an advantage by inclining it fhould be given as before faid. Inftead of which inclination a length of pipe, of fome inches perhaps, as from B to C in the figure, is commonly added to thefe machines, which, previous to the operation, is ordinarily filled as well as the reft with a grofs fluid, many degrees heavier than a like quantity of air, wherewith it is then compared; by the gravity whereof the oppofite fide becomes greatly over-balanced: and therefore liquors are by this machine ufually decanted with a good deal of rapidity.

Of

Of the Syphon disguised.

A Syphon may be difguifed in a cup, from which no liquor will flow till the fluid is raifed therein to a certain height; but when the efflux is once begun, it will continue till the veffel is emptied. For inftance: Fig. 6 is a cup, in Fig. 6. the center whereof is fixed a glafs pipe A, continued through the bottom at B, over which is put another glafs tube, made air tight at top by means of the cork at C, but left fo open at foot, by holes made at D, that the water may freely rife between the tubes as the cup is filled. Till the fluid in the cup fhall have gained the top of the inmoft pipe at A, no motion will appear: the air however from between the two pipes, being in the mean time extruded, by the rife of the denfer fluid, and paffing down the inner tube, will get away at bottom, and the water, as foon as the top of the inclofed tube fhall be covered thereby, will very foon follow, and continue to rife in this machine, as in the fyphon, till the whole is run off.

This is called by fome a *Tantalus* cup, and to humour the thought, a hollow figure is fometimes put over the inner tube, of fuch length, that when the fluid is got nearly up to the lips of the man, the fyphon may begin to act and empty the cup.

This is in effect no other than if the two legs of the fyphon were both either in the veffel, as in Fig. 7, into which Fig. 7. the water poured will rife in the fhorter leg of the machine, by its natural preffure upwards, to its own level; and when it fhall have gained the bend of the fyphon, it will come away by the longer leg, as already defcribed.

The

The Hydroſtatical Paradox.

THE hydroſtatical paradox, as by ſome it is called, depends on the equal preſſure of the parts of fluids every where at the ſame depth. It is this: any quantity of fluid, however ſmall, may be made to counterpoiſe and ſuſtain any weight, how large ſoever.

Fig. 8. Let A B D G repreſent a cylindrical veſſel, to the inſide of which is fitted the cover C, which, by means of leather at the edge, will eaſily ſlide up and down in the internal cavity, without permitting any water to paſs between its edges and the ſurface of the cylinder. In the cover is inſerted the ſmall tube C F, which is open at top, and communicates with the inſide of the cylinder beneath the cover at C. The cylinder is filled with water and the cover put on. Then, if the cover be loaded with the weight, ſuppoſe of a pound, it will be depreſſed, the water will riſe in the tube to E, and the weight will be ſuſtained. If another pound be added, the water will riſe to F, and the weight will be ſuſtained, and ſo forth, according to the weight added, and the length of the tube. Now the weight of the water in the tube is but a few grains, yet its lateral preſſure ſerves to ſuſtain as much as the weight of a column of water, whoſe baſe is equal to that of the cylinder, and height equal to that in the tube. Thus, the column E C produces a preſſure in the water contained in the cylinder, equal to what would have been produced by the column A a d D; and as this preſſure is exerted every way equally, the cover will be preſſed upwards with a force equal to the weight of A a d D; conſequently if A a d D would weigh a pound, E C will ſuſtain a pound. And the like of other heights

heights and weights. And by diminiſhing the diameter of the tube, any quantity of water, how ſmall ſoever, will, in theory ſuſtain any weight however large.

The ſame may be ſhewn ſimpler, thus, let A G B D repreſent a hollow cylinder of wood, which nearly fills the cavity. In the cylinder, ſuppoſe a little water, whoſe ſurface is g b ; then, if the wooden cylinder be put into the hollow one, the water will riſe between the ſurfaces to a and d, and the wood will be ſuſtained floating. The nearer the wooden cylinder approaches to the ſize of the cavity, the leſs water is neceſſary for the experiment. Fig. 9.

The Hydroſtatic Bellows.

IS perhaps, the beſt machine in the world for demonſtrating the upward preſſure of fluids. It conſiſts of two thick oval boards, each about 16 inches broad, and 18 inches long, covered with leather, to open and ſhut like a common bellows, but without valves; only a pipe about three feet high, is fixed into the bellows. Let ſome water be poured into the pipe, which will run into the bellows, and ſeperate the boards a little. Then lay three weights, each weighing 100 pounds, upon the upper board, and pour more water into the pipe, which will run into the bellows, and raiſe up the board with all the weights upon it, and if the pipe be kept full, until the weights are raiſed as high as the leather which covers the bellows will allow them, the water will remain in the pipe, and ſupport all the weights, even though it ſhould weigh no more than a quarter of a pound, and they 300 pounds: nor Fig. 10.

will all their force be able to cauſe them to deſcend and force the water out at the top of the pipe.

The reaſon of this will be made evident, by conſidering what has been already ſaid of the reſult of the preſſure of fluids of equal heights, without any regard to the quantities. For, if the hole be made in the upper board, and a tube be put into it, the water will riſe in the tube to the ſame height that it does in the pipe; and would riſe as high (by ſupplying the pipe) in as many tubes as the board could contain holes. Now, ſuppoſe only one hole to be made in any part of the board, of an equal diameter with the bore of the pipe and that the pipe holds juſt one quarter of a pound of water; if a perſon claps his finger upon the hole, and the pipe be filled with water, he will find his finger preſſed upward with a force equal to a quarter of a pound; and as the ſame preſſure is equal upon all equal parts of the board, each part whoſe area is equal to the area of the hole, will be preſſed upward with a force equal to that of a quarter of a pound; the ſum of all which preſſures againſt the under ſide of an oval board 16 inches broad, and 18 inches long, will amount to 300 pounds; and therefore, ſo much weight will be raiſed up and ſupported by a quarter of a pound of water in the pipe,

How a man may raiſe himſelf upwards by his breath.

Hence, if a man ſtands upon the upper board, and blows into the bellows through the pipe B, he will raiſe himſelf upward upon the board: and the ſmaller the bore of the pipe is, the eaſier he will be able to raiſe himſelf. And then, by clapping his finger on the top of the pipe, he can ſupport himſelf as long as he pleaſes; provided the bellows be air tight, ſo as not to loſe what is blown into it.

Upon

Upon this principle of the upward preſſure of fluids, a piece of lead may be made to ſwim in water, by immerſing it to a proper depth, and keeping the water from getting above it. Let C D be a glaſs tube open throughout, and E F G a flat piece of lead, exactly fitted to the lower end of the tube, not to go within it, but for it to ſtand upon; with a wet leather between the lead and the tube to make cloſe work. Let this leaden bottom be half an inch thick, and held cloſe to the tube, by pulling the packthread I H L upward at L with one hand, whilſt the tube is held in the other by the upper end C. In this ſituation, let the tube be immerſed in water, in the glaſs veſſel A B, to the depth of ſix inches below the ſurface of the water at K; and then the leaden bottom E F G will be plunged to the depth of ſomewhat more than eleven times its own thickneſs; holding the tube at that depth, you may let go the thread at L; and the lead will not fall from the tube, but will be kept to it by the upward preſſure of the water below it, occaſioned by the height of the water at K above the level of the lead. For, as lead is 11,33 times as heavy as its bulk of water, and is in this experiment immerſed to a depth ſomewhat more than 11,33 times its thickneſs, and no water getting into the tube between it and the lead, the column of water E a b c G below the lead, is preſſed upward againſt by the water K D E G L all around the tube; which water being a little more than 11,33 times as high as the lead is thick, is ſufficient to balance and ſupport the leg at the depth K E. If a little water be poured into the tube upon the lead, it will increaſe the weight upon the column of water under the lead, and cauſe the lead to fall from the tube to the bottom of the glaſs veſſel, where it will lie in the ſituation b d. Or if the tube be raiſed a little in the water, the lead will fall by its own weight, which will then be too great for

How lead may be made to ſwim in water.

Fig. 11.

the preſſure of the water around the tube, upon the column of water below it.

How light wood may be made to lie at the bottom of water. Fig. 11.

Let two pieces of wood be planed quite flat, ſo as no water may get between them when they are put together: let one of the pieces as b d, be cemented to the bottom of the veſſel A B, and the other piece be laid flat and cloſe upon it, and held down to it by a ſtick, whilſt water is poured into a veſſel; then remove the ſtick, and the upper piece of wood will not riſe from the lower one; for as the upper one is preſſed down, both by its own weight and the weight of all the water over it, whilſt the contrary preſſure of the water is kept off by the wood under it, it will lie as ſtill as a ſtone would do in its place. But if it be raiſed ever ſo little at any edge, ſome water will then get under it, which being acted upon by the water above, will immediately paſs it upward; and as it is lighter than its bulk of water, it will riſe, and float upon the ſurface of the water.

All fluids weigh juſt as much in their own elements as they do in open air. To prove this by experiment, let as much ſhot be put into a phial, as, when corked will make it ſink in water: and being thus charged, let it be weighed firſt in air, and then in water, and the weights in both caſes wrote down. Then as the phial hangs ſuſpended in water, and counterpoiſed, pull out the cork, that water may run into it, and it will deſcend and pull out that end of the beam. This done, put as much weight into the oppoſite ſcale as will reſtore the equipoiſe, which weight will be found to anſwer exactly to the additional weight of the phial when it is again weighed in air, with the water in it.

The

The velocity with which water ſpouts out at a hole in the ſide or bottom of a veſſel, is as the ſquare root of the depth or diſtance of the hole below the ſurface of the water. For in order to make double the quantity of a fluid run through one hole, as through another of the ſame ſize, it will require four times the preſſure of the other, and therefore muſt be four times the depth of the other below the ſurface of the water: and for the ſame reaſon three times the quantity running in an equal time through the ſame ſort of hole, muſt run with three times the velocity; and conſequently muſt be nine times as deep below the ſurface of the fluid, and ſo on. To prove this by an experiment, let two pipes, as C and g, of equal ſized bores, be fixed into the ſide of the veſſel A B; the pipe g being four times as deep below the ſurface of the water at b in the veſſel as the pipe C is; and whilſt theſe pipes run. let water be conſtantly poured into the veſſel, to keep the ſurface ſtill at the ſame height. Then, if a cup that holds a pint be placed ſo as to receive the water that ſpouts from the pipe C, and at the ſame moment a cup that holds a quart be ſo placed as to receive the water that ſpouts from the pipe g, both cups will be filled at the ſame time by their reſpective pipes.

The velocity of ſpouting water.

Fig. 12.

The horizontal diſtance to which a fluid will ſpout from a horizontal pipe, in any part of the ſide of an upright veſſel below the ſurface of the fluid, is equal to twice the length of a perpendicular to the ſide of the veſſel, drawn from the mouth of the pipe to a ſemi-circle deſcribed upon the altitude of the fluid; and therefore, the fluid will ſpout to the greateſt diſtance poſſible from a pipe, whoſe mouth is at the center of the ſemi-circle; becauſe a perpendicular to its diameter (ſuppoſed parallel to the ſide of the veſſel) drawn from that point is the longeſt that can poſſibly be drawn

The horizontal diſtance to which water will ſpout from pipes.

from

from any part of the diameter to the circumference of the ſemi-circle. Thus, if the veſſel A B be full of water, the horizontal pipe D be in the middle of its ſide, and the ſemi-circle N d c b be deſcribed upon D as a center, with the radius or ſemi-diameter D g N or D f b, the perpendicular D d to the diameter N D b, is the longeſt that can be drawn from any part of the diameter to the circumference N d c b. And if the veſſel be kept full, the jet G will ſpout from the pipe D, to the horizontal diſtance N M, which is double the length of the perpendicular D d. If two other pipes as C and E, be fixed into the ſide of the veſſel at equal diſtances above and below the pipe D, the perpendicular C c, and E c, from theſe pipes to the ſemi-circle will be equal; and the jets F and H ſpouting from them will each go to the horizontal diſtance N K; which is double the length of either of the equal perpendiculars C c or E H.

Of Suction by Machines.

THE quantity of the air's preſſure may be demonſtrated either by experience on the pump itſelf, or by its equipoiſing, and at a medium ſuſtaining 29½ inches of mercury, a fluid near fourteen times heavier than water, in the barometer. And that whereby we know that the air's preſſure on the ſurface of the fluid cauſes the water to riſe in the pump, and become certain that it proceeds from no property, power or efficacy in ſuction, is, that in the air, water, and even a fluid ſo denſe as mercury, may be raiſed by proper machines; but if the air's preſſure be removed, it cannot be raiſed at all; as may be ſhewn by an exhauſting ſyringe, commonly termed a ſucking ſyringe, to diſtinguiſh it from a forcing or injecting one, or by a common pump.

Let

Let this be fixed to a tranfparent tube, and the lower end thereof put into a jar of mercury, inclofed within a tall receiver; before the air is exhaufted, if the pifton be raifed the mercury will immediately follow; after it is exhaufted no fuch effect will appear. Experiment.

This being determined and certain, all we are to underftand by fuction is, that whenever by any mechanical concontrivance, the preffure of the air is in any place abated, the adjacent matter, urged on by the weight of the atmofphere, will tend thither; and if that matter be fluid, it will rife fo far above its common level, till by its abfolute weight, a juft equality is made, to preferve the equilibrium which ought every where to exift by the eftablifhed laws of nature.

Before *Galileo*'s time, philofophers fancied this rife of water and other fluids, to be the refult of nature's *abhorring a vacuum*. Not to cavil with the term *abhor*, which can only properly be applied to animal affection; but to take it as it was probably intended, in a metaphorical fenfe; we may reafonably enquire, how nature came to abhor a vacuum in the cafe before us, to the height of between 30 and 40 feet from the furface of the earth, and no farther? Had fhe abfolutely abhorred a vacuum, this abhorrence would have been indefinite; and water, upon this principle, might have been raifed 3000 as well as 30 feet high. But this is otherwife in fact; and by experience we find that nature has no antipathy to a vacuum; but that in general, *one heavy body only rifes, when another fuperior in weight defcends.*

The rife of water in the fucking pump, by the general preffure of the atmofphere incumbent on the furface of the water in the well, a preffure not to be excluded from the bowels

bowels of a body ſo porous as the earth, being thus ſettled, the parts of this machine, with the manner in which they act, will next come under conſideration.

On the Pump.

THIS uſeful piece of mechaniſm was firſt invented by *Cteſebes*, a mathematician of Alexandria, about 120 years before Chriſt. When the air's preſſure came afterwards to be known, it was much improved, and is now brought to a great degree of perfection.

Of this machine there are ſimply three kinds, viz. the the ſucking, the forcing, and the lifting pump. By the two laſt water may be raiſed to any height, with an adequate apparatus and ſufficient power: by the former it may by the general preſſure of the atmoſphere on the ſurface of the well-water, be raiſed no more than 33 feet, as was before hinted, though in practice it is ſeldom applied to the raiſing it much above 28; becauſe from the variations obſerved on the barometer, it is apprehended thrt the air may on certain occaſions be ſomething lighter than 33 feet of water; and whenever that ſhall happen, for want of the counterpoiſe, this pump may fail in its performance.

On the ſucking Pump.

Plate X. Fig. 1. THE common and moſt uſual pump, conſiſts of a pipe open at both ends, in which there is a ſliding piſton as large as the bore, which by means of the hand, or ſome other contrivance may be moved up and down without ſuffering any

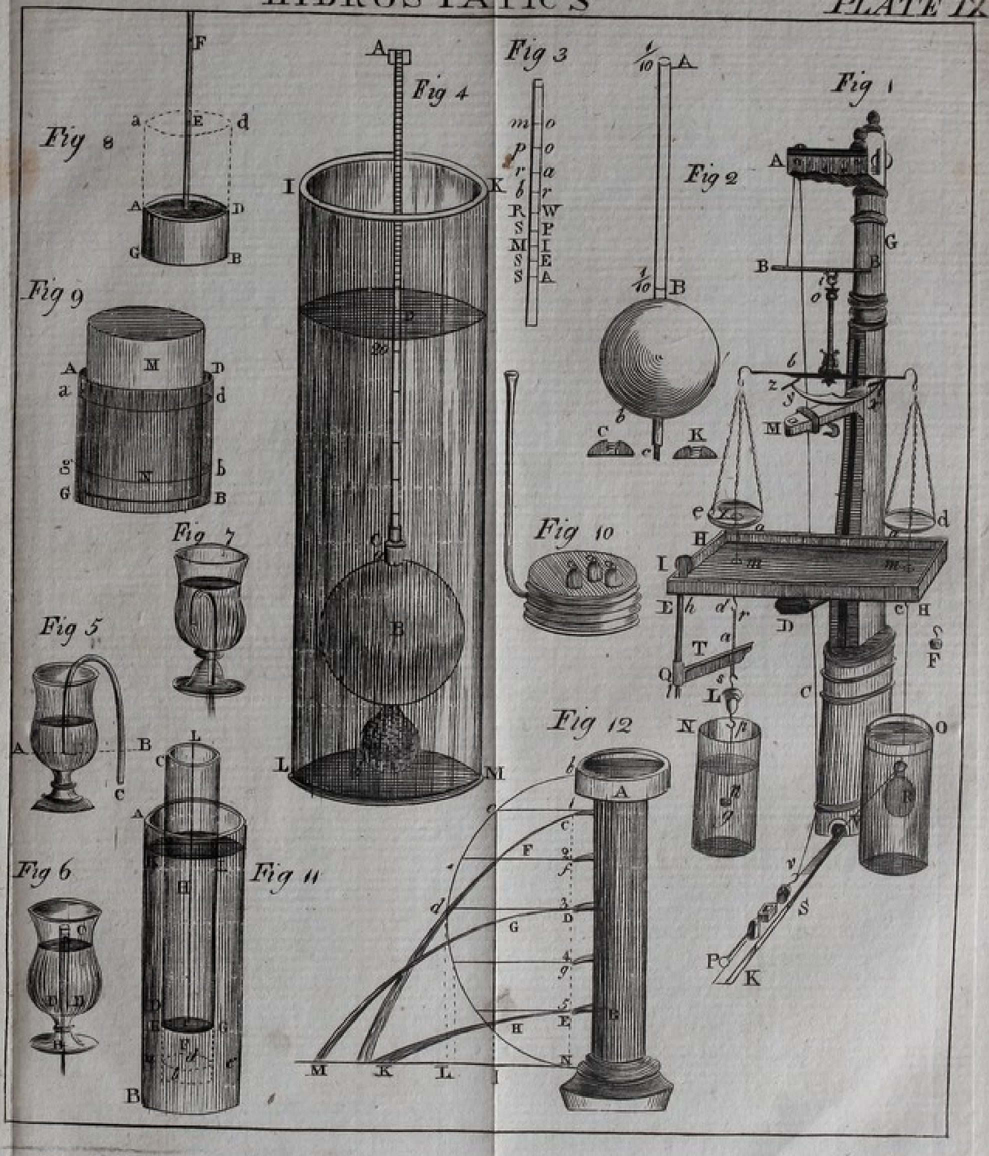


Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Fig 7
Fig 8
Fig 9
Fig 10
Fig 11
Fig 12

any air to come between it and the fides of the pipe, which is alfo called the barrel.

If the lower end of this pipe and pifton be put into water, and the pifton, by lifting away the column of upper air, a vacuum will be made in the pipe, upon which the atmofphere preffing upon the well water, will force it to follow the pifton, even to the height of 33 feet, if the ftroke could be of that continued length; and if there be a valve or clack, fomething like a trap door, to fhut downward, as Fig. 2. placed in fome convenient part of the Fig. 2. pipe, below the water fo raifed, as at C, Fig. 1, it will Fig. 1. be retained therein; but if this contrivance is wanting, upon letting down the pifton again, the water will recede along with it towards the fpring; fo that by the motion of the pifton up and down, the water indeed might rife and fink in the barrel at every ftroke; but without an under valve to confine and keep it there, none can be drawn for fervice in the common way.

The frame A of thefe valves is ufually made of wood, Fig. 2. exactly fitted to the bore of the pipe, and not over thick, that it may not ftop too much of the water way, to this the hinge of the leather flap B, which is ufually lined with lead, not only to make it fall readily, but to give it ftrength fufficient to bear the weight of the water raifed, without warping, is commonly nailed.

In this kind of pump there is, befides this fixed valve, a moveable one for conveniency, placed in the pifton as at D, Fig. 1. alfo opening upwards, or the way the water is to rife. Such a pifton is commonly called the bucket.

When the bucket of this machine defcends, if the bore of the pipe be already full of water, the refiftance thereof will pufh open the moving valve, and part of the water will get above, and when the pifton is drawn upwards, this valve will clofe under the incumbent weight, and the water will be raifed by the force applied: fo that, whenever the moveable valve by being raifed, is made to lift the weight of the column, as well of air as of water lying thereon, the fixed valve is difcharged of all preffure; and then a quantity of water, precifely equal to that lifted and drawn off by the bucket, will by the ordinary preffure of the atmofphere, as was faid, on the water in the well, be forced or rather weighed up through it, to replenifh the pipe or barrel. This alternate action of the two valves is vifible through the glafs pumps, and is worthy of remark.

But if the bore of this machine be full of air only, before water can be drawn, that air muft be exhaufted, which may be done if the pifton valve be tight, by the ordinary motion thereof: but for the greater certainty and expedition, water is commonly poured thereon down the pipe, vulgarly called fetching the water; which is of no other ufe than to wet the valves, and fupple the collar of leathers fixed to the pifton, and fpread it that it may lie clofe to the fides of the barrel, and fuffer neither the upper air or water to efcape by it, when it is moved up and down.

The firft ftroke of the pump, if fufficiently long, will make a vacuum in the pipe; if otherwife an approach is only made towards it, and but a part of the contained air lifted away; upon which the air remaining in the cavity of the bore, from its natural fpring will be confiderably dilated. To reftore the natural denfity whereof, the atmofphere then

preffing

preſſing harder on the well water, than the dilated air does on that in the pipe, will cauſe the water to riſe therein ſo far, as that, together with the included air (yet a little rarefied by the depending weight of water) it ſhall juſt counterpoiſe the weight of the outward air. The very ſame thing will happen again on a repetition of the ſtroke, till by degrees the water ſhall have reached the moving valve; and then the proceſs will go on ſteadily as before deſcribed. And water, by means of this contrivance, may be raiſed to any height whatever, if the power applied be ſufficient to lift the weight, and the pipes ſtrong enough to bear the fluid's natural preſſure.

The preſſure on the pipes in pump work is in proportion to the ſtanding height of the fluid above the part conſidered: but the weight incumbent on the bucket, or moving valve of a pump, in action, is nearly proportionable to that of a column of water raiſed. For though the puſh of the atmoſphere on the ſurface of the ſpring, when the bucket riſes be really equal to the weight of 33 feet of water; yet is this aſſiſtance counterbalanced exactly by the weight of the atmoſphere, ever incumbent on the ſurface of the water thereby raiſed: ſo that all the advantage to be obtained by, or expected from hydraulic machines, or engines to raiſe water, as well indeed as from all other pieces of mechaniſm whatever, is only the putting matters into a convenient method of being executed, and the performance depends on the moving power entirely, under the diſadvantage of friction always againſt it.

Of the Difpofition of Pump Work.

A Pump therefore intended to raife water to any height whatever, will always work as eafy, and require no greater power to give motion to the bucket, if both the valves be placed towards the bottom of the pipe, than if they were fixed 33 feet above the furface of the water.

The playing of the pifton thus low in the pipe, will befides prevent an inconvenience which might happen, was it placed above, viz. in cafe of a leak beneath the bucket, which, in a great length of pipe, may very eafily happen, the outward air getting through, would hinder the neceffary rarefaction of the air in the barrel, on moving the pifton; and confequently the pump might fail in its operation. This can only effectually be prevented by placing the pump work in or near the water. In which cafe, fhould any leak happen upward, it will only occafion the lofs of fome of the water, without any other inconvenience. And the leather valves being thus kept under water, will always be found fupple, pliant, and in a fit condition to perform their office.

It may indeed be here objected, that the fpecific weight of the iron rod, to which the bucket is fixed, will be an incumbrance to the working of the pump; but if it be made of oak, when well foaked, it will be nearly of the fame fpecific weight with water, and fo no burden on the moving power, when the ftroke is fetched.

Placing the pump-work, that is the valve and pifton, pretty low and near together, will alfo prevent the inconvenience

venience of our not being able in all cafes to fetch up water from the fpring, by the ordinary pump, when of an equal bore, by reafon of the fhortnefs of the ftroke, which therefore cannot rarefy the air fufficiently to bring the water up to the pifton from the lower valve. For inftance: take a fmooth barrelled pump, 21 feet long, having its pifton fetching fuppofe a foot ftroke, placed above, and the clack or fixed valve at the other end below. By the playing of the pifton, admit it poffible for water to rife 11 feet, or if you will, let water be poured on the clack, to the height of 11 feet; and refit the pifton. There will remain ftill 9 feet of air between it and the water, which cannot be fufficiently rarefied by a foot ftroke, to open the clack, or fetch up more water: for in this cafe the air can only be rarefied in the proportion of 9 to 10; whereas, to make a bare equilibrium with the atmofphere, it ought to be as 9 to $13\frac{1}{2}$: fince, as 22 or the complement of 11, to 33 feet of water, the weight of the whole atmofphere, is to 33 feet or the atmofphere; fo is the interval fpoken of, 9 to $13\frac{1}{2}$; to compleat which the ftroke ought to be at leaft $4\frac{1}{2}$ feet long.

However, by filling the whole void between the pifton and clack at firft with water, this laft objection might be removed.

Of the Difpofition of Pipes of Conduit.

In fome cafes the pump cannot be placed conveniently perpendicular to the well; for example, being to raife water out of the well at A by means of a pump at B, the beft way will be to carry the barrel as low as the fpring is, communicating Fig. 3.
therewith

therewith by means of the pipe at C. The bucket then playing in the barrel B C will have the fame effect, as if the well was made perpendicular to the pump; becaufe the water, by its proper weight, will always replenifh B C, through A, to the level of the well water at F.

And if it fhould happen, from fome confiderable impediment, that the barrel cannot go down to the well directly, it may be led about any other way for fake of convenience. And then making the pipe of conveyance E, lefs in diameter than the barrel, it will fooner be exhaufted of air, by moving the pifton, and the water will follow very brifkly, as by the leaden pump at D.

It will, however, always be more eafy to draw water with pipes that are large, and of an equal bore throughout; becaufe the water will have a lefs velocity in them, and the friction will be in proportion lefs. Upon this account the pumps ordinarily made by the plumbers, go not fo eafy as thofe bored out of trees; becaufe, by making their pipe that brings up water from the fpring fo much lefs than the bucket, they, as it were, wire-draw the water raifed. If the barrel, for inftance, be four inches in diameter, and the pipe of conduit one, it will in rifing move fixteen times as faft through this as it will in that, to the expence of needlefs labour, as well as the great wear and friction of the machine.

For the like reafon it will alfo be a fault to bore a pump conically upward, becaufe the water cannot with freedom get away fo faft, as a vacuum may be made in the moving pifton; and the reflection of the water from the fides, will always be a hindrance to the operation.

In

In practice, however, it is generally obferved, that fuch leaden pumps as work pleafantly, and are light upon the hand, have the water-way in the fucking pipe nearly equal to 1-fourth of the area of the barrel; and accordingly an inch and half pipe will pretty well fupply a three inch barrel; and a four inch barrel fhould have a leading pipe nearly two inches in diameter.

Of the Lifting Pump.

THE ftructure of the lifting pump differs from that of the fucking pump in nothing but the difpofition. As that has its fixed valve below, and the moveable one above, in the barrel A B, (Fig. 1.) this is juft the contrary, as C and D. As the bucket or pifton of that is moved by a rod within the bore of the pipe, this is fo by means of a ftrong frame fixed to a rod without at E. As in that, it is of advantage, for fear of a leak, to have the pump work, if poffible, in or near the fource of water; this in practice is commonly fo done, and for that reafon is very feldom fubject to any failure in its performance. An elbow in this kind of pump, to lead the lifted water clear of the playing of the rod, which of neceffity muft move perpendicularly, is unavoidable. The friction occafioned hereby will however always be lefs the nearer this bend comes to a ftraight line. Fig. 4.

From the name and ftructure of this machine, it may be imagined, perhaps, that the air's preffure is not of equal fervice to this kind of pump, as to the former; but it is quite otherwife. For if both valves be not perfectly air tight, water cannot be well raifed thereby: but in cafe neither

neither of them is defective, water will be raifed to very good purpofe, by much the fame kind of procefs as that of the fucking pump, before explained. Nor is there any doubt but that if too machines, a fucking and a lifting pump, were made of equal bores, wrought with equal force and were in every circumftance alike, they would be found of equal fervice in raifing water.

On the Forcing Pump.

Fig. 5. THIS pump confifts of a barrel A B, a pifton or forcer C, leathered upwards, that it may withftand the preffure of the atmofphere from above, that fo by fucking, when raifed, it may bring up the water to fupply the barrel; and 'tis alfo leathered downwards, that, when repreffed, it may refift the weight of the water to be forced up, or raifed for ufe. There are always two fixed valves in this kind of pump; one in fome convenient part of the fucking pipe, as at D, the other in the branching or forcing pipe, as E. Thefe ought in like manner to be air tight, and fo difpofed as to let the water freely rife, but are abfolutely to hinder its return.

When the forcer is firft moved upwards in the barrel, the air between that and the water below, having room to dilate, by its natural fpring, will of courfe be rarefied therein; the preffure of the atmofphere then being intercepted by the force of the barrel A B on one hand, and by the upper valve at E in the branching pipe on the other, the water will rife from the fpring into A B, for the reafon already given: and repeated ftrokes of the pifton will fetch up the fluid to the forcer, and at length fill the cavity of the

pipes

pipes between the fixed valves D and E. This done, the water in this manner fucceffively raifed, being hindered from going down again by the lower valve, will be preffed by the forcer every time it defcends, and be thereby obliged to make its way where the leaft refiftance is, viz. through the upper valve at E. And whenever on the rifing of the forcer, this preffure intermits, the valve at E will immediately clofe under the weight of the upper water, and prevents its return that way, while the pifton is rifing with a frefh fupply; and this is repeated at every ftroke of the forcer.

Defcription of a Pump invented by M. de la Hire, which raifes Water equally quick by the Defcent as by the Afcent of the Pifton in the Pump-barrel.

A A is a well in which the lower ends of the pipes B Fig. 6. and C are placed. D is the pump barrel, into the lowermoft end of which the top of the open pipe B is foldered, and in the uppermoft end the hollow pipe S is foldered, which opens into the barrel, and the top of the pipe C is foldered into that piece. Each of thefe pipes has a valve on its top, and fo have the crooked pipes E and F, whofe lower ends are open into the pump barrel, and their upper ends into the box G.

H is the pump handle, its center of motion is at I; and as it is moved up and down, it moves the folid plunger K up and down in the barrel, by the ftraight rod or fpear L, which moves air-tight in a long collar of leather in the neck M; and the plunger never goes higher than K, nor

lower than D; so that from K to D is the length of the stroke.

As the plunger rises from D to K, the atmosphere (pressing on the surface of the water A A in the well) forces the water up the pipe B, through the valve b, and fills the pump barrel with water up to the plunger; and during this time, the valves e and S lie close and air-tight on the tops of the pipes E and C.

When the plunger is up to its greatest height at K, it stops there for an instant, and in that instant the valve b falls, and stops the pipe B at top. Then, as the plunger goes down, it cannot force the water between K and D back through the close valve b, but forces all that water up through the crooked pipe E through the valve e, which then opens upward by the force of the water; and this water, after having filled the box G, rises into the pipe N, and runs off by the spout at O.

During the descent of the plunger K, the valve f falls down, and covers the top of the crooked pipe F; and the pressure of the atmosphere on the well A A forces the water up the pipe C, through the valve S, which then opens upward by the force of the ascending water; and this water runs from S into the pump barrel, and fills all the space in it above the plunger.

When the plunger is down to its lowest descent at D, and stops there for an instant, in that instant the valve S falls down, and shuts the top of the pipe C: and then, as the plunger is raised, it cannot force the water above it, back through the valve S, but drives all that water up to the crooked

crooked pipe F, through the valve f, which opens upward by the force of the afcending water, which water after filling the box G, is forced up from thence into the pipe N, and runs off by the fpout at O.

And thus as the plunger defcends, it forces the water below it up the pipe E; and as it afcends, it forces the water above it up the pipe F, the preffure of the atmofphere filling the pump barrel below the plunger through the pipe B while the plunger afcends, and filling the barrel with water above the plunger, through the pipe C, as the plunger goes down.

And thus there is as much water forced up the pipe N to the fpout O by the defcent of the plunger, as by its afcent; and, in each cafe, as much water difcharged at O as fills that part of the pump barrel as the plunger moves up and down in.

On the top of the pipe O is a clofe air veffel P. When the water is forced up above the fpout O it compreffes the air in the veffel P; and this air, by the force of its fpring acting on the water, caufes the water to run off by the fpout O in a conftant and (very nearly) equal ftream.

Whatever the height of the fpout O be above the furface of the well, the top S of the pipe C muft not be 32 feet above that furface; becaufe if that pipe could be entirely exhaufted of air, the preffure of the atmofphere in the well would not force the water up the pipe to a greater height than 32 feet. And if S be within 24 feet of the furface of the well, the pump will be fo much the better.

As the collar of leathers within the neck M is apt to dry and ſhrink when the pump is not uſed, and conſequently to let air get into the pump barrel, which would ſtop the operation of the atmoſphere in the pipe C; I think collars of old hats might be uſed inſtead of leathers, as they would not be liable to that inconvenience,

It matters little what the ſize of the pipe N be, through which the water is forced up to the ſpout: but a great deal depends on the ſize of the pump barrel, and according to the height of the ſpout O above the ſurface of the well, the diameter of the bore of the barrel ſhould be as follows:

For 10 feet high the bore ſhould be 6. 9 inches; for 15 feet 5, 6; for 20 feet 4. 9; for 25 feet 4. 4; for 30 feet 4. 0; for 35 feet 3. 7; for 40 feet 3. 5; for 45 feet 3. 3; for 50 feet 3. 1; for 55 feet 2. 9; for 60 feet 2. 8; for 65 feet 2. 7; for 70 feet 2. 6; for 75 feet 2. 5; for 80 feet 2. 5 will do; for 85 feet 2. 4; for 90 feet 2. 3; for 95 feet 2. 2; and for 100 feet the diameter of the bore ſhould not exceed 2. 1 or 2. 2 inches at moſt. If theſe proportions are attended to, a man of common ſtrength may raiſe water 100 feet high by one pump as eaſily as he could raiſe it 10 feet high by another.

In this pump the pipes B and C ſeem to be rather too ſmall, which will cauſe the water riſing in them to have a great deal of friction from the quickneſs of its motion: and whoever makes ſuch a pump, will find it very difficult to make the leathers in the neck M water tight, ſo as that no water ſhall be forced out that way when the piſton is drawn up.

Another

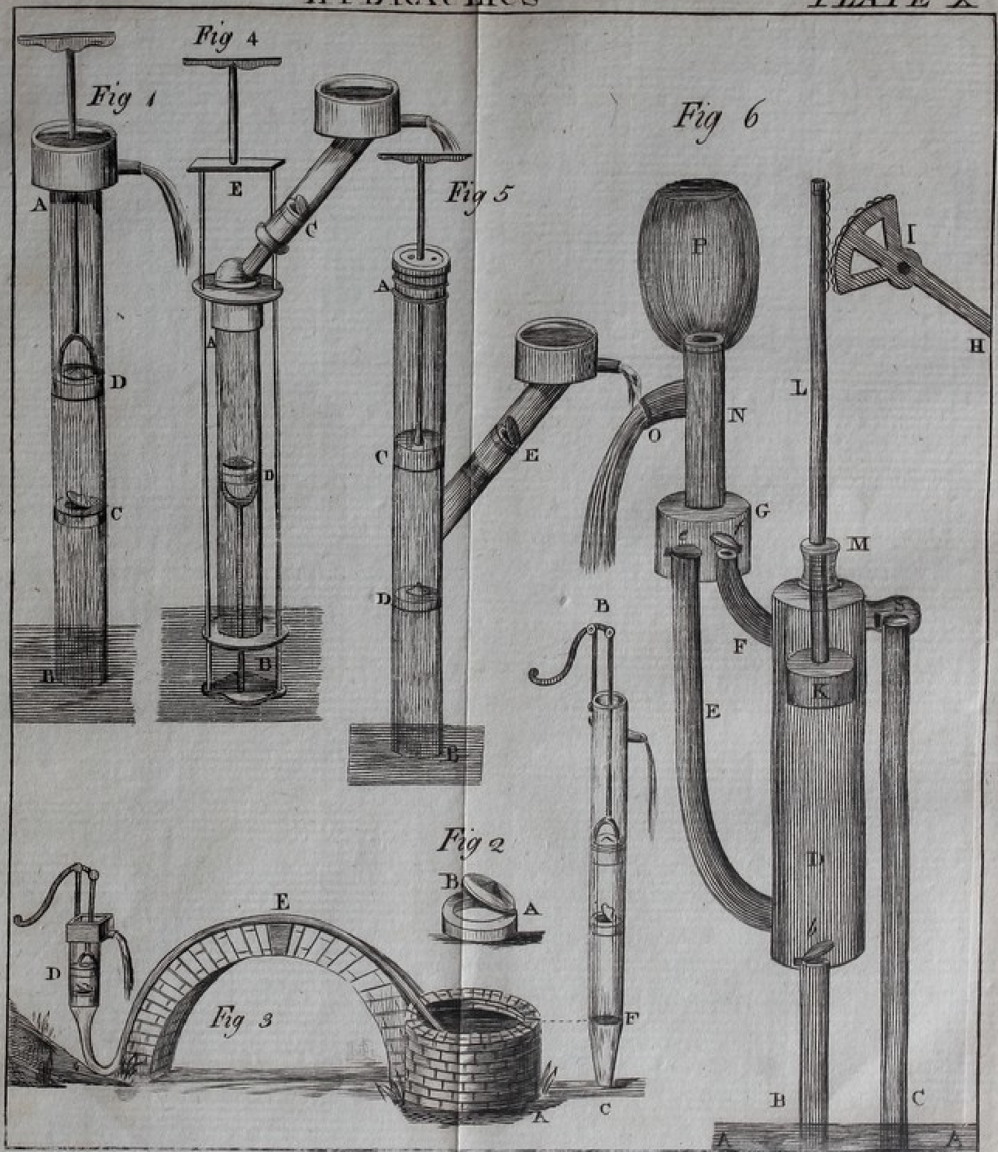


Fig 1
A
D
C
B
Fig 4
E
C
A
D
B
Fig 5
A
C
E
D
B
Fig 6
P
I
H
L
N
O
G
M
F
K
E
D
B
C
A
A
Fig 2
B
A
Fig 3
E
D
F
C

Another Pump on a more ſimple Conſtruction, invented by Mr. Noble.

THIS pump deſerves notice, as it keeps a continual ſtream; being compoſed only of one ſtraight pipe, or tube, and two piſtons, having each a bucket and a valve; it raiſes as much water with the ſame power and in the ſame time as two barrels with four valves will do; and being ſimple in its principles, may be conſtructed reaſonable, compared with M. de la Hire's pump. Plate XI. Fig. 1.

A is a ſtreight tube, or barrel, in which two buckets work; the bucket B, is worked by the rod C, and the bucket D is worked by the rod E; which rod goes through a hole in the bucket B, and is moved up and down by two circular pieces of wood F, fixed to two handles g, g, which cauſes one bucket to aſcend with its load and ſo *viſa verſa.*

An Engine for raiſing Water by a continual Stream, by means of a hair Rope, invented by Sieur Vera.

A, is a wheel 4 foot over, having an axis and a winch; B B, two pullies fourteen inches diameter, in order to keep the ropes to a proper diſtance in the well, and be in contact with a greater ſurface of the wheel; C C, a hair rope near one inch diameter; D, a reſervoir to collect the water; E, a ſpout to convey the water from the reſervoir; F, the top of the well; G, the ſurface of the water in the well; H, a frame in which the lower pulley I is fixed; I, a pulley under- Fig. 2.

der

der which the rope runs, in order to keep it tight; K, the handle to turn the wheel; L, L, L, a box made of thin boards, in order to collect the water into the refervoir D.

When the handle K is turned about with a confiderable velocity, the water, which adheres to the rope C C, (in wells not very deep) is very confiderable; the rope thus paffes through the tube D, which, being 5 or 6 inches higher than the bottom of the refervoir, hinders the water from returning back into the well, and is conveyed in a continual ftream through the fpout E. I have feen fome of the above engines improved by Mr. *Stamford*, which have raifed a greater quantity of water than any perfon, unfkilled in hydraulics, could fuppofe in the fame time, from fuch a fimple contrivance.

An Engine to raife Water by Fire.

The Marquis of Worcefter, in his *Century of Inventions*, (printed A. D. 1663) was the firft who propofed raifing great quantities of water by the force of fire, turning water into fteam; and he mentions fome engine of this kind, which he faw, which played a continual ftream in the manner of a fountain, 40 feet high. He alfo fays, that a perfon attending it, turned two cocks; that one veffel of water being confumed, another begins to force and refill with cold water; and this alternately and fucceffively, the fire being attended and kept as equal as poffible.

Captain Savery, having read this account, immediately attempted to raife water by fire, and was the firft who erected an engine for this purpofe, of the form we have fince had them

them. To ſecure the invention to himſelf, he bought up all the marquis's books that he could find, and burnt them; and then gave it out that he diſcovered the method by accident. He made many experiments to bring the machine to perfection, and erected ſeveral for gentlemen's ſeats, but could not ſucceed for mines, the depth from which water was to be raiſed from thence, being ſo great, that it required the ſteam too dangerouſly ſtrong to be attempted in his way.

Thus the progreſs of the engine was ſtopped, till long afterwards Mr. Newcomen, an ironmonger, and Mr. John Cawley, a glazier, contrived another way to raiſe water by fire, where the ſteam to raiſe the water from the greateſt depths of mines, is not required greater than the preſſure of the atmoſphere; and this is the preſent ſtructure of the common engine, and which is now of about 80 years ſtanding.

References to the common Fire Engine.

A the boiler.

B the cylinder.

C the injection cock.

D the ſteam cock, or regulator.

E the ſnifting Clack.

F the eduction pipe, or ſinking pipe.

G the

G the eduction valve.

H the ſafety valve.

I the piſton.

K the lever beam.

L Weights to counterpoiſe the piſton, and to preſs the forcer down in the pump barrel M, to drive the water through the pipe or ſpout N.

O a ciſtern to hold the injection water.

P an air veſſel to hinder the pipe N from burſting, and keep a regular ſtream.

Fig. 3. A is a copper veſſel, partly filled with water to d e, which being ſet over a fire and made to boil, will fill the upper part A D with a vaſtly elaſtic vapour, the ſufficient ſtrength whereof is known by its forcing open a valve at H: this heated elaſtic ſteam is, by turning a cock at D, let into the barrel B, where by its elaſtic force it raiſes the piſton I which drives the air above it through a proper clack at the top. After this, that the piſton may by its weight deſcend, a little cold water from the ciſtern O, is let in at the bottom, by turning a cock at C, which, in form of a jet, condenſes the hot ſteam in the barrel, into 13000 times leſs ſpace than it took up before, which makes a ſufficient *vacuum* for the piſton to deſcend in. The piſton I and lever K, being thus put into motion, do accordingly raiſe and depreſs the piſton a, in the barrel M of the forcing pump, on the other ſide; which by the pipe O, draws the water from the depth W, and forces it to riſe and ſpout through the

the tube N, continued to any height at pleaſure. This engine is uſed to draw the water from coal pits and other mines. There are various other engines of a more complex ſtructure; but as they act upon the ſame common principle, it is needleſs to ſay any thing more of them here.

The only improvement that has been made in the fire engine for thirty years paſt, the public will very juſtly attribute to the ſagacity of Mr. Watt, whoſe ſkill in pneumatics, mechanics, and hydraulics, is evinced by the powerful application of elaſtic vapour, and by making a more perfect vacuum, nearly like that of the barometer, in his new conſtructed fire engine.

But before I can explain Mr. Watt's engines, it is neceſſary to premiſe a ſhort account of the imperfections of the common ſteam engines, and their cauſes.

The ſteam or vapour, which ariſes from water confined in a cloſe veſſel, and heated a few degrees above the point at which it boils in the open air, becomes an elaſtic fluid, uniform and tranſparent, about half the gravity of atmoſpheric air, very much greater in bulk than the water of which it is compoſed, and capable of being again reduced to water, when brought into contact with matter of a leſs degree of heat than itſelf.

The preſſure of the atmoſphere or any equivalent reſiſtance, prevents the production of ſteam, until the water be heated to 212 degrees of Fahrenheits thermometer, but when that preſſure is removed, or the water placed in a veſſel exhauſted of air, ſteam is produced from it, when it is

colder than the human blood. On the contrary, if water be preſſed upon by air or ſteam, which are more compreſſed than the atmoſphere, a degree of heat above 212 degrees is neceſſary for the production of ſteam; and the difference of heats, at which water boils under different preſſures, increaſes in a leſs proportion than the preſſures themſelves; ſo that a double preſſure requires leſs than a double increaſe of ſenſible heat.

The experiments which have been publiſhed concerning the bulk of water, when converted into ſteam are erroneous, and the concluſions drawn from them make that bulk greater than it really is. It has been known for ſome time that water would boil in an exhauſted receiver at a low degree of heat.

If we conſider the common ſteam engine, we ſhall find it defective; firſt, becauſe the vacuum is produced by throwing cold water into the cylinder to condenſe the ſteam; that water becomes hot, and, being in a veſſel partially exhauſted, produces a ſteam, which in part reſiſts the preſſure of the atmoſphere upon the piſton, and leſſens the power of the engine. The ſecond defect is the deſtruction of ſteam, which unavoidably happens upon attempting to fill a cold cylinder with that fluid; for the injection water, at the ſame time that it condenſes the ſteam, not only cools the cylinder, but remains there, until it be extruded at the eduction pipe, by the ſteam which is let in to fill the cylinder for the next ſtroke: and that ſteam will be condenſed into water as faſt as it enters, until all the matter it comes in contact with, be nearly as hot as itſelf.

Every

Every attempt to make the vacuum more perfect by the addition of injection water, will cool the cylinder more effectually, and cause a greater destruction of steam in the next filling; and if the engine has already a proper load, the destruction of steam will proceed in a greater ratio, than the increase of power by the amendment of the vacuum.

Though it appears that the constructors of steam engines have never investigated these causes; yet they have been so sensible of the effects, that a judicious engineer does not attempt to load his engine with a column of water, heavier than seven pounds for each square inch of the area of the piston.

Mr. Watt's improvement is founded upon these, and some other collateral observations. He preserves an uniform heat in the cylinder of his engines, by suffering no cold water to touch it, and by protecting it from the air or other cold bodies, by a surrounding case filled with the steam, or with hot air or water, and by coating it over with substances that transmit heat slowly. He makes his vacuum to approach nearly to that of the barometer, by condensing the steam in a separate vessel, called the condenser, which may be cooled at pleasure without cooling the cylinder, either by an injection of cold water, or by surrounding the condenser with it, and generally by both. He extracts the injection water and detached air, from the cylinder or condenser, by pumps which are wrought by the engine itself, or he blows it out by the steam. As the entrance of air into the cylinder would stop the operation of the engines, and as it is hardly to be expected that such enormous pistons, as those of steam engines, can move up and down,

and yet be abfolutely air tight in the common engines; a ftream of water is kept always running upon the pifton, which prevents the entry of the air, but this mode of fecuring the pifton, though not hurtful in the common ones, would be highly prejudicial in the new engines. Their pifton is therefore made more accurately; and the outward cylinder having a lid which covers it, the fteam is introduced above the pifton; and when a vacuum is produced under it, acts upon it by its elafticity, as the atmofphere does upon common engines by its gravity. This way of working effectually excludes the air from the inner cylinder, and gives the advantage of adding to the power, by increafing the elafticity of the fteam.

References to the new improved Fire Engine.

A the boiler.

Fig. 4. B the fafety valve.

C the pipe which conveys the fteam to the outer cylinder.

D the outer cylinder.

E the inner cylinder.

F the pifton.

G the valve that admits the fteam from the outer cylinder into the inner cylinder, called the fteam valve.

H the

H the valve that admits the ſteam from the inner cylinder into the condenſer, called the condenſing valve.

I the condenſer.

K the injection valve that admits a jet of cold water into the condenſer to condenſe the ſteam.

L the air pump that exhauſts the condenſer both of air and the injection water that is let in every ſtroke, and is fixed under water in the condenſing back M.

N the lever beam.

O the great water pump for clearing the mines or raiſing water for other uſes through the pipe P.

The internal ſtructure of the new engine ſo much reſembles the common ones, that I expect thoſe who know that machine will underſtand this from the following deſcription.

The cylinder, the great beams, the pumps, &c. ſtand nearly in their uſual poſitions. The cylinder is ſmaller than uſual in proportion to the load, and is very accurately bored. In the moſt compleat engines, it is ſurrounded at a ſmall diſtance with another cylinder, furniſhed with a bottom and a lid. The interſtice between the cylinders, communicates with the boiler by a large pipe, open at both ends, ſo that it is always filled with ſteam, and thereby maintains the inner cylinder always of the ſame heat with the ſteam, and prevents any condenſation within it, which would be more detrimental than an equal condenſation in the outer one.

The

The inner cylinder has a bottom and piſton as uſual ; and as it does not reach up quite to the lid of the outer cylinder, the ſteam in the interſtice has always free acceſs to the upper ſide of the piſton. The lid of the outer cylinder has a hole in its middle ; and the piſton rod, which is made truly cylindrical, moves up and down through that hole, which is kept tight by a collar of oakum ſcrewed down upon it.

At the bottom of the inner cylinder, there are two regulating valves, one of which admits the ſteam to paſs from the interſtice into the inner cylinder below the piſton, or ſhuts it out at pleaſure ; the other opens or ſhuts the end of a pipe, which leads to the condenſer. The condenſer conſiſts of one or more pumps furniſhed with clacks and buckets (nearly the ſame as in common pumps) which are wrought by chains faſtened to the great working beam of the engine. The pipe, which comes from the cylinder, is joined to the bottom of theſe pumps, and the whole condenſer ſtands immerſed in a ciſtern of cold water ſupplied by the engine. The place of this ciſtern is either within the houſe under the floor, between the cylinder and the lever wall ; or without the houſe, between that wall and the engine ſhaft, as conveniency may require.

The condenſer being exhauſted of air by blowing, and both the cylinders being filled with ſteam, the regulating valve which admits the ſteam into the inner cylinder is ſhut, and the other regulator which communicates with the condenſer is opened, and the ſteam ruſhes into the vacuum of the condenſer with violence ; but there it comes into contact with the cold ſides of the pipe and pumps, and meets a jet of cold water which was opened at the ſame time with the exhauſtion-regulator ; theſe inſtantly deprive it of its heat,

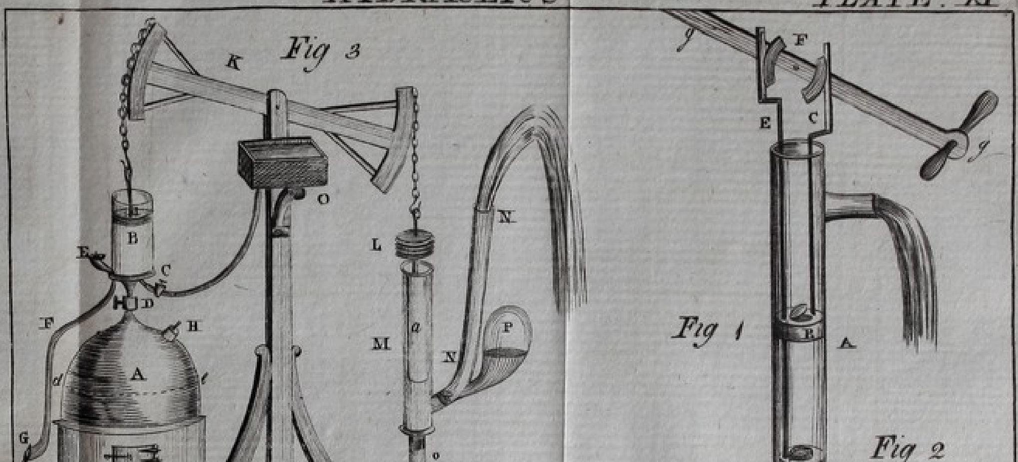


Fig 3
Fig 1
Fig 2
Fig 4
A
B
C
D
E
F
G
H
K
L
M
N
O
P

heat, and reduce it to water; and the vacuum remaining perfect, more ſteam continues to ruſh in, and be condenſed until the the inner cylinder is exhauſted. Then the ſteam which is above the piſton, ceaſing to be counteracted by that which was below it, acts upon the piſton with its whole elaſticity, and forces it to deſcend to the bottom of the cylinder, and ſo raiſes the buckets of the pumps which are hung to the other end of the beam. The exhauſtion regulator is now ſhut, and the ſteam one opened again, which by letting in the ſteam, allows the piſton to be pulled up by the ſuperior weight of the pump rods; and ſo the engine is ready for another ſtroke.

The working of theſe engines is more regular and ſteady than the common ones, and from what has been ſaid, their other advantages are apparently very conſiderable; but to ſay exactly how much they excel common engines, is difficult, as common engines differ very much among themſelves. I am told, that the ſavings amount at leaſt to two thirds of the fuel, which is a very conſiderable object where coals are expenſive.

OPTICS.

OPTICS.

AS the ſenſe of ſeeing is the nobleſt ſenſe belonging to an animal, without which he would live in perpetual darkneſs, unable to perform the neceſſary exerciſes of life; and ſince all that has been demonſtrated of glaſſes, and will hereafter be demonſtrated of all optical machines, tend only to this ſingle end, to help and improve the ſenſe of ſeeing. And ſince the eye is the organ or inſtrument by which viſion is performed; it is by nature an optical inſtrument, and the foundation of all others, and therefore it cannot be amiſs to give a ſhort deſcription thereof.

Plate XII. Fig. 1. A B C E is the eye, its figure ſpherical; by reaſon of which, it is eaſily moved any way in its ſocket. The fore-part at A is more convex than the reſt. It is contained in three membranes, the outermoſt is the *Sclerotica;* the ſecond the *Tunica choroides;* the fore-part of it is called the *Iris*, which conſiſts of many fibres like ſo many radii. The third or innermoſt is called the *Retina*, which is nothing but the optic nerve, ſpread over the bottom of the eye.

In theſe are contained the three humours of the eye; the firſt is H A I, called the *Aqueous* humour, which is a thin

thin liquor like water. The ſecond is F G the the *Chryſtalline*, in form of a lens, more convex behind towards C. Adjoining to this is the third K L called the *Vitreous* humour.

The chryſtalline is more denſe than the vitreous, and the vitreous more denſe than the aqueous humour, and all together make a compound lens, which refracts the rays of light, iſſuing from an object P R, to the bottom of the eye, and there paints its image p r in the focus upon the retina inverted.

The figure of the aqueous humour is a meniſcus, and ſo is that of the vitreous. The fore-part of the ſclerotica is called the *Cornea*, and that part adjoining to it, is called the *White* of the eye. Within the cornea is a coat called the *Uvea;* in the middle of this is a hole O called the *Pupil*, to let in the rays of light. And the pupil is contracted or dilated by ſeveral muſcular fibres in the uvea or iris, according as more or leſs light falls on the eye, and that by an involuntary motion.

D is the optic nerve going from the retina to the common ſenſorium in the brain, where theſe images are perceived. This is not in the middle of the eye, but lies nearer the ſide E, which is towards the noſe.

Round the edge of the chryſtalline F G is a ring of fibres, by help of which the diſtance A C is made longer or ſhorter, in order to bring the image p r upon the retina, for diſtinct viſion. And perhaps theſe fibres alſo make the chryſtalline more or leſs convex at the ſame time. This ring

of fibres is called the *Ligamentum ciliare;* and its back part is black, to ſtifle the rays that are reflected upon it.

The eye is moved in the head by ſeveral muſcles inſerted in the ſclerotica, ſo that it may be quickly directed to any object.

If the image of an object does not fall upon the retina at p r, the viſion will be confuſed. If it fall ſhort, or nearer F G; then a concave lens that makes the rays more diverging will bring them to the retina. This is the caſe of purblind or ſhort-ſighted people, who are forced to look very near an object; or elſe they muſt uſe concave ſpectacles.

If the rays do not unite till they get beyond the retina, as in moſt old people; then a common convex lens of a due force, held between the eye and the object, will make them converge, and fall upon the retina. Therefore long-ſighted people muſt uſe convex ſpectacles.

Although the image is painted inverted in the eye, yet we judge it erect; becauſe we always find it ſo by cuſtom and experience.

But that viſion is effected in this manner, may be demonſtrated experimentally. Take a bullock's eye while it is freſh, and having cut off the three coats from the back part, quite to the vitreous humour, put a piece of white paper over that part, and hold the eye towards any bright object, and you will ſee an inverted picture of the object upon the paper.

Seeing

Seeing the image is inverted, many have wondered why the object appears upright. But we are to consider, 1. That inverted is only a relative term: and 2. That there is a very great difference between the real object and the means or image by which we perceive it. When all the parts of a distant prospect are painted upon the retina, they are all right with respect to one another, as well as the parts of the prospect itself; and we can only judge of an object's being inverted, when it is turned reverse to its natural position, with respect to other objects which we see and compare it with. If we lay hold of an upright stick in the dark, we can tell which is the upper or lower part of it, by moving our hand upward or downward; and know very well that we cannot feel the upper end by moving our hand downward. Just so we find by experience, that upon directing our eyes towards a tall object, we cannot see its top by turning our eyes down ward, nor its foot by turning our eyes upward; but must trace the object the same way by the eye to see it from head to foot, as as we do by the hand to feel it; and as the judgment is informed by the motion of the hand in one case, so it is also by the motion of the eye in the other.

The diameters of images at the bottom of the eye, as p r, are proportional to the angles which the objects subtend at the eye, as P O R; the same as in a lens; and are reciprocally as the distances of the same object viewed in different places.

The eye is in reality no more than a camera obscura, for the rays of light flowing from all the points of an object, through the pupil of the eye, do by the refraction of the humours of the eye, paint the image thereof in the bottom

of the eye; juſt ſo it is in the camera obſcura, where all the rays refracted by a lens in the window-ſhut, or paſſing through a ſmall hole in it, paint the image on the oppoſite wall. Some properties of the eye are theſe:

1ſt. The eye can only ſee a very ſmall part of an object diſtinctly at once. For the collateral parts of an object are not repreſented diſtinctly in the eye; and therefore the eye is forced to turn itſelf ſucceſſively to the ſeveral parts of the object it wants to view, that they may fall near the axis of the eye, where alone diſtinct viſion is performed.

2d. When any point of an object is ſeen diſtinctly with both eyes, the axis of both eyes are directed to that point, and meet there. And then the object appears ſingle, though looked at with both eyes. For the optic nerves are ſo framed, that the correſpondent parts in both eyes, lead to the ſame place in the brain, and give but one ſenſation; and the image will be twice as bright with both eyes as with one. But if the axis of both eyes are not directed to the object, that object will appear double, as the pictures in the two eyes do not fall upon correſpondent or ſimilar parts of the retina.

3d. The beſt eye can hardly diſtinguiſh a particle of matter that ſubtends at the eye, an angle leſs than half a minute. And very few can diſtinguiſh it when it ſubtends a minute. If the diſtance of two ſtars in the heavens be not greater than this, they will appear as one.

4th. Young people can ſee nearer hand than old people; for as men grow old their eyes grow more flat; and to cor-

rect

rect the rays of light at the retina, the object muſt be placed further off. And this is the reaſon that ſhort-ſighted people, as they grow older, ſee at a greater diſtance.

5th. Though men may ſee diſtinctly at different diſtances, by altering the poſition and figure of the chryſtalline, yet they can only ſee diſtinctly within certain limits, and nearer than that, objects appear confuſed. But theſe limits are not the ſame in different people. A good eye can ſee diſtinctly when the rays fall parallel upon it; and then the principal focus is at the bottom of the eye.

6th. If a good eye views an object at the leaſt diſtance, it can be ſeen diſtinctly, and then at twice that diſtance, and then at an infinite diſtance; there is about the ſame alteration made in the figure of the eye, between the two laſt caſes, as there is between the two firſt.

7th. If a ſhort-ſighted perſon can ſee an object diſtinctly at two diſtances, whereof one is double the other; as great an alteration muſt be made in the figure of his eyes to ſee it at an infinite diſtance, as there was made for the firſt two diſtances, or as great an alteration as is made in a good eye to ſee diſtinctly from the greater diſtance to infinity. And therefore a ſhort-ſighted perſon can ſee diſtinctly at all diſtances with a ſingle concave glaſs, of a proper figure. And hence the cauſe of ſhort-ſightedneſs is not a want of power to change the figure of the eye; but that power is not great enough to accommodate it to all diſtances, taken from a point ſo near the eye.

8th. A man can judge at a ſmall diſtance with a ſingle eye, by frequently obſerving how much variation is made

in

in the eye to make the object diftinct; and from this a habit of judging is acquired. But this cannot be done at great diftances, becaufe, though the diftance be varied, the change in the eye becomes then infenfible.

9th. But a man can judge of greater diftances with both eyes, than he can with one eye. For the eyes being at a diftance from one another, as long as that diftance has a fenfible proportion to the diftance of the object, one gets a habit of judging, by the pofition of the axis of the eyes, which are always directed to that point. For different diftances require different pofitions of the axis, which depends on the motions of the eyes which we feel. But in very great diftances, no judgment can be made from the motion of the eyes, or their internal parts. Therefore we can only guefs at the diftances from the magnitude, colour, and the pofition of interjacent bodies.

Whatever light falls upon that part of the retina, where the optic nerve D fprings, makes no impreffion; and therefore, if the picture of an object falls thereon, it is not perceived, and fo that object is invifible. This will appear by placing a fmall bright object before you, and looking at it with one eye, and moving one eye laterally towards the contrary fide (towards the left, if it be the right eye), the object will difappear, and feem to be loft; and moving it ftill further, it will appear again. Now this place is not at the bottom of the eye, but nearer the nofe in both of them; fo that no rays, either parallel or diverging, that come from any object, can fall upon that place in both the eyes; fo that any object we direct the eyes to, will always be vifible, at leaft to one eye. But the fame bright object may be made to difappear to both eyes, by directing the axis of

both

both eyes to a point a little beyond the noſe, to be found by trials.

11th. Dimneſs of ſight generally attends old people, and this may ariſe from two cauſes; 1. by the eyes growing flat, and not uniting the rays at the retina, which cauſes indiſtinctneſs of viſion; or, 2. by the opacity of the humours of the eye, which in time loſe their tranſparency in ſome degree; from whence it follows that a great deal of the light is ſtopt and loſt, that enters the eye; and every object appears faint and dim.

12. As the rays of light flowing from an object, and painting its image upon the retina, are the immediate cauſe of ſeeing; ſo where there is no light, there can be no viſion: conſequently without light, the eye becomes a machine utterly uſeleſs; as it can give us no manner of information of the exiſtence of bodies at a diſtance from us.

DEFINITIONS.

1. OPTICS is a ſcience which teaches the nature, properties, and laws of *Viſion*, ariſing from the rays of light, either *reflected* from the ſurfaces of bodies, or *refracted* in paſſing through them, and painting the images of objects on the *Retina* on the bottom of the eye. Alſo this ſcience, in it's moſt extenſive acceptation, comprehends the whole doctrine of *Light* and *Colours*, and all the *Phænomena* or appearances of *viſible Objects*. Optics, therefore conſiſts of three parts, *viz.* *Catoptrics*, *Dioptrics*, and *Chromatics*.

2. *Catoptrics*

2. *Catoptrics* is that part which treats of *Reflex Viſion*, or all that relates to the viewing of objects by light *reflected* from the ſurfaces of bodies, whether *plain*, *convex*, *concave*, or otherwiſe; and in rays *diverging*, *converging*, or *parallel* to each other.

3. *Dioptrics* treats of the properties of light and viſion, ariſing from rays paſſing through tranſparent *Media* or bodies, as *Air*, *Water*, *Glaſs*, *Chryſtal*, *Diamond*, &c.

4. *Chromatics* treats of the *Colours* of light and natural bodies. Of this part Sir *Iſaac Newton*'s optics almoſt entirely conſiſt.

5. *Light* is that property of ſome bodies by which objects are rendered *viſible*, or capable of being *ſeen* by the eye. It conſiſts of very ſmall particles which iſſue from the luminous body in ſtraight lines.

6. *Rays* or *Beams* of light, are thoſe ſtreams or emanations of light, which proceed from the luminous body, and enlighten or illuminate all objects ſo that they may be *ſeen*.

7. The *Radiant* is that body or object which emits, or from which proceed, the rays of light under conſideration at any time.

8. The *Species* of an object is the image or repreſentation thereof, made by the rays of light in the *Focus*, or place where they unite.

9. *Parallel*

9. *Parallel* rays, are fuch as proceed *equally diftant* from each other through all their courfe; as thofe from the *Sun*, and other vaftly diftant objects. Fig. 2.

10. *Converging* rays are fuch as, proceeding from a body, approach nearer and nearer together in their progrefs, tending to one certain point, where they all unite; thus the rays proceeding from the object A B to the point F, are faid to *converge* towards that point. Fig. 3.

11. *Diverging* rays are thofe, which, proceeding from any point, as A, do continually recede from each other as they pafs along in their courfe towards B C. Fig. 4.

12. The *Focus* of *Rays* is that point to which all converging rays tend, and in which they unite and interfect each other; as the point F. And this is called the *Real Focus;* but Fig. 3.

13. The *Virtual* or *imaginary Focus*, is a point, as f, to which the rays A B tend, and where they would unite, were they not intercepted by the obftacle (fuppofe a mirrour) C D; by which means they are turned afide, and made to converge in their *Real Focus* F. Fig. 5.

14. *Reflection* of rays is their *Regrefs* or *Returning* from the furface of fuch bodies on which they fall, and cannot penetrate or enter. Thus the ray B C falling on the furface A D, is reflected or turned back or up again in the direction C E. Fig. 6.

15. The *Plane* of *Reflection* is that in which the reflecting point, or furface, is fituated, as A D and a d. Fig. 7, 8.

Fig. 6. 16. *Mirrours* or *Speculums* are thoſe bodies whoſe ſurfaces are ſo very ſmooth, and fine poliſhed, as to be impervious to the rays of light which fall on them, and which therefore they reflect ſo entirely, as to repreſent the *Images of Objects* oppoſed to them. Theſe are generally made of metal, or glaſs poliſhed on one ſide, and ſilvered on the other, and are either *plain*, *convex*, or *concave*.

17. *Plain Mirrours* are thoſe whoſe ſurfaces are perfect *Planes*, and whoſe ſection is a *ſtraight Line*, as A D. Note, theſe are vulgarly called *Looking-Glaſſes*.

18. *Convex Mirrours* are ſuch whoſe ſurfaces do every way equally and uniformly riſe above the plane of their baſes or loweſt parts; the ſection of which ſort of mirrour is a *Curve*, either *Circular*, *Elliptical*, *Parabolical*, or *Hyperbolical*. Where A C D is a *Circular* ſection, and the *Mirrour* is the ſegment of a *Globe*, or *Spherical* ſurface, which are moſt of common uſe. As

Fig. 7.

19. *Concave Mirrours* are thoſe whoſe ſurfaces ſink down with an uniform hollowneſs or curvity, below the upper parts A D, and whoſe ſection alſo is a *Curve*, as various as the convex above; but A D is circular, and its ſurface the internal part of an *hollow Sphere*, as being moſt in uſe.

Fig. .

20. The *Incident Ray* is that which comes from any object, and falls on the reflecting ſurface as B C; and C E is the *reflected Ray*. Fig. 6.

21. The *Angle* of *Incidence* is that which is contained between the *incident Ray* B C, and a perpendicular to the

the reflecting ſurface in the point of reflection F C, *viz.* the angle B C F. Fig. 6. 7. 8.

22. The *Angle of Reflection* is that contained between the ſaid perpendicular F C, and the reflected ray C E; *viz.* the angle F C E. Fig. 6, 7, 8.

23. *Refraction* of rays is their being bent or turned out of their firſt courſe, in paſſing out of one *Medium* into another. Let A D H I be a body of *Water*, A D it's Fig. 9. ſurface, C a point in which a ray of light B C (in the air) begins to enter the ſame; this ray by the greater denſity of the water, will be reſiſted, and inſtead of paſſing ſtraight forwards in its firſt direction to K, it will be bent therefrom, and made to deſcribe the tract C E, which is called the *refracted Ray*. Let F G be drawn perpendicular to the ſurface of the medium in C, then it is plain the ray B C in paſſing out of a *rarer Medium* (*viz.* of *Air*) into a *denſer Medium*, (*viz.* of *Water*) is refracted into a ray C E, which is nearer to the perpendicular C G, than the *incident Ray*; and on the contrary, the ray E C paſſing out of a *denſer* into a *rarer Medium*, will be refracted into C B, which is farther from the perpendicular.

24. The *Angle* B C F is the angle of *Incidence*, as before; and F C E is the angle of *Refraction*, as being contained between the refracted ray C K, and the perpendicular C G.

25. A *Lens* is a medium, generally of *Glaſs*, of a proper form to *collect* or *diſperſe* the rays of light which paſs through it. Of theſe there are various forms, which from thence, receive divers names. As,

26. A *Plano-Convex*, which hath one ſide plain, the
Fig. 10. other ſpherical or convex; as A.

27. A *Plano-Concave*, *plain* on one ſide, and concave on the other; as B.

28. A *Double-Convex*, is one *Convex* on both ſides; as C.

29. A *Double-Concave*, is one *Concave* on both ſides; as D.

30. A *Meniſcus*, is one *Convex* on one ſide, and *Concave* on the other; as E.

31. A *Plain Glaſs*, which is flat on both ſides, and of equal thickneſs in all its parts; as F.

32. A *Flat Plano-convex*, whoſe convex ſide is ground into ſeveral flat ſurfaces; as G.

33. A *Priſm*, with three flat ſides, and when viewed end-ways, appears like an equilateral triangle; as H.

34. Glaſſes ground into any of the ſhapes A B C D E, are called lenſes, and a line going horizontally through the middle, I K, is called the axis of the lens.

Fig. 11. 35. The *Vertex* of a *Mirrour* or *Lens*, as A B, is the middle point V, every way equally diſtant from it's baſe.

36. The

36. The *Axis* of a *Mirrour* or *Lens* is the right line E D, drawn through the vertex V, and the center C, on which it was defcribed.

37. The *Vifual* or *Optic Angle*, is that which is contained under the two right lines drawn from the extreme points of an object to the eye; thus A E B or C E D is the *Optic* *Angle*, or that under which the object A B or C D appears to the eye at E. Fig. 12.

38. A *Pencil* of ray is a double cone of rays, as L O N F L, joined together at the bafe in the *Lens* L N; of which one cone L O N has it's vertex in fome point of an object, as at O; and the other cone L F N has it's vertex in the point of convergence, or *Focus* F. The middle line O F is called the *Axis* of that pencil. Fig. 13.

Of the practical Part of Optics, with as much Theory as will be fufficient for the Conftruction and Ufe of moft Kinds of optical Inftruments.

WHAT I here propofe to lay down as the practical part of optics, is chiefly intended for thofe whofe curiofity and ingenuity may lead them to make further difcoveries in this noble fcience.

This part of optics has always been kept as fecret as poffible by people who made it their bufinefs, and the prices of optical inftruments being partly out of the reach of any, but fuch as are poffeffed of independent fortunes; by this means, fome thoufands of ingenious enquirers have been deprived from

from viewing the glorious works of nature, which afford ſuch an amazing field for contemplation and amuſement.

It has been attended with great expence, and unwearied diligence, for me to gain the little knowledge I have of this art, and which, I ſhall freely communicate to the public, in as plain a manner as I poſſibly can; in order to do this, I ſhall deſcribe the parts, as far as the conſtruction and uſe require, of every machine I ſhall have occaſion to treat of; at the ſame time, I would particularly recommend to every one who wiſh to make ſome proficiency in optics, to a cloſe application to the mathematics, as that is the only means whereby any one can attain a true knowledge of its theory.

My deſire alſo is to make people ſenſible of the pleaſure and information the microſcope, and teleſcope can afford, and inſtruct them how to manage as well as make theſe machines; likewiſe explain the effects of glaſſes on the ſight, and lead them gradually into the nature, uſe, and magnifying powers of theſe inſtruments.

Of Spectacles.

WHEN objects are ſeen through a perfectly flat glaſs, the rays of light paſs through it, from them to the eye, in a ſtraight direction, and parallel to each other; and conſequently, the objects appear very little either diminiſhed, or enlarged, or nearer, or farther off, than to the naked eye. But if the glaſs they are ſeen through, has any degree of convexity, the rays of light are directed from the circumference towards the center, in an angle proportionable to

the convexity of the glaſs, and meet in a point, at a greater or leſſer diſtance from the glaſs, as it is more or leſs convex. This point, where the rays meet, is called the focus; and this focus is nearer or farther off, according to the convexity of the glaſs; for as a little convexity throws it to a conſiderable diſtance, ſo when the convexity is much, the focus is very near. Its magnifying power is alſo in the ſame proportion to the convexity; for as a flat glaſs ſcarce magnifies at all, the leſs a glaſs departs from flatneſs, the leſs of courſe it magnifies; and the more it approaches towards a globular figure the nearer its focus is, and the more its magnifying power.

People's different length of ſight depends on the ſame principle, and ariſes from a more or leſs convexity of the cornea and chryſtalline humour of the eye; the rounder theſe are, the nearer will the focus or point of meeting rays be, and the nearer an object muſt be brought to ſee it well. The caſe of ſhort-ſighted people is only an over-roundneſs of the eye, which makes a very near focus; and that of old people is a ſinking or flattening of the eye, whereby the focus is thrown to a great diſtance: ſo that the former may properly be called eyes of too ſhort, and the latter eyes of too long a focus. Hence too, the remedy for the laſt is a convex glaſs, to ſupply the want of convexity in the eye itſelf, and brings the rays to a ſhorter focus; whereas a concave glaſs is needful for the firſt, to ſcatter the rays, and prevent their coming to a point too ſoon.

Nothing is more common than to obſerve old people holding objects they would examine at a great diſtance from them, for the reaſon above-mentioned; and every

body

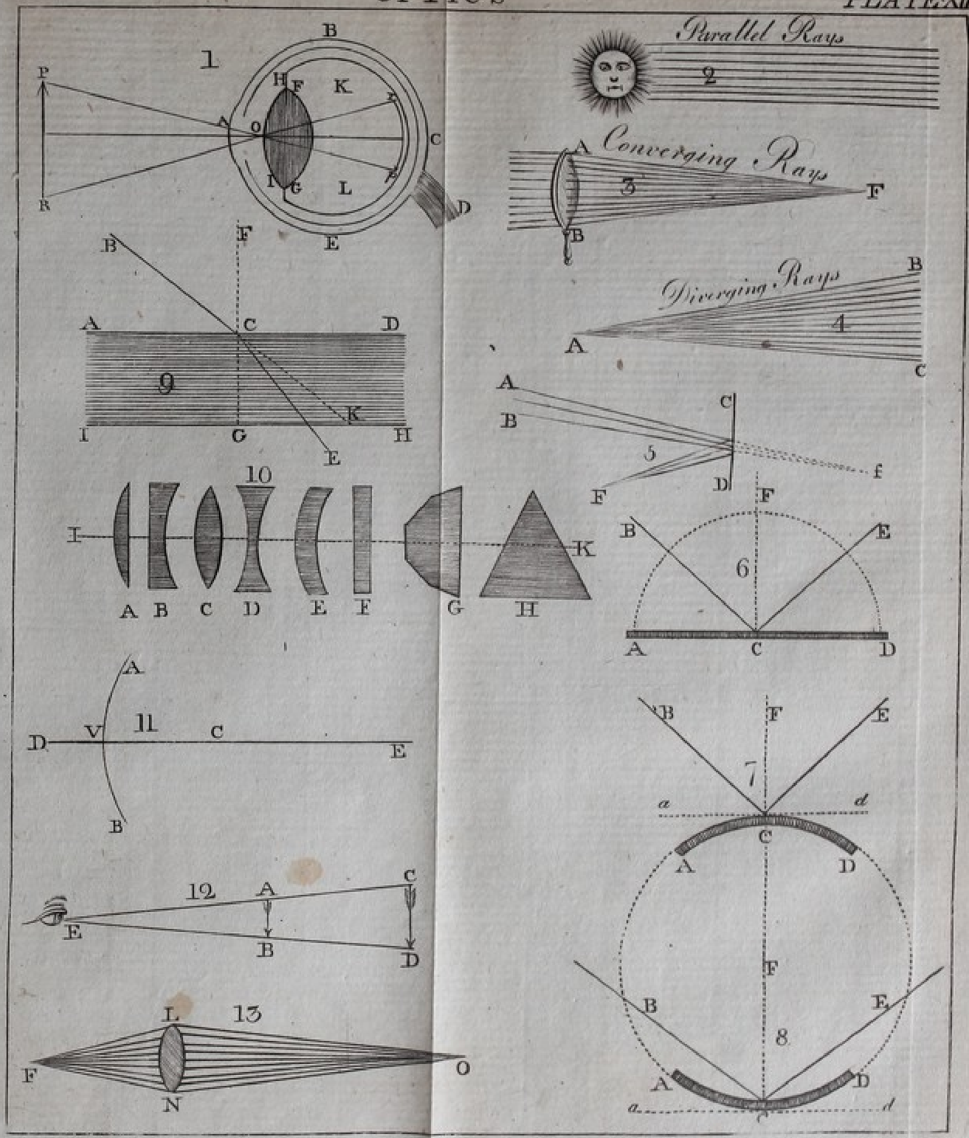
body knows, ſhort-ſighted people cannot diſtinguiſh any thing without bringing it very near their eyes. Both extremes are very inconvenient; but thoſe whoſe eyes are flat by age, ſhould remember with ſatisfaction, that they have enjoyed the pleaſure of them for many years; and the ſhort-ſighted may comfort themſelves, that they can diſtinguiſh much ſmaller objects than long-ſighted people: for the object is magnified in proportion to the roundneſs of the eye and the nearneſs of the focus, and conſequently appears four times as big to an eye whoſe focus is but four inches off, as it does to one whoſe focal diſtance is at eight inches. Short-ſighted people have alſo this farther advantage, that age improves their eyes by the ſame means it impairs other peoples, that i by making them more flat.

The nearer any object can be brought to the eye, the larger will be the angle under which it appears, and the more it will be magnified. Now, that diſtance from the naked eye, where the generality of people are ſuppoſed to ſee ſmall objects beſt, is at about ſix inches; conſequently, when ſuch objects are brought nearer than ſix inches, they will become leſs diſtinct; and if to four or three, they will ſcarce be ſeen at all. But by the help of convex glaſſes we are enabled to view things clearly at much ſhorter diſtances than theſe: for the nature of a convex lens is to render an object diſtinctly viſible to the eye at the diſtance of its focus; wherefore, the ſmaller a lens is, and the more its convexity, the nearer is its focus, and the more its magnifying power.

Plate XIII. Fig. 1. Now, it is evident, from the figure, if either the cornea, a b c, or chryſtalline humour e, or both of them, be

too

OPTICS PLATE XII



too flat, as in the eye A, their focus will not be on the retina, as at d, where it ought to be, in order to render viſion diſtinct; but, beyond the eye as at f. Conſequently thoſe rays which flow from the object C, and paſs through the humours of the eye, are not converged enough to unite at d: and therefore the obſerver can have but a very indiſtinct view of the object. This is remedied by placing a convex glaſs g h, of a proper focus, before the eye, which makes the rays converge ſooner, and imprints the image duly on the retina at d.

If either the cornea, or chriſtalline humour, or both of them, be too convex, as in the eye f, the rays that enter in from the object C, will be converged to a focus in the vitreous humour, as at f, and by diverging from thence to the retina, will form a very confuſed image thereon: and ſo, of courſe, the obſerver will have as confuſed a view of the object, as if his eye had been too flat. This inconvenience is remedied by placing a concave glaſs g h before the eye; which glaſs, by cauſing the rays to diverge between it and the eye, lengthens the focal diſtance ſo, that if the glaſs be properly choſen, the rays will unite at the retina, and form a diſtinct picture of the object upon it.

When glaſſes are put in frames for ſpectacles, their frames ought not to be ſtraight, ſo as both eyes may be as the ſame plane; but they ought to be ſo bent in the middle, that the axis of both glaſſes may be directed to one point, at ſuch a diſtance as you generally look with ſpectacles. By this means the eyes will fall perpendicular upon both glaſſes, and make the object appear diſtinct. But if they fall obliquely upon the glaſſes, it will cauſe a confuſed appearance in the objects, therefore, the ſhape of the frame,

Fig. 2. ought to be as reprefented when A B is the plane as one glafs is fixed, and C D the other.

Spectacles are the moft ufeful optical machine in the world. There are few people that grow into years, but have occafion for them to help their defective eyes, and without them would be ufelefs in a great many occafions of life.

Of MICROSCOPES.

THE word microfcope imports an inftrument for viewing feveral fmall objects. I have before obferved, that nature has fo formed the human eye, that we cannot diftinctly view an object at a nearer diftance than fix inches; and fince there is an affinity of objects, which at that diftance appear either as points, or are wholly imperceptible, whatfoever inftrument or contrivance will render fuch minute objects vifible and diftinct, we properly call a microfcope.

It is ufual to fay, that the microfcope magnifies objects feen through it; but this is true only with regard to the apparent, not the real magnitude of objects; they indeed appear to be larger with, than without a microfcope, but, in truth they are not; and the reafon why they appear to be magnified will be eafy to apprehend, by any perfon who underftands the nature of the optic angle.

The apparent magnitude of objects is meafured by the angle which they are feen under by the eye; and thofe angles are reciprocally as the diftances from the eye. If therefore, at the diftance of fix inches, I can but juft dif-

cern

cern an object, and then by an interpofing a lens, or other body, I can come to view that very object at a nearer diftance, the object will appear to be as much larger through the lens, than before to the naked eye, as its diftance from the lens is lefs than its diftance from the eye.

That this is the cafe, is evident, from where A is a point in an object not clearly vifible to the naked eye, at a lefs diftance than A B, becaufe the rays which proceed from it are too divergent to admit of diftinct vifion till they have paffed that diftance; but if the fame object be placed in the focus C of the lens D, the rays which proceed from it will become parallel, by paffing through the faid lens, and therefore the object is diftinctly vifible to the eye E, placed any where before the lens D. Confequently it will appear as much larger, through the lens than to the naked eye, as C D is lefs than A B. Fig. 3.

If an object A B be placed in one focus C of a lens D E, and the eye in the other focus F, the eye will fee juft fo much of the object as is equal to the diameter of the lens; for the rays of A D and B E, which go from the object to the extremities of the lens D and E, and are united at the focus F, muft neceffarily proceed from the object to the lens parallel to the axis F C, and therefore parallel to each other; confequently the part of the object A B, feen by the rays D F, E F, will be equal to the diameter D E of the faid lens. Fig. 4.

If only the part d e of the lens be open, then only fo much of the object a b, as is equal thereto, will be perceived by the eye. Now fince A B is equal to D E, or a b to d e, therefore the angle D F E, or d F e, is the optic

angle under which the part of the object A B or a b appears to the eye at F; and ſince G F is but one half F C, therefore the angle D F E, or d F e, is double to that under which the part A B or a b would appear to the naked eye at the diſtance F C: that is, the eye ſees the object, ſituate as above, twice as large with the lens as it would do without it.

If you would ſee a portion of an object larger than the lens, your eye muſt be placed nearer the lens than its focus. Fig. 5. Let the lens be D E, its two foci F and C; in the focus C let there be an object A B larger than the lens; ſuppoſe the rays A D, B E, proceed from the extremities of the object to thoſe of the lens, it is evident from the figure they will be convergent, and therefore will by the lens be united in a point K, between the lens D E, and its focus F: if then the eye be placed at K, it will take into its view an object, greater than the lens D E.

Again, let G H be a portion of an object A B, leſs than the lens D E; draw G D, H E, which will be diverging rays, and therefore will be united at a point I, farther diſtant from the lens than the focus F: hence, if an eye be placed farther from the lens than its focal diſtance, it can never ſee any object, or part of an object, at one view, ſo large as the lens, but always ſmaller. And univerſally, the viſible part of an object will be to the lens, as the focal diſtance of the lens, to the diſtance of the eye.

Since then it is evident, the nature of a convex lens is ſuch as will render an object diſtinctly viſible to the eye, at the diſtance of its focus, the reaſon why they are uſed

as

as microſcopes is exceeding plain. For ſuppoſe the diſtance A B be 6 inches, where the naked eye B can but juſt perceive the object A diſtinctly, and let the focal diſtance C D of the lens D be half an inch; then ſince C D is but one twelfth of A B, the length of the object at C, will appear twelve times as large as at A; if it were a ſurface, it would be one hundred and forty-four times as great: and the ſolidity or bulk would be magnified one thouſand ſeven hundred and twenty-eight times. Fig. 3.

If C D, the focal diſtance of the lens D, be but one fourth part of an inch, then will that be but one twenty-fourth of A B, equal ſix inches, and ſo the length of objects will be magnified twenty-four times; the ſurface five hundred and ſeventy-ſix times, and the ſolidity thirteen thouſand eight hundred and twenty-four times, for thoſe numbers are the ſquare and cube of twenty-four. From whence it appears, that ſingle glaſs lenſes make very good microſcopes, which have theſe advantages, that the object appears moſt clear, they lie in little room, may be carried about any where, are to be had for a ſmall price, and are moſt eaſy to be uſed.

The form of a very convenient microſcope, is where A B is a circular piece of wood, ivory, &c. in the middle of which is a ſmall hole, one twentieth of an inch diameter; upon this hole is fixed, with a wire, a ſmall lens C, whoſe focal diſtance is C D. At that diſtance is a pair of plyers D E, which may be adjuſted by means of the ſliding ſcrew as in the figure, and opened by means of the two little ſtuds a, e; with theſe you take up any ſmall object O, and view it with the eye placed in the other focus of the lens at Fig. 6.

F.

F. And according to the focal length of the lens, the object O will appear more or lefs magnified, as reprefented at I M, If the focal length be half or one fourth of an inch, the length, furface, and bulk of the object will be magnified as before defcribed. This fmall inftrument may be put into a cafe, and carried about in the pocket without any incumbrance. I have made trial of various lenfes, and find thofe whofe focal lengths are 3-tenths, 4-tenths, and 5-tenths of an inch, the beft for common ufe.

Since the nearer the eye can approach to an object, the larger it appears, it is plain a double and equally convex lens is far preferable to a plano-convex lens: becaufe if the fphere or convexity be the fame, the focal length of the former, is but half as long as of the latter: and fince the double convex confifts of two fegments of a fphere, the more an object is to be magnified, the greater muft the convexity be, and therefore the fmaller the fphere; till at laft the utmoft degree of magnifying will require that thefe fegments become hemifpheres, and confequently the lens will be reduced to a perfect fpherule, or very fmall fphere.

If the radius of the fpherule be one tenth of an inch, the eye will have diftinct vifion of an object by means thereof, at the diftance of a radius and half, i. e. 3-twentieths of an inch, which, as it is but the 40th part of fix inches, fhews that the length of an object will be magnified forty times, the furface one thoufand fix hundred times, and the folidity fixty-four thoufand times, by fuch a fmall fphere.

If the radius of a fpherule be but one twentieth of an inch, then will the eye have diftinct vifion of an object at the diftance of 3-fortieths of an inch, which, as it is but the

80th

80th part of ſix inches, ſhews the length of objects will appear eighty times greater, the ſurface ſix thouſand four hundred times, and the bulk five hundred and twelve thouſand times greater to the naked eye at ſix inches diſtance.

Again, if the diameter of a ſpherule be one twentieth of an inch, or the radius one fortieth, then will the eye approach the object ſo near as 3-80th part of an inch, which is but the 160th part of ſix inches; and therefore the length of objects will be magnified one hundred and ſixty times, the ſurface twenty-five thouſand ſix hundred times, and the ſolidity four million and ninety-ſix thouſand times by this ſpherule; which is ſo great a power of magnifying, as ſurpaſſes all human imagination and comprehenſion.

In uſing theſe ſpherule microſcopes, the objects are to be placed in one focus, and the eye in the other; and ſince the focus is ſo exceeding near the glaſs, it is impoſſible to view any but pellucid bodies: for if any opake object were to be applied, the eye being as it were juſt on the ſpherule, would entirely prevent any light falling on it, and it would be too obſcure to be viewed.

It was with theſe ſort of microſcopes, that the famous Dutch philoſopher Mr. *Leeuwenhoek* made ſuch wonderful diſcoveries; and it muſt be with theſe, if with any, that the corpuſcles or atoms, of which bodies conſiſt, are to be diſcovered; which the great *Sir Iſaac Newton* thought was poſſible. But the great difficulty of making very ſmall, and at the ſame time, very good ones; their prejudice to the eyes in poring very hard and near; the trouble of placing objects at a due diſtance and the very ſmall part which

can be feen of any, make this fort of microfcopes very little known or ufed.

Of a fingle Microfcope for Opake Objects.

THIS microfcope remedies the inconvenience of having the dark fide of an object next the eye, which has hitherto been an unfurmountable obftruction to the making obfervations on opake objects with any confiderable degree of exactnefs or fatisfaction: for in all other contrivances commonly known, the nearnefs of the inftrument to the object (when glaffes that magnify much are ufed) unavoidably overfhadows it fo much, as to render its appearance obfcure and undiftinct. And, notwithftanding, ways have been tried to point light upon an object, from the fun, or a candle, by a convex glafs placed on the fide thereof; the rays from either can be thrown upon it in fuch an acute angle only, that they ferve to give a confufed glare, but are infufficient to afford a clear and perfect view of the object.

But in this new microfcope, by means of a concave fpeculum of filver highly polifhed, in whofe center a magnifying lens is placed, fo direct and ftrong a light is reflected upon the object, that it may be examined with all imaginable eafe and pleafure.

The apparatus for this purpofe has afforded me more delight and fatisfaction than I am able to defcribe; and whoever tries it, will, I believe, join in my opinion, that he never faw an opake object with fo much clearnefs, and in fo perfect and true a manner.

The

The ſeveral parts of this inſtrument commonly made of braſs, are as follows:

Through the firſt ſide A, paſſes a fine ſcrew B, the other end whereof is faſtened to the moveable ſide C. Fig. 7.

D is a nut adapted to the ſaid ſcrew by the turning of which the two ſides A C are gradually brought together.

E is a ſpring of ſteel, that ſeparates the ſaid two ſides when the nut is unſcrewed.

F a piece of braſs turning round in a ſocket, whence proceeds a ſmall ſpring tube moving upon a rivet, through which tube there runs a ſteel wire, one end whereof terminates in a ſharp point G, and the other hath a pair of plyers H faſtened to it. The point and plyers are to thruſt into or to take up and hold any inſect or object: and either of them may be turned upwards, as ſuits your purpoſe beſt.

I is a ring of braſs with a female ſcrew within it, mounted on an upright piece of the ſame metal, which turns round on a rivet, that it may be ſet at a due diſtance when the leaſt magnifiers are employed. This ring receives the ſcrews of all the magnifiers.

P a handle turned of wood, to ſcrew into the inſtrument when it is made uſe of.

K a concave ſpeculum of ſilver, poliſhed as bright as poſſible, in the center of which a double convex lens is Fig. 8.

 placed,

placed, with a proper aperture to look through it. On the back of this ſpeculum a male ſcrew L is made to fit the braſs ring I, to ſcrew into the ſaid ring at pleaſure.

There are four of theſe concave ſpecula, of different magnifying powers, to be uſed as objects to be examined may require. The greateſt magnifiers muſt always have the leaſt apertures.

Fig. 8.

M a round object-plate, one ſide white and the other black, intended to render objects the more viſible, by placing them, if black, on the white, and if white on the black ſide. A ſteel ſpring N, turns down on each ſide to make any object faſt: and iſſuing from the object plate is a hollow pipe to ſcrew it on the needle's point G.

Fig. 10.

O is a ſmall box of braſs, with a glaſs on each ſide, contrived to confine any living object, in order to examine it: this alſo has a pipe to ſcrew upon the end of the needle G.

Fig. 11.

Q a pair of braſs plyers, to take up any object, or manage it with conveniency.

Fig. 12.

R a ſoft hair bruſh, to clean the glaſſes or ſpecula, or apply a drop of any liquid to the iſinglaſs of the box O, in order to view the animalcules.

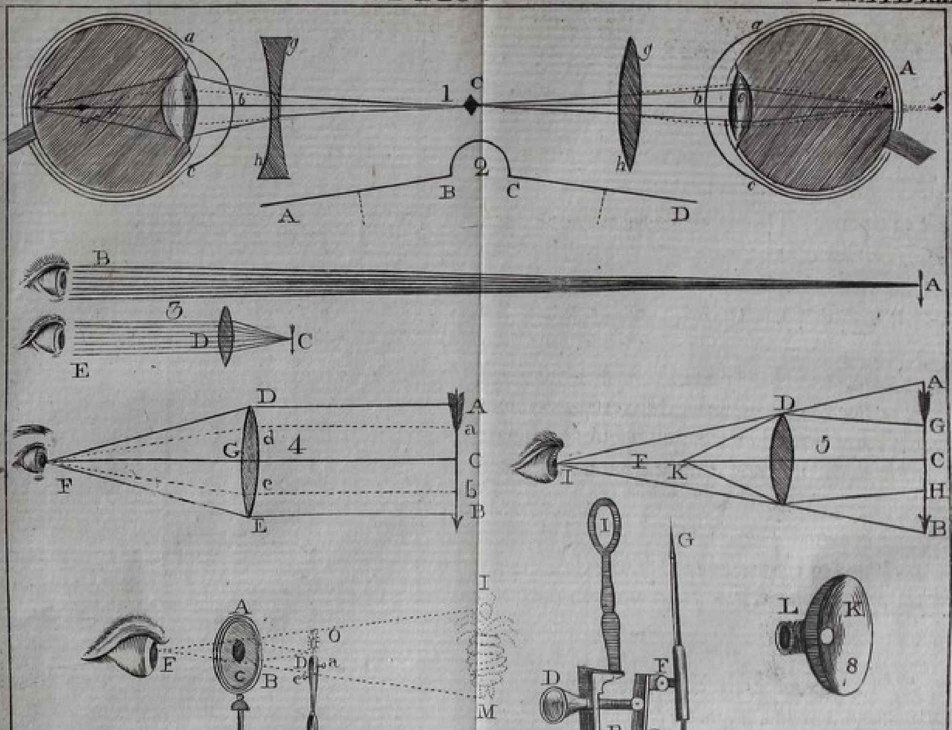
Fig. 13.

S a ſmall ivory box for the talcs, to be placed when wanted in the ſmall braſs box O.

Fig 7.

When you would view any object, ſcrew the ſpeculum, with the magnifier you would think beſt to uſe, into the braſs

OPTICS PLATE XIII



brafs ring I. Place your object either on the needle G, in the plyers H, on the object-plate M, or in the brafs hollow box O, as may be moft convenient, according to the nature and condition of it: then holding up your inftrument by the handle P, look againft the light, through the magnifying lens, and by means of the nut D, together with the motion of the needle, by managing its lower end, the object may be turned about, raifed, or depreffed, brought nearer the glafs, or put farther from it, till you hit the true focal diftance, and the light be feen reflected from the fpeculum ftrongly upon the object: by which means, it will be fhewn in a manner furprizingly diftinct and clear. And for this purpofe, the light of the fky, or of a candle, will anfwer to your fatisfaction.

This microfcope is principally intended for opake objects, but tranfparent ones may alfo be viewed by it: obferving only, that when fuch come under examination, it will not always be proper to throw on them the light reflected from the fpeculum: for the light tranfmitted through them meeting the reflected light, may, together, produce too great a glare. A little practice will teach how to regulate both thefe lights to good advantage.

There is reafon to expect great difcoveries may be made by the apparatus above defcribed, as opake objects are a large field, but little hitherto examined, by reafon of the great difficulty in doing it.

Of Mr. Wilſon's ſingle Pocket Microſcope.

Plate XIV. Fig. 1. THE body is made either of braſs, ivory, or ſilver, as repreſented A A B B.

C C is a long fine-threaded male ſcrew, that turns into the body of the microſcope.

D a convex glaſs at the end of the ſaid ſcrew.

1. Two concave round pieces of thin braſs, with holes of different diameters in the middle of them, to cover the ſaid glaſs, and thereby diminiſh the aperture when the greateſt magnifiers are employed.

E E three thin plates of braſs within the body of the microſcope, one whereof is bent ſemicircularly in the middle, ſo as to form an arched cavity for the reception of a tube of glaſs, whereas the two flat plates are to receive and hold the ſliders between them.

F a piece of wood or ivory, arched in the manner of the ſemicircular plate, and cemented thereto.

G the other end of the body of the microſcope, where a hollow female ſcrew is adapted to receive the different magnifiers.

H a ſpiral ſpring of ſteel, between the ſaid end C and the plates

plates of brafs; intended to keep the plates in a right pofition, and counteract againft the long fcrew C C.

I a fmall turn'd handle, for the better holding of the inftrument, to fcrew on or off at pleafure.

To this microfcope belong feven different magnifying glaffes: fix of them are fet in filver, brafs, or ivory, as in K, and marked 1, 2, 3, 4, 5, 6, the loweft numbers being the greateft magnifiers. Fig. 2

L is the feventh magnifier, fet in the manner of a little barrel, to be held in the hand for the viewing any larger object. Fig. 3

The figure may be of further ufe, by applying a thin cap, with a hole in it, a quarter of an inch fquare, exact in the focus of the lens; by which means, when a piece of lin cloth is applied upon the brafs, and viewed through the other end, the threads will appear greatly magnified, fo that they may be counted, and thereby the quality of the cloth may be afcertained by calculation. Fig. 4

M is a flat flip of ivory, called a flider, with four round holes through it, wherein to place objects between two glaffes or pieces of Mufcovy talc, as they appear d d d d. Fig. 5.

Eight fuch ivory fliders, and one of brafs, are ufually fold with this microfcope; fome with objects placed in them, and others empty, for viewing any thing that may offer: but whoever pleafes to make a large collection of objects, may have as many as he defires.

The

The brafs flider is to confine any fmall object, that it may be viewed without crufhing or deftroying it.

Fig. 6. N is a forceps or pair of plyers, for the taking up infects or other objects, and adjufting them to the glaffes.

Fig. 7. O is a little hair-brufh, or pencil, wherewith to wipe any duft from off the glaffes, or to take up any fmall drop of liquid one would examine, and put it upon the talcs or ifinglafs.

Fig. 8. P is a tube of glafs, contrived to confine living objects, fuch as frogs, fifhes, &c. in order to difcover the blood, as it ftreams along the veins and arteries.

All thefe particulars are contained in a little neat box, very convenient for carrying in the pocket.

When an object is to be viewed, thruft the ivory flider, in which the faid object is placed, between the two flat Fig. 1. brafs plates E E: obferving always to put that fide of the flider where the brafs rings are, fartheft from your eye. Then fcrew on the magnifying glafs you intend to ufe, at the end of the inftrument G; and looking through it againft the light, turn the long fcrew C C, till your object be brought to fit your eye; which you will know by its appearing then perfectly diftinct and clear. 'Tis beft to look at it firft, through a magnifier that can fhew the whole thereof at once, and afterwards to infpect the feveral parts more particularly with one of the greateft magnifiers: for thus you will gain a true idea of the whole, and of all its parts. And though the greateft magnifiers can fhew

but

but a minute portion of any object at once, ſuch as the claw of a flea, the horn of a louſe, or the like: yet by gently moving the ſlider that contains your object, the eye will gradually overlook it all; and if any part ſhould be out of diſtance, the ſcrew C C will eaſily bring it to the true focus.

As objects muſt be brought very near the glaſſes when the greateſt magnifiers are uſed, be particularly careful not to ſcratch them as you move it in or out. A few turns of the ſcrew C C will eaſily prevent this miſchief, by giving them room enough.

You may change the objects in your ſliders, for what others you think proper, by taking out the braſs ring with the point of a penknife; the talc will then fall out, if you but turn the ſliders; and after putting what you pleaſe between them, by replacing the braſs rings, you will faſten them as they were before. 'Tis proper to have ſome ſliders furniſhed with talcs, but without any objects between them, to be always in readineſs for the examination of fluids, ſalts, ſands, powders, the Farina of flowers, or any other caſual objects of ſuch ſort as need only be applied to the outſide of the talc.

The circulation of the blood may eaſieſt be ſeen in the tails and fins of fiſhes, in the fine membranes between a frog's toes, or beſt of all, in the tail of a water-newt. If your object be a ſmall fiſh, place it within the tube, and ſpread its tail or fin againſt the ſide thereof: if a frog, chuſe ſuch an one as can but juſt be got into your tube, and with a pen or ſtick expand the tranſparent membrane between the

the toes of the frog's hand foot as wide as you are able. When your object is fo adjufted, that no part thereof can intercept the light from the place you intend to view, unfcrew the long fcrew C C, and thruft your tube into the arched cavity, quite through the body of the microfcope; then fcrew it to the true focal diftance, and you will fee the blood paffing along its veffels with a rapid motion, and in a moft furprifing manner.

Make ufe of the third or fourth magnifier for frogs or fifhes; but for the tails of water-newts, the fifth, or fixth will do; becaufe the globules of their blood are twice as large as thofe of frogs or fifh. The firft or fecond magnifier cannot well be employed to this purpofe; for the thicknefs of the tube wherein the object lies, will fcarce admit its being brought fo near as the focal diftance of the magnifier.

A Pocket Microfcope, with a Reflecting Speculum.

A is a fcroll of brafs, fixed upright on a round pedeftal
Fig. 9. of wood B, fo as to ftand perfectly firm and fteady.

C is a brafs fcrew, that paffes through a hole in the upper limb of the fcroll, into the fide of the Microfcope D, and fcrews it faft to the faid fcroll.

E a concave looking-glafs or fpeculum, fet in a box of brafs, which hangs in the arch G, by two fmall fcrews f f, that fcrew into the oppofite fides thereof.

At

At the bottom of the ſaid arch is a pin of the ſame metal, exactly fitted tc a hole h, in the wooden pedeſtal, made for the reception of the ſaid pin.

As the arch turns on this pin, and the ſpeculum turns on the ends of the arch, it may, by this two-fold motion, be eaſily adjuſted; in ſuch a manner, as to reflect the light of the ſky, the ſun, or a candle, directly upwards, through the microſcope that is fixed perpendicularly over it; and by ſo doing, may be made to anſwer almoſt all the ends of the large double reflecting microſcope.

The body of the microſcope may alſo be fixed horizontally, and objects may be viewed in that poſition, by any light you chooſe; which is an advantage the reflecting microſcope has not.

It may alſo be rendered farther uſeful, by means of a ſlip of glaſs, one end of which being thruſt between the plates where the ſliders go, and the other extending to ſome diſtance, ſuch objects may be placed thereon, as cannot be applied to the ſliders: and then, having a limb of braſs that may be faſtened to the body of the microſcope, and extend over the projecting glaſs a hollow ring, wherein to ſcrew the magnifiers, all ſorts of ſubjects may be examined with great conveniency, if a hole be made in the pedeſtal, to place the ſpeculum exactly underneath, and thereby throw up the rays of light as in the next figure.

The pocket microſcope thus fixed, is, if I may preſume to judge, as eaſy and pleaſant in its uſe, and as fit for the moſt curious examination of the animalcules and ſalts in

 fluids

fluids, of the farinæ in vegetables, of the circulations in ſmall creatures: in ſhort, it is likely to make conſiderable diſcoveries in objects that have ſome degree of tranſparency, as any microſcopes I have ever ſeen or heard of.

Another ſingle Microſcope on a Foot or Stand.

THE ſingle microſcopes hitherto deſcribed, have been contrived in many different forms, which on ſome occaſions are very neceſſary and convenient. I have here given the form or ſtructure of one which I think, in ſome caſes, preferable to any I have ſeen.

This is the general form of the inſtrument in which A B is the baſis or foot.

Fig. 10. C D I is the ſtem, of which the lower part C is in the form of a pillar; and the upper part D has four plain ſides.

E, F, are two ſquare ſockets of braſs, moveable up and down together upon the ſquare part of the ſtem, being connected by a common ſcrew; but this motion is checked by the conſtant preſſure of a ſpring.

G is a ſcrew by which the part E is fixed to the ſtem.

H is an adjuſting ſcrew, by which the part F is gradually moved up and down; and thereby K L, the ſtage on which the objects are placed, has M N the ſlider, with its objects duly adjuſted to the focus of the magnifiers.

L is

L is a joint by which the ſtage is capable of an horizontal motion, to ſhew any part of the object without moving the ſlider.

O P is a circular piece of braſs conſiſting of two plates, between which are placed ſix ſmall lenſes or magnifiers in a circle near the extreme part, and is moveable on a ſcrew in its center, which goes into I Q a piece of braſs fixed very firmly on the top of the ſtem; upon this is Q a circular piece of braſs ſoldered on, with a hole in the center, under which the circle of glaſſes below paſſes, and, conſequently, any one of the lenſes being brought to the center of this hole, will be exactly over the center of the hole in the ſtage, and ſhew the objects when adjuſted to the focus of the ſaid lens.

R is the ſpeculum that reflects the light through the microſcope.

A Megalaſcope for viewing large Objects.

This is an optical inſtrument that may be properly called a megalaſcope for the hand; becauſe it is adapted for viewing all the larger ſort of ſmall objects, ſuch as inſects, flowers, minerals, linen, &c. to a very great advantage; as with three glaſſes only it has ſeven different magnifying powers.

A B is the caſe of braſs, ſilver, &c. Fig. 11.

D, E, F, three ſeveral lenſes with different magnifying powers, which are all contained in the ſaid caſe, and turned out at pleaſure.

H the

H the handle.

The three glaffes fingly, afford three magnifying powers; and by combining two and two, we make three more; for D with E makes one, D with F another, and E with F a third; which with the three fingly make fix; and laftly, all three combined together make another, fo that upon the whole, there are feven powers of magnifying with three glaffes only.

Of double or compound Microfcopes.

Fig. 12. The double or compound microfcope, confifts of an object glafs c d, and an eye glafs e f. The fmall object a b is placed at a little greater diftance from the glafs c d than its principal focus, fo that the pencils of rays flowing from the different points of the object, and paffing through the glafs, may be made to converge and unite in as many points between g and h, where the image of the object will be formed: which image is viewed by the eye through the eye-glafs, e f. For the eye-glafs being fo placed, that the image g h may be in its focus, and the eye much about the fame diftance on the other fide, the rays of each pencil will be parallel, after going out of the eye-glafs, as at e and f, till they come to the eye at k, where they will begin to converge by the refractive power of the humours; and after having croffed each other in the pupil, and paffed through the chryftalline and vitreous humours, they will be collected into points on the retina, and form the large inverted image A B thereon.

The

The magnifying power of this microſcope is as follows: ſuppoſe the image g h to be ſix times the diſtance of the object a b from the object glaſs c d; then will the image be ſix times the length of the object: but ſince the image could not be ſeen diſtinctly by the bare eye at a leſs diſtance than ſix inches, if it be viewed by an eye-glaſs e f, of one inch focus, it will thereby be brought ſix times nearer the eye; and conſequently viewed under an angle ſix times as large as before; ſo that it will be again magnified ſix times; that is, ſix times by the object-glaſs, and ſix times by the eye-glaſs, which multiplied into one another, makes thirty-ſix times; and ſo much is the object magnified in diameter more than what it appears to the bare-eye; and conſequently thirty-ſix times thirty-ſix, or one thouſand two hundred and ninety-ſix times in ſurface.

But becauſe the extent or field of view is very ſmall in this microſcope, there are generally two eye-glaſſes placed ſometimes cloſe together, and ſometimes an inch aſunder; by which means, although the object appears leſs magnified, yet the viſible area is much enlarged by the interpoſition of a ſecond eye-glaſs; and conſequently a much pleaſanter view is obtained.

The Deſcription and Uſe of a compound Microſcope.

Is the form of a compound microſcope for the pocket. Fig. 13.

A Q is the body or internal part which is moveable up and down in C D an external caſe of wood, braſs or ſilver.

E one

E one of the three pillars which ſupport the inſtrument.

F a plate fixed (horizontally) to the legs, uſually called the ſtage.

G a hole in the central part, in which glaſs, and other parts of the apparatus are placed, with objects to be viewed.

H an illuminating or reflecting ſpeculum.

I the foot of the inſtrument.

K is a pipe to which is ſcrewed,

Q a braſs button or caſe to hold the magnifier.

In this compound microſcope there are generally three (ſometimes four) glaſſes employed to produce the effect, viz. 1. the magnifying lens at Q which makes a large image in the upper part of the ſmall object below. 2. A large lens at B, called the body glaſs, which is the cauſe of a larger field of view. 3. An eye glaſs at A, by which we view the enlarged image of the object, in its focus.

The Method of computing the magnifying Power of ſingle and double Microſcopes.

THE magnifying power in all optical inſtruments depends upon this one principle, that every object is apparently greater or leſs in proportion, as it is nearer to, or farther

farther from the eye; becaufe the nearer it is, the larger is the vifual angle under which it appears, *& vice verfa.*

But the eye is fo formed as to admit of diftinct vifion by fuch rays only as are nearly parallel; and therefore every object muft be removed to fuch a diftance from the eye that the rays of light iffuing from every point thereof, may fall upon the eye with fmall divergency, or nearly parallel, which diftance is in different eyes from fix to eight inches, as any one may find by trial.

Now, fince a convex glafs convenes parallel rays to a point or focus; therefore, on the contrary, if an object be placed in the focus of fuch a lens, the rays proceeding from each point will be refracted parallel to the eye, and thereby produce diftinct vifion of that object in its focus.

Hence then it follows, that if a b be a very fmall object in the focus of the glafs c, whofe focal diftance is one inch, Fig. 14. the eye applied to the lens C will have the diftinct vifion thereof; and this being at a diftance fix, feven, or eight times nearer than the eye alone could clearly fee it, it muft appear fo many times larger than to the naked eye; and therefore we properly fay, it is magnified to fuch eyes, fix, feven, or eight times in length and breadth.

But all furfaces are magnified in proportion to the fquares of their lengths or fides; therefore the furfaces of objects are magnified thirty-fix, forty-nine, or fixty-four times by a lens of one inch focal diftance.

Alfo the bulk or magnitude of the whole body, will be magnified

magnified in proportion to the cubes of the ſides or length, and therefore all ſolid bodies will, by ſuch a lens, be magnified two hundred and ſixteen, three hundred and forty-three, or five hundred and twelve times, to ſuch eyes reſpectively.

If the lens C were but of half an inch focal diſtance, the lengths of objects would be magnified twice as much; the ſurfaces four times, and the magnitude or bulk, eight times as much as before.

If the focal diſtance of the lens C be a quarter of an inch, then the lengths are magnified four times as much, viz. twenty-four, twenty-eight, or thirty-two times; the ſurfaces ſixteen times as much, or 576 times more than to the naked eye at ſix inches diſtance; and ſolid bodies are magnified ſixty-four times more than by the lens of a whole inch focal diſtance.

Once more; ſuppoſe the lens ſo ſmall that its focal diſtance is but 1-tenth of an inch, then the length of an object is magnified ſixty, ſeventy, or eighty times; the ſurface 3600, 4900, or 6400 times, and the ſolidity or whole bulk 216000, 343000, or 512000 times, or ſo much larger do the bodies of mites, or their eggs, appear than to the naked eye at ſix, ſeven, or eight inches diſtance.

After the ſame manner you may compute the magnifying power of lenſes of 1-twentieth, 1-thirtieth, 1-fortieth, and even 1-fiftieth part of an inch focal diſtance, which may be made if required; but they are with difficulty uſed. By a lens 1-fiftieth of an inch, the length is magnified 300 times;

times; and the surface 90000 times; and the solidity 27000000 times.

But these enormous powers of magnifying are much better effected in compound microscopes, and be that in what degree you please, it is thus easily estimated. Let C be the object lens in the cell Q, Fig. 13, of the compound microscope, if then a small object, a b, be placed on the stage at G, a little more than the focal distance, there will be formed by the said lens C, a large image S T, in the upper part of the microscope, and this image is viewed through the glass G H in its focus below at O. Fig. 13.

Now it is easy to understand that the image S T is as much larger than the object a b, as the distance C A, exceeds the distance C a from the lens. Suppose the image S T, six times larger than the object a b; then if it be viewed by a lens G H of one inch focal distance, the image S T will appear magnified six times at least, and therefore the object a b, will be magnified six times six, or 36 times in length; and 36 times 36, or 1296 times in surface; and 36 times 1296, or 46656 times in the bulk or solidity. And yet with these great powers of magnifying, the lens C may not be of less than half an inch focal distance, in the least sort of compound pocket microscopes.

But with a single eye-glass G H, we have too small a field of view, therefore we use two, viz. A B and D E; the first contracts the image S T, into another, I M, which is less, and this is viewed by the eye glass D E. Now both these glasses may have a magnifying power equal to that of a given single glass G H by this rule; let their distance be equal to the difference of their focal lengths, and their

magnifying power will be equal to that of a lens whofe focal diftance is half that of the greater A B.

For example, fuppofe the focal length of A B to be two inches 1-half, and that of D E one inch; then if their diftance be one inch 1-half, their joint magnifying power will be equal to that of a fingle lens G H, whofe focal diftance is one 1-4th, equal half that of A B. By the two eye-glaffes the rays are converged to the eye at the compound focus F, much lefs affected by the errors arifing from the aberration of rays, both from their different refrangibility, and the figure of the glaffes.

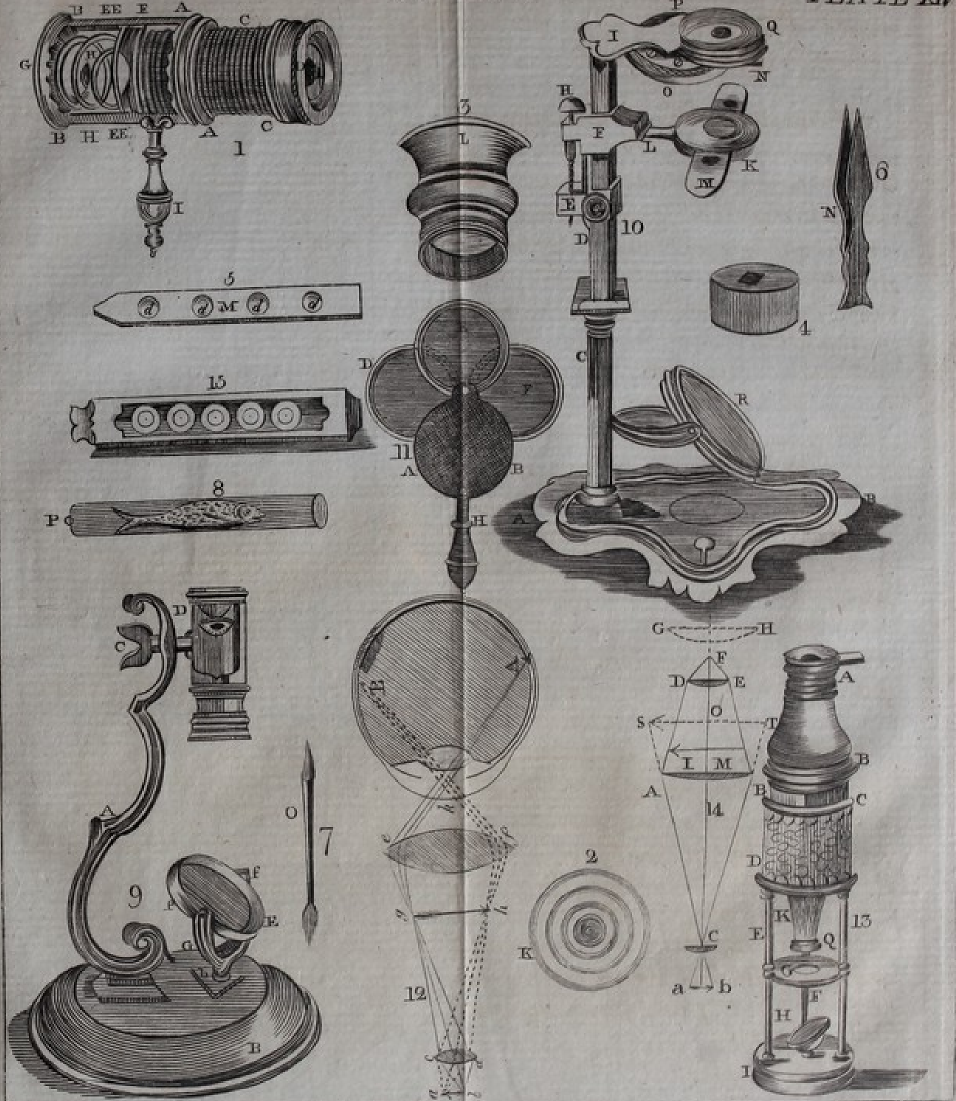
The Solar, or Camera Obfcura Microfcope.

THIS microfcope depends on the fun-fhine, and muft be made ufe of in a darkened chamber, as its name implies.

It is compofed of a tube, a looking-glafs, a convex lens, and Wilfon's fingle pocket microfcope before defcribed.

The fun's rays being directed by the looking-glafs through the tube upon the object, the image or picture of the object is thrown, diftinctly and beautifully, upon a fcreen of white paper, or a white linen fheet, placed at fome diftance to receive the fame; and may be magnified, to a fize beyond the imagination of thofe who have not feen it: for the farther off the fcreen is removed, the larger will the object appear; infomuch, that a loufe may be magnified to the length of five or fix feet, or even a great deal more: but

it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t is indeed more diſtinct, when not enlarged to above half that ſize.

The apparatus for this purpoſe, as repreſented in the plate annexed, is as follows: Plate XV.

A, a ſquare wooden frame, through which two long ſcrews paſs, and, aſſiſted by a couple of nuts 1. 1. faſten it firmly to a window-ſhutter, wherein a hole is made for its reception; the two nuts being let into the ſhutter, and made faſt thereto. Fig. 1.

A circular hole is made in the middle of this frame, to receive a piece of wood of a circular figure B, whoſe edge, that projects a little beyond the frame, compoſes a ſhallow groove 2, wherein runs a cat-gut 3; which by twiſting round, and then croſſing over a braſs pulley 4, (the handle whereof 5, paſſes through the frame) affords an eaſy motion for turning round the circular piece of wood B, with all the parts thereto affixed.

C is a braſs tube covered with ſeal-ſkin, which ſcrewing into the middle of the circular piece of wood, becomes a caſe for the uncovered braſs tube D, to be drawn backwards or forwards in.

E a ſmaller tube of about one inch in length, ſcrewed to the end of the larger tube D.

F is another ſhort braſs tube, made to ſlide over the above-deſcribed tube E. To the end hereof the microſcope muſt be ſcrewed when we come to uſe it.

5, A convex lens, whofe focus is about twelve inches, defigned to collect the fun's rays, and throw them more ftrongly upon the object.

G, a looking-glafs of an oblong figure, fet in a wooden frame, faftened by hinges to the circular piece of wood B, and turning about therewith, by means of the above-mentioned catgut.

H, a jointed wire, partly brafs and partly iron: the brafs part whereof, which is flat 6, being faftened to the looking-glafs, and the iron part, which is round 7, paffing through the wooden frame, enable the obferver (by putting it backwards or forwards) to elevate or decline the glafs according to the fun's altitude.

1, A brafs ring at the end of the jointed wire, whereby to manage it with greater eafe.

N. B. The extremities of the cat-gut are faftened to a brafs pin, by turning of which it may be braced up, if at any time it becomes too flack. This pin lying behind could not be fhown in the picture.

When this microfcope is employed, the room muft be rendered as dark as poffible: for on the darknefs of the room, and the brightnefs of the fun-fhine, depend the fharpnefs and perfection of your image. Then putting the looking-glafs G through the hole in your window-fhutter, faften the fquare frame A to the faid fhutter by its two fcrews and nuts, 1. 1.

This

This done, adjuſt your looking-glaſs to the elevation and ſituation of the ſun, by means of the jointed wire H, together with the cat-gut and pulley 3. 4. For the firſt of theſe raiſing or lowering the glaſs, and the other reclining it to either ſide, there reſults a twofold motion, which may eaſily be ſo managed as to bring the glaſs to a right poſition, that is, to make it reflect the ſun's rays directly through the lens 5, upon the paper ſcreen, and form thereon a ſpot of light exactly round.

Though obtaining a perfect circular ſpot of light upon the ſcreen before you apply the microſcope, is a certain proof that your looking-glaſs is adjuſted right, yet that proof muſt not always be expected: for the ſun is ſo low in winter, that if it ſhines in a direct line againſt the window, it cannot then afford a ſpot of light exactly round. But if it be on either ſide of you, a round ſpot may be obtained even in December.

As ſoon as this appears, ſcrew the tube C into the braſs collar provided for it in the middle of your wood-work, taking care not to alter your looking-glaſs; then ſcrewing the magnifier you chuſe to employ to the end of your microſcope, in the uſual manner, take away the lens at the other end thereof, and place a ſlider, containing the object to be examined, between the thin braſs plates, as in the other ways of uſing the microſcope.

Things being thus prepared, ſcrew the body of your microſcope to the ſhort braſs tube F, which ſlip over the ſmall end E of the tube D, and pull out the ſaid tube D leſs or more, as your object is capable of enduring the ſun's heat. Dead objects may be brought within about an inch of the focus

focus of the convex lens 5; but the diſtance muſt be ſhortened for living creatures, or they will ſoon be killed.

If the light falls not exactly right, you may eaſily, by a gentle motion of the jointed wire and pulley, direct it through the axis of the microſcopic lens.

The ſhort tube F, which your microſcope is ſcrewed to, enables you, by ſliding it backwards or forwards on the other tube E, to bring your objects to their true focal diſtance; which will be known by the ſharpneſs and clearneſs of their appearance; they may alſo be turned round by the ſame means, without being in the leaſt diſordered.

The magnifiers moſt uſeful in the ſolar microſcope are, in general, the fourth, fifth, or ſixth.

Mention having been often made of a ſcreen to throw the images of objects on, it is proper to inform the reader, that ſuch a ſcreen is uſually compoſed of a ſheet of the largeſt elephant paper, ſtrained on a frame, which ſlides up, or down, or turns about at pleaſure on a round wooden pillar, in the manner of ſome fire-ſcreens. Larger ſcreens are likewiſe made ſometimes, with ſeveral ſheets of the ſame paper paſted together on cloth, and let down from the cieling with a roller, like a large map.

This microſcope is the moſt entertaining of any; and, perhaps, the moſt capable of making diſcoveries in objects that are not too opake; as it ſhews them much larger than can be done any other way. There are alſo ſeveral conveniencies attending it, which no other microſcope can have

have: for the weakeſt eyes may uſe it without the leaſt ſtraining or fatigue: numbers of people may view any object, together, at the ſame time, and, by pointing to the particular parts thereof, and diſcourſing on what lies before them, may be able better to underſtand one another, and more likely to find out the truth, than when, in other microſcopes, they muſt peep one after another, and perhaps ſee the object neither in the ſame light, nor the ſame poſition. Such too as have no ſkill in drawing, may, by this contrivance, eaſily ſketch out the exact figure of any object they have a mind to preſerve a figure of; ſince they need only faſten a paper upon the ſcreen, and trace it out thereon either with a pen or pencil, as it appears before them.

It is worth their while, who are deſirous to take many draughts in this way, to get a frame, wherein a ſheet of paper may be put in or taken out at pleaſure; for if the paper be ſingle, the image of an object will be ſeen as plainly almoſt on the back as on the other ſide, and by ſtanding behind the ſcreen, the ſhade of the hand will not obſtruct the light in drawing, as it muſt in ſome degree when one ſtands before it.

I muſt obſerve, that Dr. Liberkhun's ſolar microſcope had no looking-glaſs belonging to it, and therefore was of uſe a few hours only in a day, when the tube could be placed directly againſt the body of the ſun, and even then not without a good deal of trouble; but by this lucky contrivance of a looking-glaſs, the ſun's rays may be reflected through the tube, whatever its height or ſituation be, provided

vided it ſhines at all upon the window, and that too with much eaſe and advantage.

Of the Nature and Uſe of the Micrometer in viewing ſmall Objects.

MANY and expenſive have been the contrivances for meaſuring ſmall objects, in all their dimenſions, by that inſtrument called, a micrometer; I ſhall refer the reader to the ſeveral writers on optics for an account of them, and ſhall here only propoſe one other method, which will come eaſy, and be very ready in practice; the conſtruction of which is a ſufficient explanation of its reaſon and uſe.

The new micrometer is nothing more than a ſtage (on which the objects are placed) moveable by a fine ſcrew which has a hand or ſmall index paſſing over the diviſions of a graduated circle. A fine threaded ſcrew is the eſſential part in all micrometers, of the beſt or moſt perfect kind. This ſcrew was formerly placed in the focus of the eye-glaſs D E, juſt where the image I M is formed, but I found this method of applying it gave ſome trouble in underſtanding and computing the dimenſions taken by it; and therefore I have here applied to the ſtage, or rather to the object itſelf; which being attended with no difficulty, will, I preſume, render the uſe of it more general and pleaſant.

Plate XIV. Fig. 14.

The upper part of the microſcope which contains the glaſs D E has a very fine wire in its focus, and to it any part of the image I M may be applied; or that wire may be applied to any part of the image, by a proper conſtruction

of

of the upper part of the microſcope for that purpoſe. The object being then placed in a proper manner on the ſtage, the ſcrew is to be turned, 'till the image of the object has paſſed its whole length or breadth under the wire, and then the quantity of its dimenſion will be known. Thus for example:

The number of threads on the ſcrew in one inch is fifty, and the number of diviſions on the circular plate is twenty. Therefore one thread, or one turn of the ſcrew, meaſures one fiftieth part of an inch; and one diviſion of the plate is one twentieth of one fiftieth, that is one thouſandth part of an inch. So that ſuch a micrometer will very exactly meaſure any ſmall object, or its ſmaller parts, to the thouſandth part of an inch.

Suppoſe the ſubject were a mite, and it were required to meaſure the length thereof; then I place it in a ſlider, and that ſlider on a ſtage in ſuch a manner, that the mite may move length-wiſe in the direction of a ſcrew, then I move or ſet the wire at right angles thereto, and ſo as to touch the image of the mite at one end, very exactly. This done, I turn the wire 'till the image has paſſed its whole length under the wire; and having counted the turns, I find them four, and fourteen diviſions of another; the four turns are 4-fiftieths or 80-thouſandths and the fourteen diviſions are 14-thouſandths, ſo that the whole length of the mite is 94-thouſandths part of an inch, which is almoſt 1-tenth part of an inch.

Again, for a ſecond example: ſuppoſe you meaſure the length of the egg of a mite, and find one turn of the ſcrew, and three diviſions on the plate, carry it completely

under the wire; then one revolution of the ſcrew is 1-fiftieth or 20-thouſandth, and three diviſions are 3-thouſandth, ſo the whole length of the egg is equal to 23-thouſandth of an inch; that is, almoſt one forty-fourth part of an inch; or forty-four ſuch eggs of a mite will, if laid contiguouſly in a right line, be nearly equal to one inch in length.

I may here add, that the micrometer may be eaſily applied to the ſolar microſcope; for let a fine ſtraight line be drawn on the ſcreen, and the end or ſide of the image be placed to touch it, then by turning the ſcrew, it will thereby be meaſured in thouſandth parts of an inch.

How great the pleaſure ariſing to the curious naturaliſts muſt be in the uſe of the micrometer, meaſuring the ſmalleſt objects, may be better conceived than expreſſed: when by this means he acquires an idea of the wonderful diſproportion there is between the magnitudes or dimenſions of the ſmalleſt and largeſt objects of the ſame ſpecies; as between the ſmalleſt of the finny fry and the largeſt whale; an animacule in vinegar and a rattleſnake thirty or forty feet long. And that the reader may have a clear perception of ſuch a ſurpriſing contraſt in the works of nature, I ſhall here give him a calculation of the comparative magnitude of the egg of a mite, and that of an oſtrich.

Suppoſe the length of an oſtrich's egg be five inches (and ſome are larger); alſo let the length of the egg of a mite be one fiftieth of an inch, and ſome are leſs than that; then the lengths of theſe two eggs will be to each other as five to one fiftieth or two hundred and fifty to one; then as they are ſimilar bodies, their magnitudes will be as the cubes

cubes of theſe numbers, viz. as 15625000 to one: that is in words, one egg of an oſtrich is equal to fifteen million ſix hundred and twenty-five thouſand eggs of a mite. And there is great reaſon to believe, that there are eggs o other animacules in a ſtill greater degree leſs than thoſe o a mite. Indeed the greateſt ſtretch of the human mind is infinitely inſufficient to explore the amazing and inconceivable gradations of miniature in every part of nature, even at their very commencement, and nothing but the all-piercing eye of boundleſs intelligence can ſee through a ſeries of ſuch infinitely decreaſing progreſſions.

A Diagram of the Solar Microſcope.

LET A B be a ſection of the window ſhutter of a dark room, C D of the frame containing a ſcioptric ball E F; in the forepart whereof is ſcrewed the tube G I K H, at one end of which is a lens G H, which, by converging the ſun-beams into a narrow compaſs, does ſtrongly enlighten the ſmall object a b, placed on a ſlip of glaſs, or otherwiſe, in the part of the tube N Q, where a ſlit is made on each ſide for that purpoſe. Within this tube there ſlides another L m r M, which contains a ſmall magnifying lens m r. Plate XV. Fig. 2.

By moving the exterior tube I G H K one way, and the other, the glaſs G H, will be brought to receive the rays of the ſun directly, and will therefore moſt intenſely illuminate the object a b. The other tube L M, being ſlid backwards and forwards, will adjuſt the diſtance of the ſmall lens m r, ſo that the image of the object a b ſhall be made very diſtinct, on the oppoſite ſide of the room at

O P; and the magnitude of the image will be to that of the object, as the diſtance from the lens m r is to the diſtance of the object from it, as is evident from the figure.

Of TELESCOPES.

BEFORE we enter upon the deſcription of teleſcopes, it will be proper to ſhew how the rays of light are affected by paſſing through concave glaſſes, and alſo by falling upon concave mirrours.

Fig. 3. When parallel rays, as a b c d e f g h, paſs directly through a glaſs A B, which is equally concave on both ſides, they will diverge after paſſing through the glaſs, as if they had come from a radiant point C, in the center of the glaſs's concavity; which point is called the negative or virtual focus of the glaſs. Thus the ray a, after paſſing through the glaſs A B, will go on in the direction k l, as if it had proceeded from the point C, and no glaſs been in the way. The ray b will go on in the direction m n; the ray c in the direction o p, &c. The ray C, that falls directly upon the middle of the glaſs, ſuffers no refraction in paſſing through it; but goes on in the ſame rectilineal direction, as if no glaſs had been in its way.

If the glaſs had been concave only on one ſide, and the other ſide quite plane, the rays would have diverged, after paſſing through it, as if they had come from a radiant point at double the diſtance of C from the glaſs; that is, as if the radiant had been at the diſtance of a whole diameter of the glaſs's concavity.

If

If rays come more converging to ſuch a glaſs, than parallel rays diverge after paſſing through it, they will continue to converge after paſſing through it; but will not meet ſo ſoon as if no glaſs had been in the way; and will incline towards the ſame ſide to which they would have diverged, if they had come parallel to the glaſs. Thus the rays f and h, going in a converging ſtate towards the edge of the glaſs at B, and converging more in their way to it than the parallel rays diverge after paſſing through it, they will go on converging after they paſs through it, though in a leſs degree than they did before, and will meet at I: but if no glaſs had been in their way, they would have met at i.

When the parallel rays, as d f a, C m b, e l c, fall upon a concave mirrour A B (which is not tranſparent, but has only the ſurface A b B of a clear poliſh) they will be reflected back from that mirrour, and meet in a point m, at half the diſtance of the ſurface of the mirrour from C, the center of its concavity: for they will be reflected at as great an angle from the perpendicular to the ſurface of the mirrour, as they fell upon it, with regard to that perpendicular; but on the other ſide thereof. Thus, let C be the center of concavity of the mirrour A b B, and let the parallel rays d f a, C m b, and e l c, fall upon it at the points a b, and c. Draw the lines C i a, C m b, and C h c, from the center C to theſe points; and all theſe lines will be perpendicular to the ſurface of the mirrour, becauſe they proceed thereto like ſo many radii or ſpokes from its center. Make the angle C a h equal to the angle d a C, and draw the line a m h, which will be the direction of the ray d f a, after it is reflected from the point of the mirrour: ſo that the angle of incidence d a C, is equal Fig. 44

to

to the angle of reflection C a h; the rays making equal angles with the perpendicular C i a on its oppofite fides.

Draw alfo the perpendicular C h c to the point c, where the ray e l c touches the mirrour; and, having made the angle C c i, equal to the angle C c e, draw the line c m i, which will be the courfe of the ray e l c, after it is reflected from the mirrour.

The ray C m b paffes through the center of concavity of the mirrour, and falls upon it at b, the perpendicular to it; and is therefore reflected back from it in the fame limb b m C.

All thefe reflected rays meet in the point m; and in that point the image of the body which emits the parallel rays d a, C d, and e c, will be formed: which point is diftant from the mirrour equal to half the radius b m C of its concavity.

The rays which proceed from any celeftial object may be efteemed parallel at the earth; and therefore, the images of that object will be formed at m, when the reflecting furface of the concave mirrour is turned directly towards the object. Hence the focus of the parallel rays is not in the center of the mirrour's concavity, but half way between the mirrour and that center.

The rays which proceed from any remote terreftrial object, are nearly parallel at the mirrour: not ftrictly fo, but come diverging to it, in feparate pencils, or, as it were, bundles of rays, from each point of the fide of the object next the mirrour; therefore they will not be converged

verged to a point, at the diſtance of half the radius of the mirrour's concavity from its reflecting ſurface; but in ſeparate points at a little greater diſtance from the mirrour. And the nearer the object is to the mirrour, the farther theſe points will be from it; and an inverted image of the object will be formed in them, which will ſeem to hang pendent in the air: and will be ſeen by an eye placed beyond it (with regard to the mirrour) in all reſpects like the object, and as diſtinct as the object itſelf.

Let A c B be the reflecting ſurface of a mirrour, whoſe center of concavity is at C; and let the upright object D E be placed beyond the center C, and ſend out a conical pencil of diverging rays from its upper extremity D, to every point of the concave ſurface of the mirrour A c B. But to avoid confuſion, we only draw three rays of that pencil, as D A, D c, D B. Fig. 5.

From the center of concavity C, draw the three right lines C A, C c, C B, touching the mirrour in the ſame points where the aforeſaid rays touch it; and all theſe lines will be perpendicular to the ſurface of the mirrour. Make the angle C A d equal to the angle D A C, and draw the right line A d for the courſe of the reflected ray D A: make the angle C c d equal to the angle D c C, and draw the right line c d for the courſe of the reflected ray D d: make alſo the angle C B d equal to the angle D B C, and draw the right light line B d for the courſe of the reflected ray D B. All theſe reflected rays will meet in point d, where they will form the extremity d of the inverted image e d, ſimilar to the extremity D of the upright object D E.

If

If the pencils of rays E f, E g, E h be alſo continued to the mirrour, and their angles of reflection from it be made equal to their angles of incidence upon it, as in the former pencil from D, they will all meet at the point e by reflection, and form the extremity e of the image e d, ſimilar to the extremity E of the object D E.

And as each intermediate point of the object, between D and E, ſends out a pencil of rays in like manner to every part of the mirrour, the rays of each pencil will be reflected back from it, and meet in all the intermediate points between the extremities e and d of the image; and ſo the whole image will be formed, not at i, half the diſtance of the mirrour from its center of concavity C; but at a greater diſtance, between i, and the object D E; and the image will be inverted with reſpect to the object.

This being well underſtood, the reader will eaſily ſee how the image is formed by the large concave mirrour of the reflecting teleſcope, when he comes to the deſcription of that inſtrument.

When the object is more remote from the mirrour than its center of concavity C, the image will be leſs than the object, and between the object and the mirrour; when the object is nearer than the center of concavity, the image will be more remote and bigger than the object: thus, if D E be the object, e d will be its image; for, as the object recedes from the mirrour, the image approaches nearer to it; and as the object approaches nearer to the mirrour, the image recedes farther from it; on account of the leſſer or greater divergency of the pencils of rays which proceed from the object; for, the leſs they diverge, the

ſooner

fooner they are converged to points by reflection; and the more they diverge, the farther they muft be reflected before they meet.

If the radius of the mirrour's concavity and the diftance of the object from it be known, the diftance of the image from the mirrour is found by this rule: divide the product of the diftance and radius by double the diftance made lefs by the radius, and the quotient is the diftance required.

If the object be in the center of the mirrour's concavity, the image and object will be coincident, and equal in bulk.

If a man places himfelf directly before a large concave mirrour, but farther from it than it's center of concavity, he will fee an inverted image of himfelf in the air, between him and the mirrour, of a lefs fize than himfelf. And if he holds out his hand towards the mirrour, the hand of the image will come out towards his hand, and coincide with it, of an equal bulk, when his hand is in the center of concavity; and he will imagine, he may fhake hands with his image. If he reaches his hand farther, the hand of the image will pafs by his hand, and come between his hand and his body: and if he moves his hand towards either fide, the hand of the image will move towards the other; fo that whatever way the object moves, the image will move the contrary way

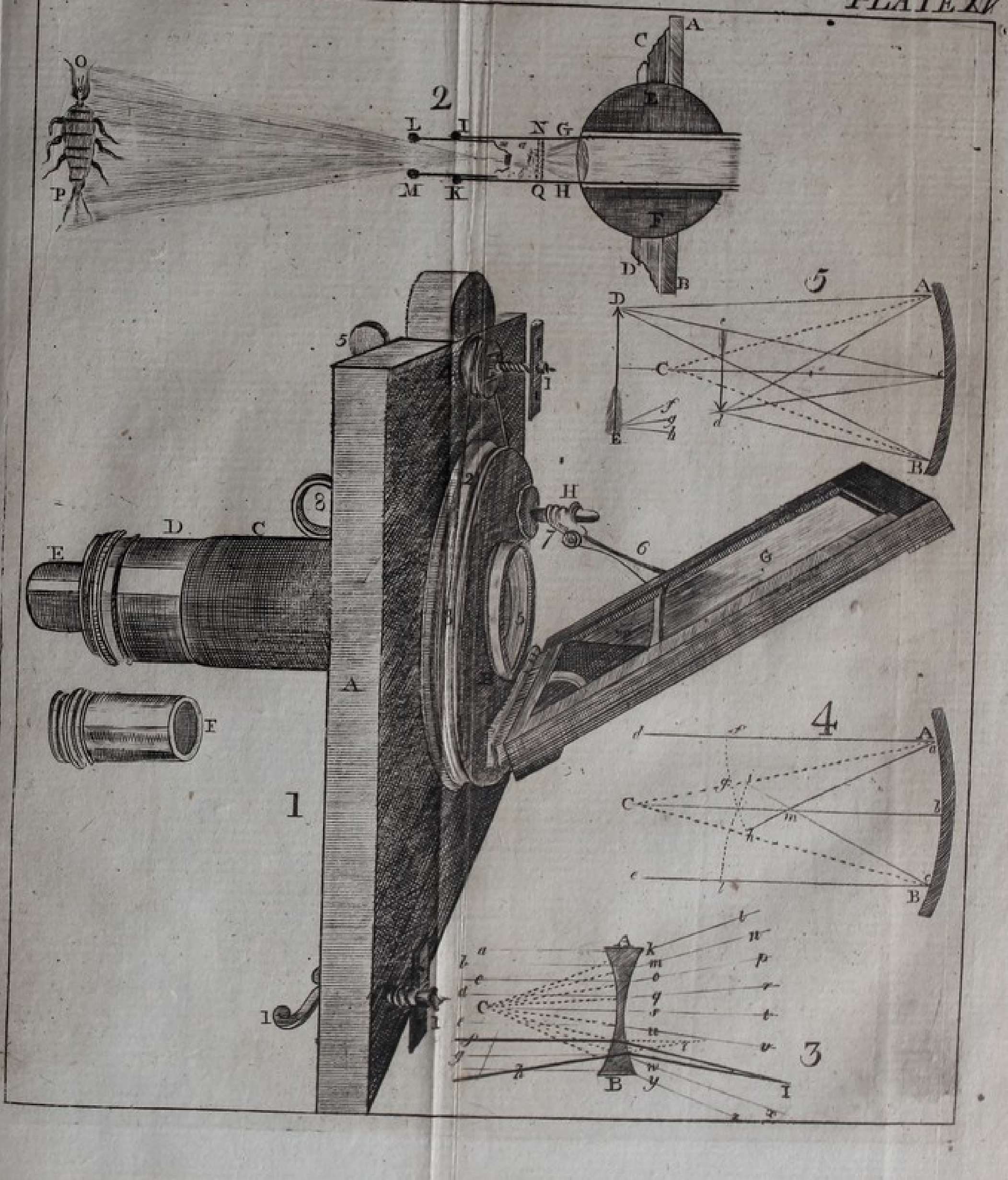
All the while a bye-ftander will fee nothing of the image, becaufe none of the reflected rays that form it enter his eyes.

If a fire be made in a large room, and a ſmooth mahogany table be placed at a good diſtance near the wall, before a large concave mirrour, ſo placed, that the light of the fire may be reflected from the mirrour to its focus upon the table; if a perſon ſtands by the table, he will ſee nothing upon it but a longiſh beam of light: but if he ſtands at a diſtance towards the fire, not directly between the fire and mirrour, he will ſee an image of the fire upon the table, large and erect. And if another perſon, who knows nothing of this matter before-hand, ſhould chance to come into the room, and ſhould look from the fire towards the table, he would be ſtartled at the appearance; for the table would ſeem to be on fire, and by being near the wainſcot, to endanger the whole houſe. In this experiment, there ſhould be no light in the room but what proceeds from the fire; and the mirrour ought to be at leaſt fifteen inches in diameter.

If the fire be darkened by a ſcreen, and a large candle be placed at the back of the ſcreen; a perſon ſtanding by the candle will ſee the appearance of a fine large ſtar, or rather planet, upon the table, as bright as Venus or Jupiter. And if a ſmall wax taper (whoſe flame is much leſs than the flame of the candle) be placed near the candle, a ſatellite to the planet will appear on the table: and if the taper be moved round the candle, the ſatellite will go round the planet.

The Refracting Teleſcope.

IN a refracting teleſcope, the glaſs which is neareſt the object in viewing it, is called the object glaſs; and that which



which is nearest the eye, is called the eye-glass. The object-glass must be convex, but the eye-glass may be either convex or concave: and generally, in looking through a telescope, the eye is in the focus of the eye-glass; though that it is not very material: for the distance of the eye, as to distinct vision, is indifferent, provided the rays of the pencils fall upon it parallel: only, the nearer the eye is to the end of the telescope, the larger is the scope or area of the field of view.

Let c d be a convex glass fixed in a long tube, and have its focus at E. Then, a pencil of rays g h i, flowing from the upper extremity A of the remote object A B, will be so refracted by passing through the glass, as to converge and meet in point f; whilst the pencil of rays k l m flowing from the lower extremity B, of the same object A B, and passing through the glass, will converge and meet in the point e: and the images of the points A and B, will be formed in the points f and e. And as all the intermediate points of the object, between A and B, send out pencils of rays in the same manner, a sufficient number of these pencils will pass through the object glass c d, and converge to as many intermediate points between e and f; and so will form the whole inverted image e E f, of the distinct object. But because this image is small, a concave glass n o is so placed in the end of the tube next the eye, that its virtual focus may be at F. And as the rays of the pencils pass converging through the concave glass, but converge less after passing through it than before, they go on further, as to b and a, before they meet; and the pencils themselves being made to diverge by passing through the concave glass, they enter the eye, and form the large

Plate XVI. Fig. 1

picture a b upon the retina, whereon it is magnified under the angle b F a.

But this telefcope has one inconveniency which renders it unfit for moft purpofes, which is, that the pencils of rays being made to diverge by paffing through the concave glafs n o, very few of them can enter the pupil of the eye; and therefore the field of view is but very fmall, as is evident by the figure. For none of the pencils which flow either from the top or bottom of the object A B can enter the pupil of the eye at C, but are all ftopt by falling upon the iris above and below the pupil: and therefore only the middle part of the object can be feen when the telefcope lies directly towards it, by means of thofe rays which proceed from the middle of the object. So that to fee the whole of it, the telefcope muft be moved upwards and downwards, unlefs the object be very remote; and then it is never feen diftinctly.

Fig. 2. This inconvenience is remedied by fubftituting a convex eye-glafs, as g h, in place of the concave one; and fixing it fo in the tube, that its focus may be coincident with the focus of the object glafs c d, as at E. For then, the rays of the pencils flowing from the object A B, and paffing through the object glafs c d, will meet in its focus, and form the inverted image m E p, and as the image is formed in the focus of the eye glafs g h, the rays of each pencil will be parallel, after paffing through that glafs; but the pencils themfelves will crofs in its focus, on the other fide, as at e: and the pupil of the eye being in this focus, the image will be viewed through the glafs, under the angle g e h; and being at E, it will appear magnified, fo as to fill the whole fpace C m e p D.

But

But, as this telefcope inverts the image with refpect to the oqject, it gives an unpleafant view of terreftrial objects; and is only fit for viewing the heavenly bodies, in which we regard not their pofition, becaufe their being inverted does not appear, on account of their being round. But whatever way the object feems to move, this telefcope muft be moved the contrary way, in order to keep fight of it; for, fince the object is inverted, its motion will be fo too.

The magnifying power of this telefcope is, as the focal diftance of the object glafs to the focal diftance of the eye glafs. Therefore, if the former be divided by the latter, the quotient will exprefs the magnifying power.

When we fpeak of magnifying by a telefcope or microfcope, it is only meant with regard to the diameter, not to the area or folidity of the object. But as the inftrument magnifies the vertical diameter, as much as it does the horizontal, it is eafy to find how much the whole vifible area or furface is magnified: for, if the diameters be multiplied into one another, the product will exprefs the magnification of the whole vifible area. Thus, fuppofe the focal diftance of the object-glafs be ten times as great as the focal diftance of the eye-glafs; then, the object will be magnified ten times, both in length and breadth: and ten multiplied by ten, produces one hundred; which fhews, that the area of the object will appear one hundred times as big when feen through fuch a telefcope, as it does to the bare eye.

Hence it appears, that if the focal diftance of the eye-glafs, were equal to the focal diftance of the object-

glafs,

glafs, the magnifying power of the telefcope would be nothing.

This telefcope may be made to magnify in any given degree, provided it be of a fufficient length. For, the greater the focal diftance of the object-glafs, the lefs may be the focal diftance of the eye-glafs; though not directly in proportion. Thus, an object-glafs of ten feet focal diftance, will admit of an eye-glafs whofe focal diftance is little more than two inches and a half; which will magnify near forty-eight times; but an object-glafs, of one hundred feet focus, will require an eye-glafs fomewhat more than fix inches; and will therefore magnify almoft two hundred times.

Fig. 3. A telefcope for viewing terreftrial objects, fhould be fo conftructed, as to fhew them in their natural pofture. And this is done by one object-glafs c d, and three eye-glaffes, e f, g h, i k, fo placed, that the diftance between any two, which are neareft to each other, may be equal to the fum of their focal diftances; as in the figure, where the focus of the glaffes c d and e f meet at F, thofe of the glaffes e f and g h, meet at l, and of g h and i k, at m; the eye being at n, in or near the focus of the eye-glafs i k, on the other fide. Then, it is plain, that thefe pencils of rays which flow from the object A B, and pafs through the object-glafs c d, will meet and form an inverted image C F D in the focus of that glafs; and the image being alfo in the focus of the glafs e f, the rays of the pencils will become parallel, after paffing through that glafs(and crofs at l, in the focus of the glafs e f; from whence they pafs on to the next glafs g h, and by going through it they are converged to the points in its other focus, where they form an erect

erect image E m F, of the object A B; and as this image is alſo in the focus of the eye-glaſs i k, and the eye on the oppoſite ſide of the ſame glaſs; the image is viewed thro' the eye-glaſs, in this teleſcope, in the ſame manner as through the eye-glaſs in the former one; only in a contrary poſition, that is, in the ſame poſition with the object.

The three glaſſes next the eye, have all their focal diſtances equal: and the magnifying power of this teleſcope is found the ſame way as that of the laſt above; viz. by dividing the focal diſtance of the object-glaſs c d, by the focal diſtance of the eye-glaſs i k, or g h, or e f, ſince all theſe three are equal.

When the rays of light are ſeparated by refraction, they become coloured, and if they be united again, they will be a perfect white. But thoſe rays which paſs through a convex glaſs, near its edges are more unequally refracted than thoſe which are nearer the middle of the glaſs. And when the rays of any pencil are unequally refracted by the glaſs, they do not all meet again in one and the ſame point, but in ſeparate points; which makes the object indiſtinct, and coloured about the edges. The remedy is, to have a plate with a ſmall round hole in its middle, fixed in the tube at m, parallel to the glaſſes. For, the wandering rays about the middle of the glaſſes will be ſtopt, by the plate, from coming to the eye; and none admitted but thoſe which come through the middle of the glaſs, or at leaſt at a good diſtance from its edges, and paſs through a hole in the middle of the plate. But this circumſcribes the image, and leſſens the field of view, which would be much larger if the plate could be diſpenſed with.

Why the object appears coloured when ſeen through a teleſcope.

The

The Binocular, or Double Telescope.

BESIDES the telescopes described before, there is also one called a binocular, or double telescope. This is no more than two equal telescopes set in a frame, parallel to one another; and these may be set at a proper distance from one another, by the help of screws: and that distance is to be the same, as the distance of the two pupils of the eyes. When that is adjusted, a person is to look through them both at once; through one with each eye, to any object; which will then be seen by both eyes, and appear far brighter than through a single telescope.

All telescopes in general represent all terrestrial objects to be nearer hand, but not larger; and this nearness, vicinity, or seeming approach of the object, is as the magnifying power of the telescope. Thus looking at a man one hundred yards off, with a telescope that magnifies one hundred times; the man will appear to be no bigger, but will seem only to be a yard off; and the like of other objects situated on the earth.

The magnifying power of a telescope, will be found if you make two equal circles of paper of an inch diameter or more, and fix one of them upon a wall one hundred or two hundred yards distant; and the other at a small distance, in a line with the first. Then look at the further circle through the telescope with one eye, and at the near circle with the other eye naked. Move the near circle (or else the telescope) back and forward, till the two circles appear equal, or coincide. Then measure the two distances

tances, from the eye-glafs of the telefcope to the two circles; then divide the greater diftance by the leffer, and you have the magnifying power of the telefcope.

To try the Goodnefs of an Object Glafs.

THERE is no better way for trying the goodnefs of an object glafs than putting it in a tube, and trying it with feveral fmall eye-glaffes, by looking at feveral diftant objects, and particularly at the title page of a book. For that glafs which reprefents objects the moft bright and diftinct, and bears the greateft aperture, and the fhorteft eye-glafs, without colouring or dimnefs, is the beft glafs.

If feveral telefcopes of the fame length be compared together, thofe are the beft, with which you can read the fame print, at the greateft diftance. And this may be a rule for thofe that buy telefcopes, by which they may know how to chufe the beft.

There are four principal things in a telefcope to be confidered: 1. Magnifying power. 2. Diftinctnefs. 3. Brightnefs. 4. The vifible angle, or linear view it takes in.

A TABLE *of the focal Distances, Apertures, and magnifying Powers of Refracting Telescopes.*

Foc. obj. glass	aper. obj. glass	Foc. eye glass.	mag. power.
Feet.	Inch.	Inch.	
1	.54	.60	20
2	.76	.83	28
3	.94	1.03	34
4	1.08	1.19	40
5	1.22	1.34	44
6	1.32	1.45	49
7	1.43	1.57	52
8	1.53	1.68	56
9	1.62	1.78	60
10	1.71	1.88	64
13	1.95	2.14	73
15	2.09	2.30	78
20	2.42	2.66	90
25	2.70	2.97	101
30	2.96	3.25	110
35	3.20	3.52	119
40	3.41	3.75	128
45	3.62	3.98	135
50	3.82	4.20	143
55	4.00	4.40	150
60	4.18	4.60	156
70	4.52	4.97	169
80	4.83	5.31	181
90	5.13	5.64	192
100	5.40	5.94	202
120	5.91	6.50	222
140	6.39	7.03	239
160	6.83	7.51	255
180	7.25	7.97	271
200	7.64	8.40	284

The

The Reflecting Telescope.

THE great inconvenience attending the management of long telescopes of the refracting kind, has brought them much into disuse ever since the reflecting telescope was invented. For one of this sort, six feet in length, magnifies as much as one of the other at an hundred. It was invented by Sir Isaac Newton, but has received considerable improvements since his time; and is now generally constructed in the following manner, which was first proposed by Dr. Gregory.

At the bottom of the great tube T T T T, is placed the large concave mirrour D U V F, whose principal focus is at m; and in its middle is a round hole P, opposite to which is placed the small mirrour L, concave toward the great one; and so fixed to a strong wire M, that it may be moved farther from the great mirrour, or nearer to it, by means of a long screw on the outside of the tube, keeping its axis still in the same line P m n with that of the great one. Now, since in viewing a very remote object, we can scarce see a point of it but what is at least as broad as the great mirrour, we may consider the rays of each pencil, which flow from every point of the object, to be parallel to each other, and to cover the whole reflecting surface D U V F. But to avoid confusion in the figure, we shall only draw two rays of a pencil flowing from each extremity of the object into the great tube, and trace their progress, through all their reflections and refractions, to the eye f, at the end of the small tube t t, which is joined to the great one. Fig. 4.

Let us then ſuppoſe the object A B to be at ſuch a diſtance, that the rays C may flow from its lower extremity B, and the rays E from its upper extremity A. Then the rays C falling parallel upon the great mirrour at D, will be thence reflected, converging in the direction D G; and by croſſing at I in the principal focus of the mirrour, they will form the upper extremity I of the inverted image I K, ſimilar to the lower extremity B of the object A B: and paſſing on to the concave mirrour L (whoſe focus is at n) they will fall upon it at g, and be thence reflected converging, in the direction g N, becauſe, g m is longer than g n; and paſſing through the hole P in the large mirrour, they would meet ſomewhere about r, and form the lower extremity d of the erect image a d, ſimilar to the lower extremity B of the object A B. But by paſſing through the plano-convex-glaſs R in their way, they form that extremity of the image at b. In like manner, the rays E, which come from the top of the object A B, and fall parallel upon the great mirrour at F, are thence reflected converging to its focus, where they form the lower extremity K of the inverted image I K, ſimilar to the upper extremity A of the object A B; and thence paſſing on to the ſmall mirrour L, and falling upon it at h, they are thence reflected in the converging ſtate h O; and going on through the hole P of the great mirrour, they would meet ſomewhere about q, and form there the upper extremity a of the erect image a d, ſimilar to the upper extremity A of the object A B: but by paſſing through the convex-glaſs R in their way, they meet and croſs ſooner, as at a, where that point of the erect image is formed. The like being underſtood of all thoſe rays which flow from the intermediate points of the object, between A and B, and enter the tube T T; all the intermediate points of the image between a and b will be formed: and the rays

paſſing

paſſing on from the image through the eye-glaſs S, and through a ſmall hole e in the end of the leſſer tube t t, they enter the eye f, which ſees the image a d (by means of the eye-glaſs) under the large angle c e d, and magnified in length, under that angle from c to d.

In the beſt reflecting teleſcopes, the focus of the ſmall mirrour is never co-incident with the focus m of the great one, where the firſt image I K is formed, but a little beyond it (with reſpect to the eye) as at n: the conſequence of which is, that the rays of the pencils will not be parallel after reflection from the ſmall mirrour, but converge ſo as to meet in points about q, e, r; where they will form a larger upright image than a d, if the glaſs R was not in their way: and this image might be viewed by means of a ſingle eye-glaſs properly placed between the image and the eye: but then the field of view would be leſs, and conſequently not ſo pleaſant; for which reaſon, the glaſs R is ſtill retained, to enlarge the ſcope or area of the field.

To find the magnifying power of this teleſcope multiply the focal diſtance of the great mirrour by the diſtance of the ſmall mirrour from the image next the eye, and multiply the focal diſtance of the ſmall mirrour by the focal diſtance of the eye-glaſs: then, divide the product of the former multiplication by the product of the latter, and the quotient will expreſs the magnifying power.

I ſhall here ſet down the dimenſions of one of Mr. Short's reflecting teleſcopes, as deſcribed in Dr. Smith's optics.

The focal diſtance of the great mirrour 9.6 inches, its breadth 2.3; the focal diſtance of the ſmall mirrour 1.5, its

its breadth 0.6: the breadth of the hole in the great mirrour 0,5; the diſtance between the ſmall mirrour and the next eye-glaſs 14.2; the diſtance between the two eye-glaſſes 2.4; the focal diſtance of the eye-glaſs next the metal 3.8; and the focal diſtance of the eye-glaſs next the eye 1.1.

One great advantage of the reflecting teleſcope is, that it will admit of an eye-glaſs of a much ſhorter focal diſtance than a refracting teleſcope will; and, conſequently, it will magnify ſo much the more: for the rays are not coloured by reflection from a concave mirrour, if it be ground to a true figure, as they are by paſſing through a convex-glaſs, let it be ground ever ſo true.

The adjuſting ſcrew on the outſide of the great tube fits this teleſcope to all ſorts of eyes, by bringing the ſmall mirrour either nearer to the eye, or removing it farther: by which means the rays are made to diverge a little, for ſhort-ſighted eyes, or to converge for thoſe of a long-ſight.

The nearer an object is to the teleſcope, the more its pencils of rays will diverge before they fall upon the great mirrour, and therefore they will be the longer of meeting in points after reflection; ſo that the firſt image I K will be formed at a greater diſtance from the large mirrour, when the object is near the teleſcope, than when it is very remote. But as this image muſt be formed farther from the ſmall mirrour than its principal focus n, this mirrour muſt be always ſet at a greater diſtance from the large one, in viewing near objects, than in viewing remote ones. And this is done by turning the ſcrew on the outſide of the tube, until the ſmall mirrour be ſo adjuſted, that the object (or rather its image) appears perfect.

In

In looking through any telefcope towards an object, we never fee the object itfelf, but only that image of it which is formed next the eye in the telefcope. For, if a man holds his finger or a ftick between his bare eye and an object, it will hide part (if not the whole) of the object from his view. But if he ties a ftick acrofs the mouth of a telefcope, before the object-glafs, it will hide no part of the imaginary object he faw through the telefcope before, unlefs it covers the whole mouth of the tube: for, all the effect will be, to make the object appear dimmer, becaufe it intercepts part of the rays. Whereas, if he puts only a piece of wire acrofs the infide of the tube, between the eye-glafs and his eye, it will hide part of the object which he thinks he fees: which proves that he fees not the real object, but its image. This is alfo confirmed by means of the fmall mirrour L, in the reflecting telefcope, which is made of opake metal, and ftands directly between the eye and the object towards which the telefcope is turned; and will hide the whole object from the eye at e, if the two glaffes R and S are taken out of the tube.

A TABLE *of the Apertures, Powers, &c. of Telescopes of the the Newtonian Construction, in which the Figure of the great Metal is supposed to be truly Spherical.*

Focal distance of the Concave Metal.	Aperture of Concave Metal.	Sir Isaac Newton's Numbers	Focal distance of single eye glass.	Magnifying power.
Feet.	In. dec.		In. dec.	
½	0.86	100	0.167	36
1	1.44	168	0.199	60
2	2.45	283	0.236	102
3	3.31	383	0.261	138
4	4.10	476	0.281	171
5	4.85	562	0.297	202
6	5.57	645	0.311	232
7	6.24	—	0.323	260
8	6.89	800	0.334	287
9	7.54	—	0.344	314
10	8.16	946	0.353	340
11	8.76		0.362	365
12	9.36	1084	0.367	390
13	9.94	—	0.377	414
14	10.49	—	0.384	437
15	11.04	—	0.391	460
16	11.59	1345	0.397	483
17	12.14	—	0.403	506
18	12.67	—	0.409	528
19	13.20	—	0.414	550
20	13.71	1591	0.420	571
21	14.23	—	0.425	593
22	14.73	—	0.430	614
23	15.21	—	0.435	635
24	15.73	1824	0.439	656

As

AS telefcopes of Sir Ifaac Newton's conftruction are now found (particularly by the late exquifite obfervations of Mr. Herfchell) to perform moft excellently in the *minutiæ* of aftronomy, efpecially if fmall apertures and long foci are made ufe of, I have added the foregoing table chiefly taken from Dr. Smith's optics, and have continued it from 17 to 24 feet focal diftance of the great mirrour: I have alfo annexed to it Sir Ifaac Newton's numbers, by means of which the apertures of reflecting telefcopes of any conftruction may be eafily computed. See appendix to Gregory's optics.

It may be neceffary to mention that the preceding table was conftructed by ufing the dimenfions of the middle aperture and power of Mr. Hadley's excellent *Newtonian* telefcope as a ftandard; viz. the focal diftance of great mirrour 62½ inches; aperture of concave metal 5 inches, and power 208 times. Mr. Herfchell chiefly makes ufe of a Newtonian reflector, the focal diftance of whofe great mirrour is 7 feet, its aperture 6.25 inches, and powers 227 and 460 times; though fometimes he ufes a power of 6450 for the fixed ftars; but he is now conftructing a telefcope which will infinitely exceed the former.

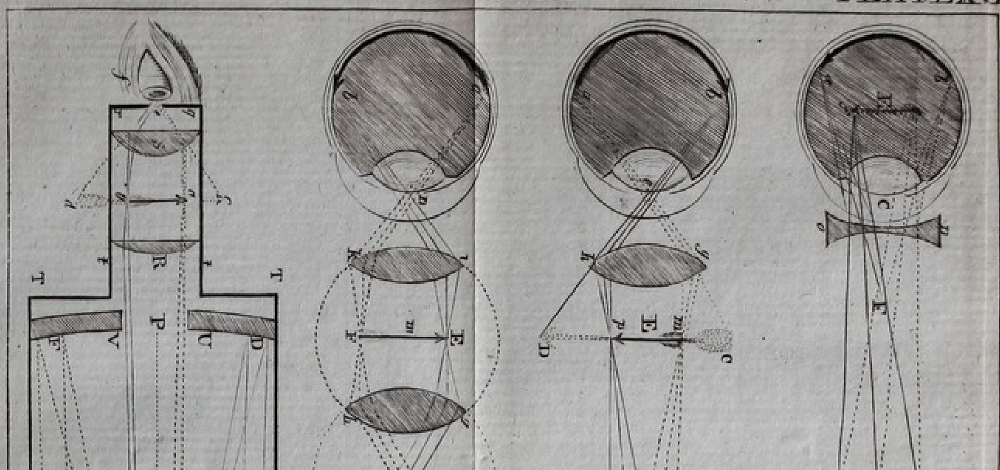
If the metals of a *Newtonian* telefcope are worked as exquifitely as thofe in Mr. Herfchell's 7 feet reflector, the higheft power that fuch a telefcope fhould bear with perfect diftinctnefs will be given by multiplying the diameter of the great fpeculum by 74; and the focal diftance of the fingle eye-glafs may be found by dividing the focal diftance of the great mirrour by the magnifying power; thus 6.25 multiplied by 74 is 462 the magnifying power; and

7 multiplied by 12 and divided by 462 is 0.182 of an inch, the focal diſtance of the ſingle eye-glaſs required. To this I ſhall add,

A TABLE *of the Dimenſions and magnifying Powers of Gregorian Reflecting Teleſcopes, as conſtructed by* Mr. Short, *computed by* Dr. Smith, *from the Dimenſions of one given before. See Page* 261.

Focal diſtance of the great mirror.	Breadth of the great mirror.	Focus of the little ſpeculum.	Breadth of the hole in the great ſpeculum.	Diſtance between the little ſpeculum and the firſt eye-glaſs.	Focal diſtance of the glaſs next the Metals.	Focal diſtance of the glaſs next the eye.	Diſtance between the two glaſſes.	Magnifying Power.
In. dec.	In. dec.	In. dec.	In. dec.	In. dec.	In. dec.	In. dec.	In. dec.	
5.65	1.54	1.10	.31	8.54	2.44	.81	1.68	39
9.60	2.30	1.50	.39	14.61	3.13	1.04	2.08	60
15.50	3.30	2.14	.50	23.81	3.94	1.31	2.63	86
36.00	6.26	3.43	.65	41.16	5.12	1.70	3.41	165
60.00	9.21	5.00	.85	68.17	6.43	2.4	4.28	242

The



The Multiplying Glaſs.

THE multiplying glaſs is made by grinding down the round ſide h i k of a convex glaſs A B into ſeveral flat ſurfaces, as h b, b l d, d k. An object C will not appear magnified, when ſeen through this glaſs, by the eye at H; but it will appear multiplied into as many different objects as the glaſs contains plane ſurfaces. For, ſince rays will flow from the object C to all parts of the glaſs, and each plane ſurface will refract theſe rays to the eye, the ſame object will appear to the eye, in the direction of the rays which enter it through each ſurface. Thus, a ray g i H, falling perpendicularly on the middle ſurface will go through the glaſs to the eye, without ſuffering any refraction; and will therefore ſhew the object in its true place at C: whilſt a ray a b flowing from the ſame object, and falling obliquely on the plane ſurface b h, will be refracted in the direction b e, by paſſing through the glaſs; and upon leaving it, will go on to the eye in the direction e H; which will cauſe the ſame object C to appear alſo at E, in the direction of the ray H e, produced in the right line H e n. And the ray c d, flowing from the object C, and falling obliquely on the plane ſurface d k, will be refracted (by paſſing through the glaſs and leaving it at f) to the eye at H; which will cauſe the ſame object to appear at D, in the direction H f m. If the glaſs be turned round the line g l H, as an axis, the object C will keep its place, becauſe the ſurface b l d is not removed; but all the other objects will ſeem to go round C, becauſe the oblique planes, on which the rays a b, c d fall, will go round by the turning of the glaſs. Plate XVII Fig. 1.

The Camera Obſcura.

Fig. 2. THE camera obſcura is made by a convex glaſs C D, placed in a hole of a window-ſhutter. Then, if the room be darkened ſo as no light can enter but what comes through the glaſs, the pictures of all the objects (as fields, trees, buildings, men, cattle, &c.) on the outſide, will be ſhewn in an inverted order, on a white paper, placed at G H in the focus of the glaſs; and will afford a moſt beautiful and perfect piece of perſpective or landſcape of whatever is before the glaſs: eſpecially if the ſun ſhines upon the objects.

If the convex glaſs C D be placed in a tube in the ſide of a ſquare box, within which is the plane mirrour E F, reclining backwards in an angle of forty-five degrees from the perpendicular k q, the pencils of rays flowing from the outward objects, and paſſing through the convex glaſs to the plane mirrour, will be reflected upwards from it, and meet in points, as I and K (at the ſame diſtance that they would have met at H and G, if the mirrour had not been in the way) and will form the aforeſaid images on an oiled paper ſtretched horizontally in the direction I K; on which paper the out-lines of the images may be eaſily drawn with a black lead pencil; and then copied on a clean ſheet and coloured by art, as the objects themſelves are by nature. In this machine, it is uſual to place a plain glaſs, unpoliſhed, in the horizontal ſituation I K, which glaſs receives the images of the outward objects; and their out-lines may be traced upon it by a black lead pencil.

The

The tube in which the convex glafs C D is fixed, muft be made to draw out, or pufh in, fo as to adjuft the diftance of that glafs from the plain mirrour, in proportion to the diftance of the outward objects; which the operator does, until he fees their images diftinctly painted on the horizontal glafs at I K.

The forming a horizontal image, as I K, of an upright object A B, depends upon the angles of incidence of the rays upon the plane mirrour E F, being equal to their angles of reflection from it. For, if a perpendicular be fuppofed to be drawn to the furface of the plain mirrour at e, where the ray A a C e falls upon it, that ray will be reflected upwards in an equal angle with the other fide of the perpendicular, in the line e d I. Again, if a perpendicular be drawn to the mirrour from the point f, where the ray A b f falls upon it, that ray will be reflected in an equal angle from the other fide of the perpendicular, in the line f h I. And if a perpendicular be drawn from the point g, where the ray A c g falls upon the mirrour, that ray will be reflected in an equal angle from the other fide of the perpendicular, in the line g i I. So that all the rays of the pencil a b c, flowing from the upper extremity of the object A B, and paffing through the convex-glafs C D, to the plain mirrour E F, will be reflected from the mirrour and meet at I, where they will form the extremity I of the image I K, fimilar to the extremity A of the object A B. The like is to be underftood of the pencil q r s, flowing from the lower extremity of the object A B, and meeting at K (after reflection from the plain mirrour) the rays from the extremity K of the image, fimilar to the extremity B of the object: and fo of all the pencils that flow from the intermediate points of the object

to

to the mirrour, through the convex-glaſs. This may be further improved by placing a convex lens of ſix inches focal diſtance, and four inches diameter, or more if it be required longer between the mirrour and the ground glaſs, and though this will reduce the picture, yet it will be more illuminated, and afford a pleaſanter view.

The Solar Teleſcope,

IS a curious inſtrument and is applied to uſe in the following manner. A ſcioptric ball and ſocket being faſtened againſt a hole in the window ſhutter in a darkened chamber, place the end of a common refracting teleſcope with its object-glaſs and eye-glaſs into the cylindrical hole of the ſcioptric ball, and draw out the tube to its proper length; this being done, the teleſcope and ball are moved about till it receives the ſun-beams perpendicular on the object-glaſs through the cylindrical hole of the ball; the tube with the eye-glaſs is then to be adjuſted by moving it either in or out, till the image of the ſun, formed on a white plane or ſcreen, is very diſtinct, large, and luminous.

In this manner the ſun's face is viewed without offence to the eyes, and whatever changes happen therein may be moſt accurately obſerved; the ſpots, which are ſeldom ſeen even when viewed through ſmall teleſcopes in the common way, are here conſpicuous, and eaſy to be obſerved with all the different circumſtances of the ſpots beginning to appear, their increaſe, diviſion of one into many, or the uniting of many into one, their magnitude, and decreaſe, their vaniſhing, and their diſappearance behind the ſun.

An

An eclipse of the ſun may by the ſolar teleſcope be viewed to the greateſt advantage, we having it in our power to repreſent the face of the ſun as large as we pleaſe, conſequently the eclipſe proportionally conſpicuous; alſo the circle of the ſun's diſh may be ſo divided by lines and circles drawn thereon, that the quantity of the eclipſe intimated in digits may this way be exactly determined; alſo the exact time of the beginning, middle and end thereof, for determining the longitude of the place, are ſeen to the greateſt advantage. The tranſits of Mercury and Venus over the face of the ſun, are exhibited moſt delightfully by this inſtrument: they will here appear truly round, well defined, and very black: their comparative diameters to that of the ſun may this way be obſerved, the direction of their motion, and the times of ingreſs and egreſs are here viewed to the greateſt perfection.

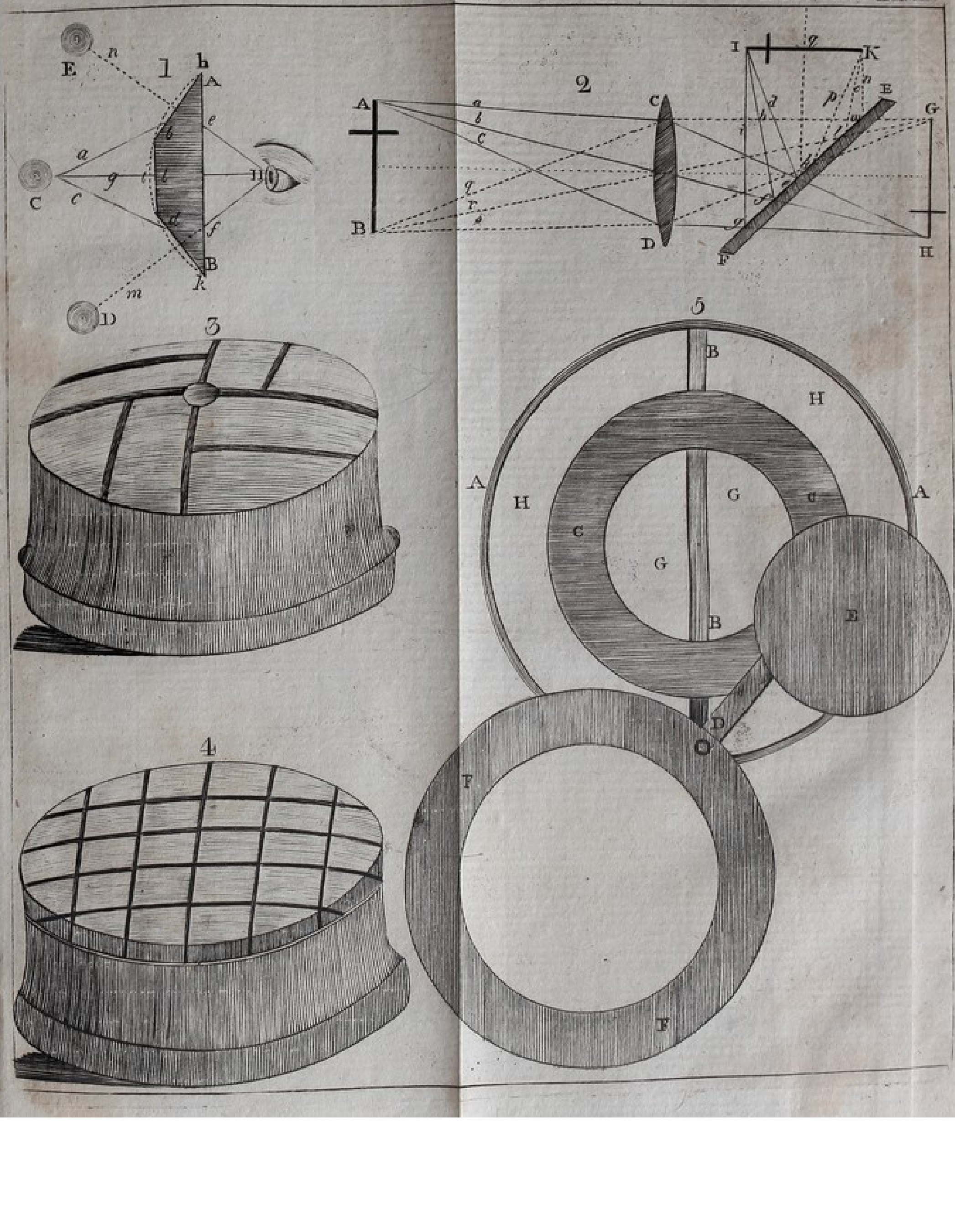
The *Helioſtata* to take off the inconveniencies which ariſe from the motion of the earth, in making experiments on the ſolar light, was an excellent invention of Dr's *Graveſand*, it conſiſts of two principal parts each of which conſiſts of many ſmaller parts, The firſt is a plain metallic ſpeculum, ſupported by a ſtand; the other is a clock which directs the ſpeculum according to the earth's motion, keeping the ſun in the ſame point of view.

The Acromatic Teleſcope.

THIS conſiſts of a double or treble object-glaſs; the double object-glaſs conſiſts of a double concave of white flint and a double convex of crown glaſs. The parts of the lenſes, which

which are of the fame fide of the centers may be conceived to act like two prifms, which refract contrary ways; and if the excefs of refraction in the crown glafs be fuch as to deftroy the divergency of colour caufed by the flint-glafs, the incident ray will be refracted without any production of colour: the fame is true of all the incident rays, and confequently the image formed in the focus of this compound object-glafs will be free from colours; or in other words by means of the different refractive power of thefe two forts of glafs and their unequal figure, it comes to pafs that all the rays of light incident upon thofe glaffes from diftant radiant objects, will pafs through them in fuch a manner, that whatever aberration is occafioned in the heterogeneal rays in refraction through the firft glafs, is fo far corrected by the fecond, that thofe rays emerge from it nearly parallel among themfelves, and are converged to one focus, forming an image not fenfibly compounded or coloured, and therefore are more perfect and diftinct. It will therefore admit a much larger aperture, and of courfe a greater magnifying power than the common refracting telefcopes poffibly can; if the telefcope be fhort the convexity of the lenfes will be confiderable, and in fuch cafes it is moft convenient to combine three lenfes, one concave of white flint glafs between two convex of crown glafs; but ftill, where a great magnifying power is wanted, recourfe muft be had to refracting telefcopes: thefe and all other optical and philofophical inftruments are to be had in their greateft perfection of that ingenious artift Mr. George Adams, *Fleet Street, London;* whofe affiduity in rendering philofophical refearches familiar is well known to the fcientific.

CLOCK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CLOCK MAKING.

Of the Terms of Art, or Names by which the Parts of an Automaton are called.

IT is neceffary that I fhould fhew the meaning of the terms which clock makers ufe, that gentlemen, and others, unfkiled in the art, may know how to exprefs themfelves properly, in fpeaking; and alfo underftand what I fhall fay in the following treatife:

I begin with the more general terms: as, the frame; which is that which contains the wheels, and the reft of the Work. The pillars and plates, are what it chiefly confifts of.

Next for the main-fpring, and its appurtenances. That which the fpring lies in, is the fpring-box: that which the fpring laps about, in the middle of the fpring-box, is the fpring-arbor; to which the fpring is hooked at one end. At the top of the fpring-arbor, is the endlefs-fcrew, and its wheel: but in fpring-clocks, it is a ratchet-wheel, with its click that ftops it.

That which the main-ſpring draweth, and about which the chain or ſtring is wrapped, and which is commonly taper, is the fuſy. In larger work, going with weights, where it is cylindrical, it is called the barrel: the ſmall teeth at the bottom of the fuſy, or barrel, that ſtop it in winding up, is the ratchet. That which ſtops it when wound up, and is for that end driven up by the ſtring, is the gardegut.

The parts of a wheel are, the hoop, or rim: the teeth: the croſs: and the collet, or piece of braſs, ſoldered on the arbor, or ſpindle, on which the wheel is rivetted.

A pinion, is that little wheel, which plays in the teeth of the wheel: its teeth (which are commonly 4, 5, 6, 7, 8, &c.) are called leaves, not teeth.

The ends of the ſpindle, are called pivots: the holes in which they run, pivot holes.

The guttered wheel, with iron ſpikes at the bottom, in which the line of ordinary thirty-hour houſe-clocks doth run, is called the pulley.

I need not ſpeak of the dial-plate, the hands, ſcrews, wedges, ſtops, &c.

Thus much for general names, which are common to all parts of a movement.

The moſt uſual movements are watches and clocks. Watches, ſtrictly taken, are all ſuch movements as ſhew the parts of time: and clocks are ſuch as publiſh it, by ſtriking

ſtriking on a bell, &c. But commonly the name of watches is appropriated to ſuch as are carried in the pocket; and that of clock to the larger movements, whether they ſtrike the hour or no. As for watches which ſtrike the hour, they are called pocket-clocks.

The parts of a movement, which I ſhall conſider, are the watch and clock parts.

The watch part of a movement, is that which ſerveth to the meaſuring the hours. In which, the firſt thing I ſhall conſider, is the balance: whoſe parts are the rim, which is the circular part of it; the verge, is its ſpindle, to which belong the two pallets, or leaves. which play in the teeth of the crown-wheel: in pocket watches, that ſtrong ſtud, in which the lower pivot of the verge plays, and in the middle of which, one pivot of the balance-wheel plays, is called the pottance. The bottom of this is called the foot; the middle part (in which the pivot of the balance-wheel turns), is called the noſe; the upper part, the ſhoulder of the pottance. The piece which covers the balance, and in which the upper pivot of the balance plays, is the cock. The ſmall ſpring in pocket watches, underneath the balance, is the regulator, or pendulum-ſpring.

The parts of a pendulum, are the verge, pallets and cocks, as before. The ball in long pendulums, the bob in ſhort ones, is the weight at the bottom: the rod, or wire, is plain. The term peculiar to the royal-ſwing, are the pads, which are the pallets in others, and are fixed on the arbor, the fork is alſo fixed to the arbor, and about ſix inches below, catcheth hold on the rod, at a flat piece of braſs, called the flatt, in which, the lower end of the ſpring is faſtened.

The names of the wheels next follow: the crown-whee in ſmall pieces, and the ſwing-wheel in royal pendulums, is that wheel which drives the balance, or pendulum.

The contrate-wheel, is that wheel in pocket-watches, and others, which is next to the crown-wheel, whoſe teeth and hoop lie contrary to thoſe of other wheels; whence it hath its name.

The great-wheel, or firſt-wheel, is that which the fuſy, &c. immediately driveth. Next it, are the ſecond-wheel, third-wheel, &c.

Next followeth the work between the frame and dial-plate: and firſt, is the pinion of report; which is that pinion, which is commonly fixed on the arbor of the great wheel, and, in old watches, uſed to have commonly but four leaves; which driveth the dial-wheel, and this carrieth about the hand.

The laſt part which I ſhall ſpeak of is the clock, which is that part which ſerveth to ſtrike the hours: in which, I ſhall firſt ſpeak of the great, or firſt wheel; which is that which the weight or ſpring firſt drives. In thirty-hour clocks, this is commonly the pin-wheel: this wheel, thus with pins, is called the ſtriking-wheel, or pin-wheel.

Next to this ſtriking-wheel, followeth the detent-wheel, or hoop-wheel, it having a hoop almoſt round it, in which is a vacancy, at which the clock locks.

The next is the third, or fourth-wheel (according as it is diſtant from the firſt-wheel), called alſo the warning-wheel.

And

And laſtly, is the flying-pinion, with a fly, or fan, to gather air, and ſo bridle the rapidity of the clock's motion.

Beſides theſe, there are the pinion of report, of which before, which driveth round the locking wheel, called alſo the count-wheel, with eleven notches in it commonly, unequally diſtant from one another, to make the clock ſtrike the hours of 1, 2, 3, &c.

Thus much for wheels of the clock part.

The detents are thoſe ſtops, which, by being lifted up, or let fall down, do lock and unlock the clock in ſtriking.

The hammers ſtrike the bell: the hammer-tails are what the ſtriking-pins draw back the hammers by.

Latches are what lift up, and unlock the work.

Catches are what hold by hooking, or catching hold of.

The lifting pieces do lift up, and unlock the detents, in the clock part.

The train is the number of beats or vibrations, which the watch maketh in an hour, or any other certain time.

There are, beſides theſe, divers other terms with clock-makers uſe in various ſorts of pieces, as the ſnail, or ſtep-wheel, in repeating-clocks, the rack, the ſafeguards, the ſeveral

ſeveral levers, lifters, and detents: but it would be tedious, and it is needleſs to mention the particulars.

For the better underſtanding theſe terms of art, and the parts of a clock, I have repreſented them to the eye: in which, two diſtinct parts may be obſerved, the watch, and the clock part.

The wheels, &c. on the right hand, is the watch part: they on the left, the clock.

Plate XVIII. Fig. 2. D. D. The ſpring-boxes of the watch and clock part.

E. E. The great wheel of each part,

F. F. The fuſy of each part, about which, the chain, or ſtring is wrapped.

o. o. The click and ſpring of each part,

g. g. The ratchet of each part.

a The hoop, or rim of the ſecond-wheel,

b. The croſs thereof.

c. The pinion.

d. The third-wheel.

x. The pallet-wheel.

L. The pin-wheel, with the ſtriking-pins e. e. e.

m. The hoop-wheel.

n. The

n. The warning-wheel, or fourth-wheel.

O. The detent.

P. The lifting-piece.

2. The fan, and flying-pinion.

R. The bell.

S. The hammer.

T. The hammer-tail.

y. The hammer-ſpring.

V. V, The chain, or ſtring of the watch and clock.

The pendulum conſiſts of 1. The rod. 2. The fork. 3. The flatt. 4. The great-ball. 5. The corrector, or regulator; being a contrivance of very great uſe to bring the pendulum to its niceſt vibrations, and is fixed on the verge at the end of the pallets 5. 5.

To find the Length of a Pendulum that ſhall make any given Number of Vibrations in a Minute, and vice verſa.

A Pendulum whoſe length is 39.2 inches, from the point of ſuſpenſion to the center of oſcillation, makes 60 vibrations in a minute; and this is called the ſtandard length. Then, for any other number of vibrations in a minute, ſay, as the ſquare of the given number of vibrations is to the ſquare

ſquare of 60, ſo is the length of the ſtandard to the length ſought. Thus, ſuppoſe the given number of vibrations to be 30 per minute: the ſquare of 30 is 900, and the ſquare of 60 is 3600: then, as 900 is to 3600, ſo is 39.2 to 156.8; ſo that the length required for 30 vibrations per minute is 156.8 inches.

If the length of the pendulum be given, and the number of vibratiens it makes in a minute be required; ſay, as the given length is to the ſtandard length (39.2 inches) ſo is the ſquare of 60 vibrations to the ſquare of the of the number required: the ſquare root of which ſhall be the number of vibrations made by the pendulum in a minute. Thus, ſuppoſe the given length to be 156.8 inches: as 156.8 is to 39.2, ſo is 3600 (the ſquare of 60) to 900; the ſquare root of which is 30, the number of vibrations that this pendulum will make in a minute.

The length of a pendulum that would make only one vibration in a minute is 3920 yards, or 141120 inches: and the length of a pendulum that would make 240 vibrations, in a minute (or 4 in a ſecond) is 2.45 inches.

In theſe calculations, it is ſuppoſed, that the weight of the pendulum-rod bears little or no ſenſible proportion to the weight of the ball. But as this cannot be the caſe in practice, the center of oſcillation will always be further from the point of ſuſpenſion than the calculation makes it; and this muſt be found by trial.

To

To divide the Circumference of a Circle into any given Number of equal Parts, whether even or odd.

AS there are very uncommon and odd numbers of teeth in ſome of the wheels of aſtronomical clocks, and which conſequently could not be cut by any common engine uſed by clock-makers for cutting the numbers of teeth in their clock-wheels, I thought proper to ſhew how to divide the circumference of a circle into any given odd or even number of equal parts, ſo as that number may be laid down upon the dividing plate of a cutting engine.

There is no odd number, but from which, if a certain number be ſubtracted, there will remain an even number, eaſy to be ſubdivided: thus, ſuppoſing the given number of equal diviſions of a circle on the dividing plate to be 69; ſubtract 9, and there will remain 60.

Every circle is ſuppoſed to contain 360 degrees: therefore ſay, as the given number of parts in the circle, which is 69, is to 360 degrees, ſo is 9 parts to the correſponding arc of the circle that will contain them: which arc, by the rule of three, will be found to be 46 95-100. Therefore, by the line of chords on a common ſcale, or rather on a ſector, ſet off 46 95-100 (or 46 9-10) degrees with your compaſſes, in the periphery of the circle, and divide that arc or portion of the circle into 9 equal parts, and the reſt of the circle into 60; and the whole will be divided into 69 equal parts, as was required.

Again, ſuppoſe it were required to divide the circumference of a circle into 83 equal parts; ſubtract 3, and 80 will

 remain.

remain. Then, as 83 parts are to 360 degrees, so (by the rule of proportion) are 3 parts to 13 degrees and one hundredth part of a degree; which small fraction may be neglected. Therefore, by the line of chords, and compasses, set off 13 degrees in the periphery of the circle, and divide that portion or arc into 3 equal parts, and the rest of the circle into 80; and the thing will be done.

Once more, suppose it were required to divide a given circle into 365 equal parts: subtract 5, and 360 will remain. Then, as 365 parts are to 360 degrees, so are 5 parts to 4 93-100 degrees. Therefore, set off 4 93-100 (or 4 9-10) degrees in the circle; divide that space into 5 equal parts, and the rest of the circle into 360; and the whole will be divided into 365 equal parts, as was required.

I have often found this rule or method very useful in dividing circles into an odd number of equal parts, or wheels into odd numbers of equal sized teeth with equal spaces between them: and now I find it just as easy to divide any given circle into any odd number of equal parts, as to divide it into any even number. And, for this purpose, I prefer the line of chords on a sector, to that on a plain scale; because the sector may be opened so, as to make the radius of the line of chords upon it equal to the radius of the given circle, unless the radius of the circle exceeds the whole length of the sector when it is opened so as to resemble a straight ruler; or scale; and this is what very seldom happens.

Any person who is used to handle the compasses, and the scale or sector, may very easily, by a little practice, take

take off degrees, and fractional parts of a degree, by the accuracy of his eye, from a line of chords, near enough the truth for the above-mentioned purpofe.

Suppofing the Diftance between the Centers of two Wheels, one of which is to turn the other, be given; that the Number of Teeth in one of thefe Wheels is different from the Number of Teeth in the other, and it is required to make the Diameters of thefe Wheels in fuch Proportion to one another as their Numbers of Teeth are, fo that the Teeth in both Wheels may be of equal Size, and the Spaces between them equal, that either of them may turn the other eafily and freely: it is required to find their Diameters.

HERE it is plain, that the diftance between the centers of the wheels is equal to the fum of both their radii in the working parts of the teeth. Therefore, as the number of teeth in both wheels, taken together, is to the diftance between their centers, taken in any kind of meafure, as feet, inches, or parts of an inch; fo is the number of teeth in either of the wheels to the radius or femi-diameter of that wheel, taken in the like meafure, from its center to the working part of any one of its teeth.

Thus, fuppofe the two wheels muft be of fuch fizes, as to have their diftances between their centers 5 inches; that one wheel is to have 75 teeth, and the other to have 33, and that the fizes of the teeth in both the wheels is equal, fo that either of them may turn the other. The fum of the teeth in both wheels is 108; therefore fay, as 108 teeth is to 5 inches, fo is 75 teeth to 3 inches and 47 hundred parts of an inch; and as 108 is to 5, fo is 33 to 1 inch and 53

 hundred

hundred parts of an inch. So that, from the center of the wheel of 75 teeth to the working part of any tooth in it, is 3 inches and 47 hundred parts of an inch; and, from the center of the wheel of 33 teeth to the working part of either of its teeth, is 1 inch and 53 hundred parts of an inch.

General preliminary Rules and Directions for Calculation.

FOR the more clear underſtanding this, it muſt be obſerved, that thoſe automata (whoſe calculation I chiefly intend) do by little interſtices, or ſtrokes, meaſure out long portions of time. Thus the ſtrokes of the balance of a watch, do meaſure out minutes, hours, days, &c.

Now to ſcatter thoſe ſtrokes amongſt wheels and pinions, and to proportionate them, ſo as to meaſure time regularly, is the deſign of calculation.

And in the firſt place, you are to know, that any wheel being divided by it's pinions, ſhews how many turns that pinion hath to one turn of that wheel. Thus a wheel of 60 teeth driving a pinion of 6, will turn round the pinion 10 times in going round once. 6)60(10.

From the fuſy to the balance, the wheels drive the pinions; and conſequently the pinions run faſter, or go more turns, than the wheels they run in. But it is contrary, from the great wheel to the dial-wheel. Thus, in the laſt example, the wheel drives round the pinion 10 times: but if the pinion drove the wheel, it muſt turn 10 times to drive the wheel round once.

Before I proceed further, I muſt ſhew how to write down the wheels and pinions; which may be done either as vulgar fractions, or in the way of diviſion in vulgar arithmetic. For example, a wheel of 60 moving a pinion of 5, may ſet down thus, $\frac{60}{5}$: or thus 5)60: where the uppermoſt figure 60, or numerator is the wheel, the lowermoſt or denominator, is the pinion: or, in the latter example, the firſt figure is the pinion, the next without the hook, the wheel.

The number of turns, which the pinion hath in one turn of the wheel, is ſet without a hook on the right hand, as 5)60(12; i. e. a pinion 5 playing in a wheel of 60, moveth round 12 times in one turn of the wheel.

4)36(9
―――――
5)55(11
5)45(9
5)40(8
―――――
17

A whole movement may be noted thus, $\frac{4}{36}$ $\frac{55}{5}$ $\frac{45}{5}$ $\frac{40}{5}$ ſeventeen notches in the crown wheel. Or rather becauſe it will be eaſieſt to mean capacities, as you ſee here in the margin: where the uppermoſt number above the line is the pinion of report 4, the dial-wheel 36, and 9 turns of the pin of report. The ſecond number (under the line) is 5 the pinion, 55 is the great wheel, and 11 turns of the pinion it driveth. The third numbers are the ſecond wheel, &c. The fourth the contrate wheel, &c. And the ſingle number 17 under all, is the number of the crown wheel.

By knowing the number of turns, which any pinion hath in one turn of the wheel it worketh in, you may alſo find out how many turns a wheel or pinion hath, at a greater diſtance; as the contrate wheel, crown wheel, &c. For it is but multiplying together the quotients (by the

quotients

quotients, I commonly mean the number of turns; which number is ſet on the right hand, without the hook, as is ſhewn in the laſt example), and the number produced is the number of turns. An example will make what I ſay plain: let us chuſe three numbers here ſet down; the firſt of which hath 11 turns, the next 9, and the laſt 8. If you multiply 11 and 9, it produceth 99, for 9 times 11 is 99, that is in one turn of the wheel 55, there are 99 turns of the ſecond pinion 5, or the wheel 40, which runs concentrical, or on the ſame arbor with the ſecond pinion 5. For as there are 11 turns of the firſt pinion 5, in one turn of the great wheel 55, or (which is the ſame) of the ſecond wheel 45, which is on the ſame ſpindle with that pinion 5; ſo there are 9 times 11 turns in the ſecond pinion 5, or wheel 40 in one turn of the great wheel 55. If you multiply the laſt quotient 8 (that is, 8 times 99 is 792) it ſhews the number of turns, which the third and laſt pinion 5 hath. So that this third and laſt pinion turns 792 times in one turn of the firſt wheel 55. Another example will make it ſtill more plain. The example is in the margin. The turns are 10, 9, and 8. Theſe multiplied as before, run thus, viz. 10 times 9 is 90, that is, the pinion 6 (which is the pinion of the third wheel 40, and runs in the ſecond wheel 54) turns 90 times in one turn of the firſt wheel 80. This laſt product 90 being multiplied by 8, produces 720; that is, the pinion 5 (which is the pin of the crown wheel 15) turns 720 times in one turn of the firſt wheel, of 80 teeth.

5)55(11
5)45(9
5)40(8

8)80(10
6)54(9
5)40(8
———
15

A whole

A whole Movement of a modern Pocket Watch may be noted thus:

	Teeth	Leaves
The great wheel	48	12
Centre wheel	54	6
Third wheel	48	6
Contrate wheel	48	6
Balance wheel	15	2 pallets.

Thus when the watch is wound up, the chain from the ſpring exerts a force upon the fuſee, which gives motion to all the parts of the machine.

The great wheel on the fuſee having 48 teeth, and driving the center wheel by a pinion of 12 leaves, make the center wheel turn round 4 times in one turn of the fuſee. Thus alſo we may account for all others; for,

If 12) 48 (4 = Turns of the center wheel,
So 6) 54 (9 = Turns of the third wheel.
6) 48 (8 = Turns of the contrate wheel,
6) 48 (8 = Turns of the balance.

Then multiply theſe ſeveral quotients together ſucceſſively, and you will find the turns of each of thoſe wheels reſpectively, in one turn of the fuſee.

Thus 1 turn of the fuſee, or great wheel; 4 mul. 1 = to 4 turns of the center wheel; 9 mul. 4, mul. 1 = to 36 turns of the third wheel; 8 mul. 9, mul. 4. mul. 1 = to 288 turns of the contrate wheel; 8 mul, 9 mul. 4 mul, 1 = to 2304 turns of the balance wheel.

And

And the balance wheel having 15 teeth, and each ſtriking a pallet twice in one revolution, there will be thirty ſtrokes upon the axis of the balance, which are called the beats of the balance: conſequently there muſt be 2304 mul. 30 = 69120 ſtrokes or beats in one turn of the fuſee or great wheel.

But though theſe particulars are neceſſary to be premiſed, our principal regard, in the diviſion of time, is to be paid to the center wheel. For this wheel alone is that upon which both the hour and minute hand is moved or carried round upon the face of the watch, to ſhew the hour of the day, and the minute of the hour, &c.

If we would find out the number of beats of the balance in the time of thoſe turns above-mentioned, it muſt be noted, that as the watch goes thirty hours, and the minute hand, and conſequently the center wheel goes round once in an hour, the ſaid center wheel will have thirty turns in the time of the watch's going round; and becauſe it hath four turns in one of the fuſee, therefore we muſt ſay 4(30) = $7\frac{1}{2}$ = the number of turns of the fuſee, in winding up the watch. Whence we find 69120 mul. 7, 5 = 518400 = the number of the beats in 30 hours. Then if we divide 518400 by 30, the quotient will be 17280 = number of beats in an hour, which is called the train of a watch; which train is called ſwifter or ſlower, as the number of beats in an hour is more or leſs: ſo again, if we divide this train 17280 by 3600, the ſeconds in an hour, the quotient will be almoſt 5, or almoſt 5 beats per ſecond in ſuch a watch.

By

By this analyfis, it is eafy to form an idea of the manner of calculation for the numbers of the teeth and leaves for the feveral wheels and pinions in a watch; which may further be illuftrated by an example of a train 14400, which will beat quarter feconds, becaufe fuch a train is ufeful in many philofophical cafes, as well as in the juft divifion of time.

Suppofe the intended watch is to go 32 hours: then it will be found that 14400 multiplied by 32 = 460800 = the beats of the balance in 32 hours. And if the number of turns in the fufee be 8, then 8)460800 (= 57600 = the beats in one turn of the fufee.

Again, fuppofe the number of teeth in the balance wheel, be 15, there will be 30 beats in one turn of this wheel; then 30) 57600 (= 1920, which will be the number arifing from the continued multiplication of all the quotients of the wheels, divided by the pinions they drive from the great wheel to the balance wheel, as has been already exemplified.

Our next care is to break this number into four convenient fmall numbers, which multiplied together, fhall make the fame number 1920. Then I fay 4) 1920 (= 480. Again, I fay 6)480(=80. And as I plainly fee that 80 = 8 multiplied by 10, confequently the four numbers fought for, are 4, 6, 8, and 10: becaufe multiply thefe numbers together, and they will make exactly 1920, thus 4 mul. 6 mull. 8 mul. 10 = 1920.

The quotients thus inveftigated, we may eafily find what large numbers, divided by fmall ones, will produce the faid

 quotients;

quotients; thus 12)48(=4. Confequently, if we allow 48 teeth to the great wheel on the fufee, it muft drive a pinion of 12 on the center wheel. So again, if for the quotient 6, we chufe 54 and 9, thus 9)54(=6, it fhews that the teeth of the center wheel may be 54; and it muft drive a pinion of 9 on the third wheel. Or, if inftead of 54 and 9, we chufe 48 and 8, it will anfwer the fame end, thus 8)48(=6. As for the quotient 10, we may eafily perceive that 50 and 5 will anfwer the enquiry, thus 5)50(= 10: fo the third wheel having 50 teeth, muft drive a pinion of 5 on the contrate wheel. Where note, that if the faid wheel has 40 or 60 teeth, and drive a pinion of 4 or 6, we fhall find the fame number of turns exactly. And as for the quotient 8, we have the number 48 and 6: thus 6)48(=8: or 7)56(= 8: or 5(40(=8: therefore if the contrate wheel be allowed 40, or 48, or 56 teeth, it will drive a pinion of 5, 6, or 7 leaves on the balance wheel.

Thus it is to determine and adjuft all the wheels and pinions in the body of a watch, from the fufee to the balance, fo far as to relate to the minute of an hour, and to the fecond and quarter feconds of a minute.

Having fhewed, as clearly as I can, the way of calculating numbers for the watch-part, I fhall alfo briefly fhew the principles of the ftriking part.

Although this part confifts of many wheels and pinions, yet refpect needs to be had only to the count wheel, ftriking-wheel, and detent-wheel, which move round in this Fig. 4. proportion; the count-wheel B moveth round commonly once in 12, or 24 hours. The detent-wheel moves round

every

every ftroke the clock ftriketh, fometimes but once in two ftrokes. From whence it follows,

1. That as many pins as are in the pin-wheel, fo many turns hath the detent-wheel, in one turn of the pin-wheel. Or (which is the fame) the pins of the pin-wheel are the quotient of that wheel, divided by the pinion of the detent-wheel. But if the detent-wheel moveth but once round in two ftrokes of the clock, then the faid quotient is but half the number of pins.

2. As many turns of the pin-wheel as are required to perform the ftrokes of 12 hours (which are 78), fo many turns muft the pinion of report have, to turn round the count-wheel once. Or, thus: divide 78 by the number of ftriking-pins, and the quotient thereof fhall be the quotient for the pinion of report, and the count-wheel. All this is, in cafe the pinion of report be fixed to the arbor of the pin wheel, as is very commonly done.

All this I take to be very plain: or if it be not, the example in the margin will clear all difficulties. Here the locking wheel A is 48, the pinion of report is 8, the pin-wheel is 78, the ftriking pins are 13. And fo the reft. I need only to remark here, that 78 being divided by the 13 pins, gives 6; which is the quotient of the pinion of report O: as was before hinted; and the notches of the plate B, ferve to let the locking-piece C fall into; which comes from the dextent D.

8)48(6
———
6)78(13 pins
6)60(10
6)48(8

As for the warning-wheel and flying-pinion, it matters little what numbers they have, their uſe being only to bridle the rapidity of the motion of the other wheels.

Numbers of ſeveral Sorts of Movements.

Although I have before given ſuch plain directions, as may, I hope, accompliſh a young practitioner in the art of calculation; yet it may be very convenient to ſet down ſome numbers fit for ſeveral movements; partly to be as examples to exerciſe the young reader: and partly, to ſerve ſuch, who want leiſure or underſtanding to attain to the art of calculation.

Numbers of an eight-day piece, with 16 turns of the barrel, the pendulum vibrates ſeconds, and ſhews minutes, ſeconds, &c.

The watch part.	The clock part.
8)96	8)78
8)60---40)40---6)72	7)56 8 pins.
7)56	7)49
——	7)49
30	

In the watch part, the wheel 60 is the minute-wheel, which is ſet in the middle of the clock, that its ſpindle may go through the middle of the dial-plate to carry the minute hand.

Fig. 3. Alſo on this ſpindle is the wheel 40, a, which driveth another wheel b of 40, which laſt hath a pinion 6, c, which driveth round the wheel 72 d in 12 hours. Note here two things:

things: 1. That the two wheels 40, are of no other uſe, but to ſet the pinion 6 at a convenient diſtance from the minute-wheel, to drive the wheel 72, which is concentrical with the minute-wheel. For a pinion 6 driving a wheel 72, would be ſufficient, if the minute-hand and hour-hand had two different centers. 2. Theſe numbers, 60---40) 40---6)72, ſet thus, ought according as above to be thus read, viz. The wheel 60, hath another wheel 40 on the ſame ſpindle; which wheel 40 divideth (playeth in, or turns round) another wheel 40; which hath a pinion 6 concentrical with it: which pinion driveth or divideth a wheel of 72. For a line parting two numbers (as 60--48) denoteth thoſe two numbers to be concentrical, or to be placed upon the ſame ſpindle. And when two numbers have a hook between them (as 48) 48) it ſignifies one to run in the other.

In the ſtriking-part, there are 8 pins on the ſecond-wheel 56. The count-wheel may be fixed unto the great wheel, which goeth round once in 12 hours.

A piece of 32 days, with 16 turns both parts: the watch ſheweth hours, minutes, and ſeconds; and the pendulum vibrateth ſeconds.

Watch part. With 16 turns.	Striking part. With 16 turns.
16)96	10)130
9)72	8)96 } 24 pins / 12)39
8)60--48)48--6)72	6)72 double hoop.
7)56	6)60
30	

The

The pinion of report is fixed on the end of the arbor of the pin-wheel. This pinion is 12, the count-wheel 39; thus, 12)39.

A two months piece of 64 days; with 16 turns; pendulum vibrateth seconds, and sheweth minutes, seconds, &c.

Watch part.	Clock part.
9)90	10)80
8)76	10)65
8)60--48)48--6)72	9)54 } 12 pins --- 8)52
7)56	5)60 double hoop.
39	5)59

Here the third wheel is the pin-wheel, which also carrieth the pinion of report 8, driving the count- wheel 52.

A seven month-piece, with turns, pendulum, and motions, as before.

The watch.	The clock.
8)60	
8)56	8)96
8)48	8)88--27)12
6)45--48)48--6)72	8)64--16 pins
5)40	6)48 double hoop.
	6)48
30	

A year-piece, of 384 days, with turns, pendulums, and motions, as before.

The

The watch.	The clock.
12)108	
9)72	10)120
8)64	8)96--36)9
8)60--48)48--6)72	6)78.26 pins
7)56	6)72 double hoop.
	6)60
30	

If you had rather have the pinion of report of the ſpindle of the pin-wheel, it muſt be 13)39.

A piece of 30 hours, pendulum about 6 inches.

The watch.	The clock.
12)48	8)48
6)78	6)78 13 pins.
6)60	6)60
6)42	6)48
15	

A 30 hour piece to ſwing ſeconds.

Watch part.	Clock part.
6)90	6)78 13 pins
6)72	6)54
	7)49
30	

Repeating Work.

LET A be a piece of braſs cut down in twelve ſpiral ſteps in form of a ſnail (from whence it takes its name) as Fig. 1
in the figure; let this be fixed on the ſocket of the hour wheel; and B G L F the rack, with fourteen teeth, turning on its center L, having a ſpring H to foece the end F upon

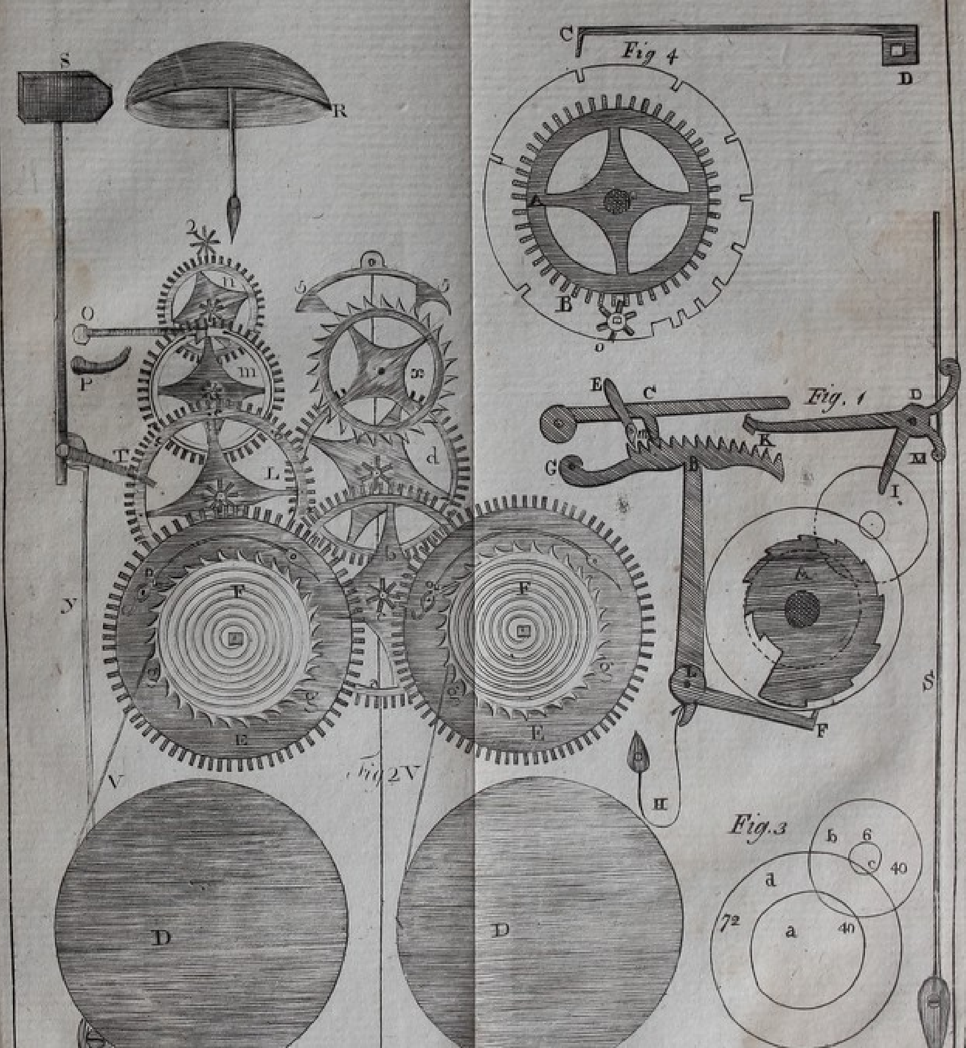
upon the ſteps of the ſnail A, when at liberty. The pin at I in the motion wheel, takes hold of the lifting piece D M K, and the end K, in riſing, lift up the hook C which lays in the teeth of the rack, and riſes until the teeth are diſengaged from it; the end F then falls down and ſtops againſt the ſteps of the ſnail A, which in the figure is at two o'clock.

The arbor of the third or gathering wheel m, (fig. 2.) comes through the plate, on which the pallet E m (fig 1.) is fixed; a turn of which anſwering to one ſtroke of the hammer, gathers the rack up one tooth; 12 ſteps of the ſnail, anſwers 12 teeth in the rack; and when the gathering pallet E m, has taken as many teeth in the rack, as the number of the hour, the end E of the pallet, ſtops againſt a pin in the rack at G, and is there at reſt until the hook C is again lifted out of the teeth, by the lifting piece as before.

When the hook C is lifted out of the teeth of the rack, the clock would ſtrike continually, as the hook being out of the teeth, prevents the rack being gathered up; but that the end K of the lifting piece has a ſmall arm which goes through the plate, and a pin in the wheel n, which ſtops againſt it in ſuch a manner, that when the lifting piece is ſuffered to fall by the pin I, having gone paſt the pin in the rim of the wheel n, it is clear of the arm at the end of the lifting piece K; the wheel being then at liberty, the clock ſtrikes until the gathering pallet E, ſtops againſt the pin of the rack at G as before. By putting a ſmall ſtring to the top end of the ſpring S, to come through the caſe, it may be made to ſtrike the laſt hour at any time, except when on the warning.

ASTRO-

CLOCK-WORK *PLATE XVIII*



A S T R O N O M Y.

A brief Deſcription of the Solar Syſtem.

THE ſun, with the planets and comets which move round him as their center, conſtitute the ſolar ſyſtem. Thoſe planets which are near the ſun not only finiſh their circuits ſooner, but likewiſe move faſter in their reſpective orbits, than thoſe which are more remote to him. Their motions are all performed from weſt to eaſt, in orbits nearly circular. Their names, diſtances, bulks, and periodical revolutions, are as follow. Plate XII.

The ſun, an immenſe globe of fire, is placed near the common center of all the planets, and turns round his axis in 25 days 6 hours, as is evident by the motion of ſpots ſeen on his ſurface, which have often been remarked to keep this time before they diſappeared. His diameter is computed to be 763,000 miles; all planets ſeen from him, move the ſame way, and according to the order of the ſigns in the graduated circle Aries, Taurus, Gemini, Cancer, &c. which repreſents the great ecliptic in the heavens; but as ſeen from any one planet, the reſt appears ſometimes to go backward, and ſometimes forward, and ſometimes to ſtand ſtill; not in circles nor eclipſes; but in looped curves which never return into themſelves.

Mercury.

Mercury, the neareſt planet to the ſun, goes round him in 87 days 23 hours of our time nearly; which is the the length of his year. But being ſeldom ſeen, and no ſpots appearing upon his ſurface or diſc, the time of his rotation on his axis, or the length of his days and nights, is as yet unknown. His diſtance from the ſun, is computed to be 32,000,000 of miles, and his diameter 2600. In his courſe round the ſun, he moves at the rate of 95,000 miles every hour. His light and heat from the ſun are almoſt ſeven times as great as ours; and the ſun appears to him almoſt ſeven times as large as to us.

His orbit is inclined ſeven degrees to the ecliptic; and that node from which he aſcends northward above the ecliptic, is in the 14th degree of Taurus; the oppoſite in the 14th degree of Scorpio. The earth is in theſe points on the 6th of November, and 4th of May, new ſtile; and when Mercury comes to either of his nodes, when he is between the earth and ſun in the nearer part of his orbit, he will appear to paſs over the diſc or face of the ſun like a dark round ſpot. But in all other parts of his orbit, his conjunctions are inviſible, becauſe he either goes above or below the ſun.

According to Mr. Whiſton, he will appear on the ſun's diſc in 1789, Dec. 6th. at 3h. 55m. in the afternoon. 1799, May 7th, at 2h. 34m. in the afternoon. There will be ſeveral intermediate tranſits, but none of them viſible in this latitude.

Venus.

Venus, the next planet in order, is computed to be 59,000,000 miles from the ſun; and by moving at the rate of

of 69,000 miles every hour in her orbit, ſhe goes round the ſun in 224 days 17 hours of our time nearly; in which, though it be the full length of her year, ſhe has only nine days one quarter, according to the beſt obſervations, ſo that to her, every day and night together is as 24 1-3d days and nights with us. This odd 1-4th of a day in every year makes every fourth year a leap-year to Venus, as the like does to our earth. Her diameter is 7906 miles; and by her diurnal motion, the inhabitants about her equator are carried 43 miles every hour, beſides that 69,000 above-mentioned.

Venus's orbit is inclined 3 1-half degrees to the earth's, and croſſes it in the 14th degree of Gemini and of Sagittarius.

The axis of Venus is inclined 75 degrees to the axis of her orbit: which is 51 1-half degrees more than our earth's axis is inclined to the axis of the ecliptic; and therefore, her ſeaſons vary much more than ours do. The north pole of her axis inclines toward the 20th degree of Aquarius, our earth's to the beginning of Cancer; conſequently the northern parts of Venus have ſummer in the ſigns where thoſe of our earth have winter, and vice verſa.

As her annual revolution contains only 9 1-4th of her days, the ſun will always appear to go through a whole ſign, or twelfth part of her orbit, in little more than three quarters of her natural day, or nearly in 13 3-4ths of our days and nights.

She ſhews the ſame appearances to us regularly every eight years; her conjunctions, elongations, and times of

 riſing

rising and setting, being very nearly the same on the same days as before.

Earth. The earth is the next planet above Venus in the system. It is 82,000,000 of miles from the sun, and goes round him in 365 days 5 hours 49 minutes, from any equinox or solstice to the same again: but from any fixed star to the same again, as seen from the sun, in 365 days 6 hours and 9 minutes, the former being the length of the tropical year, and the latter the length of the sydereal. It travels at the rate of 58,000 miles every hour, which motion, though 120 times swifter than that of a cannon-ball, is little more than half as swift as Mercury's motion in his orbit. The earth's diameter is 7970 miles; and by turning round its axis every 24 hours from west to east, it causes an apparent diurnal motion of all the heavenly bodies from east to west. By this rapid motion of the earth on its axis, the inhabitants about the equator are carried 1042 miles every hour, while those on the parallel of London are carried only about 580, besides the 58,000 miles by the annual motion above-mentioned, which is common to all places whatever. The earth's axis makes an angle of 23½ degrees with the axis of its orbit; and keeps nearly the same oblique direction, inclining toward the same fixed stars throughout its annual course, which causes the return of spring, summer, autumn, and winter.

Moon. The moon is not a planet, but only a satellite or attendant of the earth, going round the earth from change to change, in 29 days, 12 hours, and 44 minutes; and round the sun with it every year. The moon's diameter is 2180 miles; and her distance from the earth's center 24,000. She goes round her orbit in 27 days, 7 hours, 43 minutes,

moving

moving about 2290 miles every hour; and turns round her axis exactly in the time that ſhe goes round the earth, which is the reaſon of her keeping always the ſame ſide towards us; and that her day and night together, is as long as our lunar month.

The moon is an opaque globe like the earth, and ſhines only by reflecting the light of the ſun; therefore, whilſt that half of her which is towards the ſun is enlightened, the other half muſt be dark and inviſible. Hence, ſhe diſappears when ſhe comes between us and the ſun, becauſe her dark ſide is then towards us. When ſhe is gone a little forward, we ſee a little of her enlightened ſide: which ſtill increaſes to our view, as ſhe advances forward, until ſhe comes to be oppoſite to the ſun, and then her whole enlightened ſide is towards the earth, and ſhe appears with a round illuminated orb, which we call the full moon; her dark ſide being then turned away from the earth. From the full, ſhe ſeems to decreaſe gradually, as ſhe goes through the other half of her courſe; ſhewing us leſs and leſs of her enlightened ſide every day, till her next change or conjunction with the ſun, and then ſhe diſappears as before.

This continual change of the moon's phaſes demonſtrates, that ſhe ſhines not by any light of her own: for if ſhe did, being globular, we ſhould always ſee her with a round full orb, like the ſun. She has very little difference of ſeaſons, her axis being almoſt perpendicular to the ecliptic. What is very ſingular, one half of her has no darkneſs at all; the earth conſtantly affording it a ſtrong light in the ſun's abſence; while the other half has a fortnight's darkneſs, and a fortnight's light, by turns.

Our

Our earth is a moon to the moon, waxing and weaning, regularly, but appearing thirteen times as big, and affording her thirteen times as much light as ſhe does to us. When ſhe changes to us, the earth appears full to her; and when ſhe is in her firſt quarter to us, the earth is in its third quarter to her, and *vice verſa*.

But from one half of the moon, the earth is never ſeen at all: from the middle of the other half, it is always ſeen over head: turning round almoſt thirty times as quick as the moon does. From the circle which limits our view of the moon, only one half of the earth-ſide next her is ſeen; the other half being hid below the horizon of all places on that circle. To her the earth ſeems to be the biggeſt body in the univerſe, for it appears 13 times as big as ſhe does to us. Her orbit croſſes the ecliptic in two oppoſite points called the moon's nodes; ſo that one half of her orbit is above the ecliptic, and the other below it. The angle of obliquity is 5 1-3d degrees, as the earth turns round its axis, the ſeveral continents, ſeas, and iſlands, appear to the moon's inhabitants like ſo many ſpots of different forms and brightneſs, moving over its ſurface; but much fainter at ſome times than others, as our clouds cover them or leave them. By theſe ſpots the lunarians can determine the time of the earth's diurnal motion, juſt as we do the motion of the ſun; and perhaps they meaſure their time by the motion of the earth's ſpots, for they cannot have a truer dial.

Mars. The planet Mars is next in order, being the firſt above the earth's orbit; his diſtance from the ſun is computed to be 125,000,000 of miles; and he moves at the rate of 47000 miles every hour; he goes round the ſun in 686 of our days and

and 23 hours; which is the length of his year, and contains 667 3-4ths of his days; every day and night together being 40 minutes longer than with us. His diameter is 4444 miles, and by his diurnal rotation, the inhabitants about his equator are carried 556 miles every hour. His quantity of light and heat is equal but to one half of ours; and the ſun appears but half as big to him as to us.

This planet being but a fifth part ſo big as the earth, if any moon attends him, ſhe muſt be very ſmall, and has not yet been diſcovered by our beſt teleſcopes. He is of a fiery red colour, and by his appulſes to ſome of the fixed ſtars, ſeems to be encompaſſed by a very groſs atmoſphere. He appears ſometimes gibbous, but never horned, which both ſhews that his orbit includes the earth within it, and that he ſhines not by his own light.

To Mars our earth and moon appear like two moons, a bigger and a leſs, changing places with one another, and appearing ſometimes horned, ſometimes half or three quarters illuminated, but never full; nor at moſt above one quarter of a degree from each other, although they are 240 thouſand miles aſunder.

Our earth appears almoſt as big to Mars as Venus does to us, and at Mars it is never ſeen above 48 degrees from the ſun; ſometimes it appears to paſs over the diſc of the ſun, and ſo do Mercury and Venus: but Mercury can never be ſeen from Mars, by ſuch eyes as ours, unaſſiſted by pro-proper inſtruments; and Venus will be as ſeldom ſeen as we ſee Mercury. Jupiter and Saturn are as viſible to Mars as to us. His axis is perpendicular to the ecliptic, and his orbit is two degrees inclined to it.

Jupiter,

Jupiter.

Jupiter, the biggeſt of all the planets, is ſtill higher in the ſyſtem, being about 426 millions of miles from the ſun: and going at the rate of 25 thouſand miles every hour in his orbit, finiſhes his annual period in eleven of our years 314 days and 12 hours. He is above 1000 times as big as the earth, for his diameter is 81,000 miles; which is more than ten times the diameter of the earth.

Jupiter turns round his axis in 9 hours 56 minutes; ſo that his year contains 10 thouſand 470 days; and the diurnal velocity of his equatoreal parts is greater than the ſwiftneſs with which he moves in his annual orbit; a ſingular circumſtance, as far as we know. By this prodigious quick rotation, his equatoreal inhabitants are carried 25 thouſand 920 miles every hour (which is 920 miles an hour more than an inhabitant of our earth's equator moves in twenty-four hours) beſides the 25 thouſand above-mentioned, which is common to all parts of his ſurface, by his annual motion.

His belts and ſpots.

Jupiter is ſurrounded by faint ſubſtances, called belts, in which ſo many changes appear, that they are generally thought to be clouds: for ſome of them have been firſt interrupted and broken, and then have vaniſhed entirely. They have ſometimes been obſerved of different breadths and afterwards have all become nearly of the ſame breadth. Large ſpots have been ſeen in theſe belts; and when a belt vaniſhes, the contiguous ſpots diſappear with it.

He has no change of ſeaſons;

The axis of Jupiter is ſo nearly perpendicular to his orbit, that he has no ſenſible change of ſeaſons; which is a great advantage, and wiſely ordered by the Author of nature. For, if the axis of this planet were inclined any conſiderable,

ſiderable number of degrees, juſt ſo many degrees round each pole would in their turn be almoſt ſix of our years together in darkneſs. And, as each degree of a great circle on Jupiter contains 706 of our miles at a mean rate, it is eaſy to judge what vaſt tracts of land would be rendered uninhabitable by any conſiderable inclination of his axis.

The ſun appears but 1-28th part ſo big to Jupiter as to us; and his light and heat are in the ſame ſmall proportion, but compenſated by the quick returns thereof, and by four moons (ſome bigger and ſome leſs than our earth) which revolve about him: ſo that there is ſcarce any part of this huge planet but what is during the whole night enlightened by one or more of theſe moons, except his poles, whence only the fartheſt moons can be ſeen, and where their light is not wanted, becauſe the ſun conſtantly circulates in or near the horizon, and is very probably kept in view of both poles by the refraction of Jupiter's atmoſphere, which, if it be like ours, has certainly refractive power enough for that purpoſe. but has four moons.

The orbits of theſe moons are repreſented in this ſcheme of the ſolar ſyſtem by four ſmall circles on Jupiter's orbit, but they are drawn fifty times too large in proportion to it. The firſt moon, or that neareſt to Jupiter, goes round him in 1 day 18 hours and 36 minutes of our time; and is 229 thouſand miles diſtant from his center: The ſecond performs its revolution in three days 13 hours and 15 minutes, at 364 thouſand miles diſtance: The third in 7 days 3 hours and 59 minutes, at the diſtance of 580 thouſand miles: And the fourth, or outermoſt, in 16 days 18 hours and 30 min. at the diſtance of 1 million of miles from his center. Their periods round Jupiter.

Two grand discoveries made by the eclipse of Jupiter's moons.

Jupiter's three nearest moons fall into his shadow, and are eclipsed in every revolution: but the orbit of the fourth moon is so much inclined, that it passeth by its opposition to Jupiter, without falling into his shadow, two years in every six. By these eclipses, astronomers have not only discovered that the sun's light takes up eight minutes of time in coming to us; but they have also determined the longitudes of places on this earth with greater certainty and facility, than by any other method yet known.

The place of his nodes

Jupiter's orbit is 1 degree 20 minutes inclined to the ecliptic. His north node is in the 7th degree of Cancer, and his south node in the 7th degree of Capricorn.

Saturn.

Saturn, next in order, is about 780 millions of miles from the sun; and travelling at the rate of 18 thousand miles every hour, performs its annual circuit in 29 years 167 days and 5 hours of our time; which makes only one year to that planet. Its diameter is 67,000 miles; and therefore it is near 600 times as big as the earth.

His ring.

This planet is surrounded by a thin broad ring, as an artificial globe is by a horizon. The ring appears double when seen through a good telescope. It is inclined 30 degrees to the ecliptic, and is about 21 thousand miles in breadth: which is equal to its distance from Saturn on all sides. There is reason to believe that the ring turns round its axis, because, when it is almost edgewise to us, it appears somewhat thicker on one side of the planet than on the other; and the thickest edge has been seen on different sides at different times. But Saturn having no visible spots on his body, whereby to determine the time of his turning round his axis,

the

the length of his days and nights, and the position of his axis, are unknown to us at present.

To Saturn, the sun appears only 1-90th part so big as to us; and the light and heat he receives from the sun are in the same proportion to ours. But to compensate for the small quantity of sun-light, he has five moons, all going round him on the outside of his ring, and nearly in the same plane with it. The first, or nearest moon to Saturn, goes round him in one day 21 hours 19 minutes; and is 140 thousand miles from his center. The second, in 2 days 17 hours 40 minutes; at the distance of 187 thousand miles. The third, in 4 days 10 hours 25 minutes; at 263 thousand miles distance. The fourth, in 15 days 22 hours 41 minutes; at the distance of 600 thousand miles. And the fifth, or outermost, at 1 million 800 thousand miles from Saturn's center, goes round him in 72 days 7 hours 48 minutes. Their orbits in the scheme of the solar system are represented by the five small circles, on Saturn's orbit; but these, like the orbits of the other satellites, are drawn fifty times too large in proportion to the orbits of their primary planets.

His five moons.

This ring, seen from Saturn, appears like a vast luminous arch in the heavens, as if it did not belong to the planet. When we see the ring most open, its shadow upon the planet is broadest: and from that time the shadow grows narrower, as the ring appears to do to us; until, by Saturn's annual motion, the sun comes to the plane of the ring, or even with its edge; which being then directed towards us, becomes invisible on account of its thinness. The ring disappears twice in every annual revolution of Saturn, namely, when he is in the 19th degree both of Pisces and of Virgo.

How the ring appears to Saturn and to us.

In what signs Saturn appear to lose his ring; and in

what figns it appears moft open to us. Virgo. And when Saturn is in the middle between thefe points, or in the 19th degree either of Gemini or of Sagittarius, his ring appears moft open to us; and then its longeft diameter is to its fhorteft, as 9 to 4.

Places of Saturn's nodes. The orbit of Saturn is $2\frac{1}{2}$ degrees inclined to the ecliptic, or orbit of our earth, and interfects it in the 21ft degree of Cancer and of Capricorn; fo that Saturn's nodes are only 14 degrees from Jupiter's.

Georgium Sidus. On the 13th day of March, 1781, between the hours of ten and twelve at night, as Dr. Herfchell, the Aftronomer Royal, at Windfor, was attempting to difcover the parallax of the ftars, by means of double, triple, and quadruple fixed ftars, he difcovered a new planet, belonging to our fyftem, as he was examining the fmall ftars near the feet of Gemini, which he named Georgium Sidus, in honour to our prefent fovereign: it is feldom to be feen very plainly by the naked eye; it is nearly the colour of Jupiter, or fomewhat paler and more faint, and its apparent diameter about 4 feconds, by the calculation of M. De la Lande; we are told that his diftance from the fun is 19 times farther than the earth is; and its diameter is 4 1-half times that of the earth's.

It is highly probable that all the planets are inhabited. Every perfon who looks upon, and compares the fyftems of moons together, which belong to Jupiter and Saturn, muft be amazed at the vaft magnitude of thefe two planets, and the noble attendance they have in refpect of our little earth: and can never bring himfelf to think, that an infinitely wife Creator fhould difpofe of all his animals and vegetables here, leaving the other planets bare and deftitute of rational creatures. To fuppofe that he had any

view

view to our benefit in creating thefe moons, and giving them their motions round Jupiter and Saturn; to imagine that he intended thefe vaft bodies for any advantage to us, when he well knew that they could never be feen but by a few aftronomers peeping through telefcopes; and that he gave to the planets regular returns of days and nights, and different feafons to all where they would be convenient; but of no manner of fervice to us; except only what immediately regards our own planet the earth; to imagine, I fay, that he did all this on our account, would be charging him impioufly with having done much in vain; and as abfurd, as to imagine that he has created a little fun and a planetary fyftem within the fhell of our earth, and intended them for our ufe. Thefe confiderations amount to little lefs than a pofitive proof, that all the planets are inhabited: for if they are not, why all this care in furnifhing them with fo many moons, to fupply thofe with light which are at the greater diftances from the fun? Do we not fee, that the farther a planet is from the fun, the greater apparatus it has for that purpofe? fave only Mars, which being but a fmall planet, may have moons too fmall to be feen by us. And Georgium Sidus being at too great a diftance for us to attain any knowledge of his moons. We know that the earth goes round the fun, and turns round its own axis, to produce the viciffitudes of fummer and winter by the former, and of day and night by the latter motion, for the benefit of its inhabitants. May we not then fairly conclude, by parity of reafon, that the end and defign of all the other planets is the fame; and is not this agreeable to the beautiful harmony which exifts throughout the univerfe? Surely it is: and raifes in us the moft magnificent ideas of the Supreme Being, who is every where, and at all times prefent; difplaying his power, wifdom, and goodnefs

neſs among all his creatures! and diſtributing happineſs to innumerable ranks of various beings!

Aſtronomical Characters explained.

♈ Aries.	♌ Leo.	♐ Sagitary.
♉ Taurus.	♍ Virgo.	♑ Capricorn.
♊ Gemini.	♎ Libra.	♒ Aquarius.
♋ Cancer.	♏ Scorpio.	♓ Piſces.

♄ Saturn.	☿ Mercury.	☋ Her ſouth node.
♃ Jupiter.	☽ Luna, (the Moon)	⊖ Tellus, Terra, (or the Earth)
♂ Mars.	☊ Moon's north node.	
☉ Sol, (the Sun)		
♀ Venus.		

☌ Conjunction when planets are in the ſame ſign, deg. min. &c.

⚹ Sextile when 2 ſigns diſt.	△ Trine when 4 ſigns diſt.
□ Quartile when 3 ſigns diſt.	☍ Oppoſition when 6 ſigns diſt.

Eclipſes. Every planet and ſatellite is illuminated by the ſun; and caſts a ſhadow towards that point of the heaven which is oppoſite to the ſun. This ſhadow is nothing but a privation of light in the ſpace hid from the ſun by the opaque body that intercepts his rays.

When the ſun's light is ſo intercepted by the moon, that to any place of the earth the ſun appears partly or wholly covered, he is ſaid to undergo an eclipſe; though, properly ſpeaking, it is only an eclipſe of that part of the earth where the moon's ſhadow or penumbra falls. When the earth comes between the ſun and moon, the moon falls

into

into the earth's ſhadow; and having no light of her own, ſhe ſuffers a real eclipſe from the interception of the ſun's rays. When the ſun is eclipſed to us, the moon's inhabitants on the ſide next the earth (if any ſuch there be) ſee her ſhadow like a dark ſpot travelling over the earth, about twice as faſt as its equatoreal parts move, and the ſame way as they move. When the moon is in an eclipſe, the ſun appears eclipſed to her, total to all thoſe parts on which the earth's ſhadow falls, and of as long continuance as they are in the ſhadow.

If the earth and ſun were equally big, the earth's ſhadow would be infinitely extended, and all of the ſame bulk; and the planet Mars, in either of its nodes, and oppoſite to the ſun, would be eclipſed in the earth's ſhadow. Were the earth bigger than the ſun, its ſhadow would increaſe in bulk the farther it extended, and would eclipſe the great planets Jupiter and Saturn, with all their moons, when they were oppoſite to the ſun. But as Mars in oppoſition never falls into the earth's ſhadow, although he is not then above 42 millions of miles from the earth, it is plain, that the earth is much leſs than the ſun; for otherwiſe its ſhadow could not end in a point at ſo ſmall a diſtance. If the ſun and moon were equally big, the moon's ſhadow would go on to the earth with an equal breadth, and cover a portion of the earth's ſurface more than 2000 miles broad, even if it fell directly againſt the earth's center, as ſeen from the moon; and much more if it fell obliquely on the earth: but the moon's ſhadow is ſeldom 150 miles broad at the earth, unleſs when it falls very obliquely on the earth, in total eclipſes of the ſun. In annular eclipſes, the moon's real ſhadow ends in a point at ſome diſtance from the earth. The moon's ſmall diſtance from the earth, and the ſhortneſs of her ſhadow, prove her to be leſs than the ſun.

fun. And as the earth's fhadow is large enough to cover the moon, if her diameter were three times as large as it is (which is evident from her long continuance in the fhadow when fhe goes through its center) it is plain, that the earth is much bigger than the moon.

Why there are fo few eclipfes.

If the moon's orbit were coincident with the plane of the ecliptic, in which the earth always moves and the fun appears to move, the moon's fhadow would fall upon the earth at every change, and eclipfe the fun to fome parts of the earth. In like manner the moon would go through the middle of the earth's fhadow, and be eclipfed at every full; but with this difference, that fhe would be totally darkened for above an hour and an half; whereas the fun never was above four minutes totally eclipfed by the interpofition of the moon. But one half of the moon's orbit is elevated 5 1-3d degrees above the ecliptic, and the other half as much depreffed below it; confequently, the moon's orbit interfects the ecliptic in two oppofite points called the moon's nodes, as has been already taken notice of. When points are in a right line with the center of the fun at new or full moon, the fun, moon, and earth are all in a right line; and if the moon be then new, her fhadow falls upon the earth; if full, the earth's fhadow falls upon her. When the fun and moon are more than 17 degrees from either of the nodes at the time of conjunction, the moon is then generally too high or too low in her orbit to caft any part of her fhadow upon the earth. And when the fun is more than 12 degrees from either of the nodes at the time of full moon, the moon is generally too high or too low in her orbit to go through any part of the earth's fhadow: and in both thefe cafes there will be no eclipfe. But when the moon is lefs than 17 degrees from either node at the

The moon's nodes.

Limits of eclipfes,

time

time of conjunction, her ſhadow or penumbra falls more or leſs upon the earth, as ſhe is more or leſs within this limit. This admits of ſome variation; for, in apogeal eclipſes, the ſolar limit is but 16 1-half degrees; and in perigeal eclipſes it is 18 1-3d. When the full moon is in her apogee, ſhe will be eclipſed if ſhe be within 10 1-half degrees of the node; and when ſhe is full in her perigee, ſhe will be eclipſed if ſhe be within 12 1-30th degrees of the node. And when ſhe is leſs than 12 degrees from either node at the time of oppoſition, ſhe goes through a greater or leſs portion of the earth's ſhadow, as ſhe is more or leſs within this limit. Her orbit contains 360 degrees; of which 17, the limit of ſolar eclipſes on either ſide of the nodes, and 12 the limit of lunar eclipſes, are but ſmall portions: and as the ſun commonly paſſes by the nodes but twice in a year, it is no wonder that we have ſo many new and full moons without eclipſes.

To illuſtrate this, let A B C D be the ecliptic, R S T U a circle lying in the ſame plane with the ecliptic, and V W X Y, the moon's orbit, all thrown into an oblique view, which gives them an elliptical ſhape to the eye. One half the moon's orbit, as V W X, is always below the ecliptic, and the other half X Y V above it. The points V and X, where the moon's orbit interſects the circle R S T U, which lies even with the ecliptic, are the moon's nodes; and the right line, as X E V, drawn, from one ſide to the other through the earth's center, is called the line of the nodes, which is carried almoſt parallel to itſelf round the ſun in a year. Plate XX. Fig. 1. Line of the nodes.

If the moon moved round the earth in the orbit R S T U which is coincident with the plane of the ecliptic, her

 ſhadow

ſhadow would fall upon the earth every time ſhe is in conjunction with the ſun, and at every oppoſition ſhe would go through the earth's ſhadow. Were this the caſe, the ſun would be eclipſed at every change, and the moon at every full, as already mentioned.

But although the moon's ſhadow N muſt fall upon the earth at a, when the earth is at E, and the moon in conjunction with the ſun at i, becauſe ſhe is then very near one of her nodes; and at her oppoſition n ſhe muſt go through the earth's ſhadow I, becauſe ſhe is then near the other node; yet, in the time that ſhe goes round the earth to her next change, according to the order of the letters X Y V W, the earth advances from E to e, according to the order of the letters E F G H, and the lines of the nodes V E X being carried nearly parallel to itſelf, brings the point f of the moon's orbit in conjunction with the ſun at that next change; and then the moon being at f, is too high above the eclipſe to caſt her ſhadow on the earth: and as the earth is ſtill moving forward, the moon at her next oppoſition will be at g, too far below the ecliptic to go through any part of the earth's ſhadow; for by that time the point g will be at a conſiderable diſtance from the earth as ſeen from the ſun.

When the earth comes to F, the moon in conjunction with the ſun Z is not at k, in a plane coincident with the ecliptic, but above it at Y in the higheſt part of her orbit: and then the point b of her ſhadow O goes far above the earth, as in fig. 2, which is an edge view of fig 1. The moon at her next oppoſition is not at o, fig. 1, but at W, where the earth's ſhadow goes far above her, as in fig. 2. In both theſe caſes the line of the nodes V F X, fig. 1, is about

about 90 degrees from the ſun, and both luminaries are as far as poſſible from the limits of eclipſes.

When the earth has gone half round the ecliptic from E to G, the line of the nodes V G X is nearly, if not exactly, directed towards the ſun at Z; and then the new moon l caſts her ſhadow P on the earth G; and the full moon p goes through the earth's ſhadow L; which brings on eclipſes again, as when the earth was at E.

When the earth comes to H, the new moon falls not at m in a plane coincident with the ecliptic C D, but at W in her orbit below it: and then her ſhadow Q fig. 2, goes far below the earth. At the next full ſhe is not at q, fig. 1, but at Y in her orbit 5 1-3d degrees above q, and at her greateſt height above the ecliptic C D; being then as far as poſſible, at any oppoſition, from the earth's ſhadow M, as in fig. 2.

So, when the earth is at E and G, the moon is about her nodes at new and full; and in her greateſt north and ſouth declination (or latitude as it is generally called) from the ecliptic at her quarters: but when the earth is at F or H, the moon is in her greateſt north and ſouth declination from the ecliptic at new and full, and in the nodes about her quarters.

The moon's aſcending and deſcending node.

The point X where the moon's orbit croſſes the ecliptic is called the aſcending node, becauſe the moon aſcends from it above the ecliptic: and the oppoſite point of interſection V is called the deſcending node, becauſe the moon deſcends from it below the ecliptic. When the moon is at Y, in the higheſt point of her orbit, ſhe is in her greateſt north latitude;

Her north and ſouth latitude.

latitude; and when ſhe is at W in the loweſt point of her orbit, ſhe is in her greateſt ſouth latitude.

The nodes have a retrograde motion.

If the line of nodes, like the earth's axis, was carried parallel to itſelf round the ſun, there would be juſt half a year between the conjunctions of the ſun and nodes. But the nodes ſhift backward, or contrary to the earth's annual motion, 19 1-third degrees every year; and therefore the ſame node comes round the ſun 19 days ſooner every year than on the year before. Conſequently, from the time that the aſcending node X (when the earth is at E) paſſes by the ſun as ſeen from the earth, it is only 173 days (not half a year) till the deſcending node V paſſes him. Therefore, in whatever time of the year we have eclipſes of the luminaries about either node, we may be ſure, that in 173 days afterward, we ſhall have eclipſes about the other node. And when at any time of the year the line of the nodes is in the ſituation V G X, at the ſame time next year it will be in the ſituation r G s; the aſcending node having gone backward, that is, contrary to the order of ſigns, from X to s, and the deſcending node from V to r; each 19 1-3d degrees. At this rate the nodes ſhift through all the ſigns and degrees of the ecliptic in 18 years and 225 days; in which time there would always be a regular period of eclipſes, if any complete number of lunations were finiſhed without a fraction. But this never happens; for if both the ſun and moon ſhould ſtart from a line of conjunction with either of the nodes in any point of the ecliptic, the ſun would perform 18 annual revolutions and 222 degrees over and above, and the moon 230 lunations and 85 degrees of the 231ſt, by the time the node came round to the ſame point of the ecliptic again: ſo that the ſun would then be

Which brings on the eclipſes ſooner every year than they would be if the nodes had not ſuch a motion.

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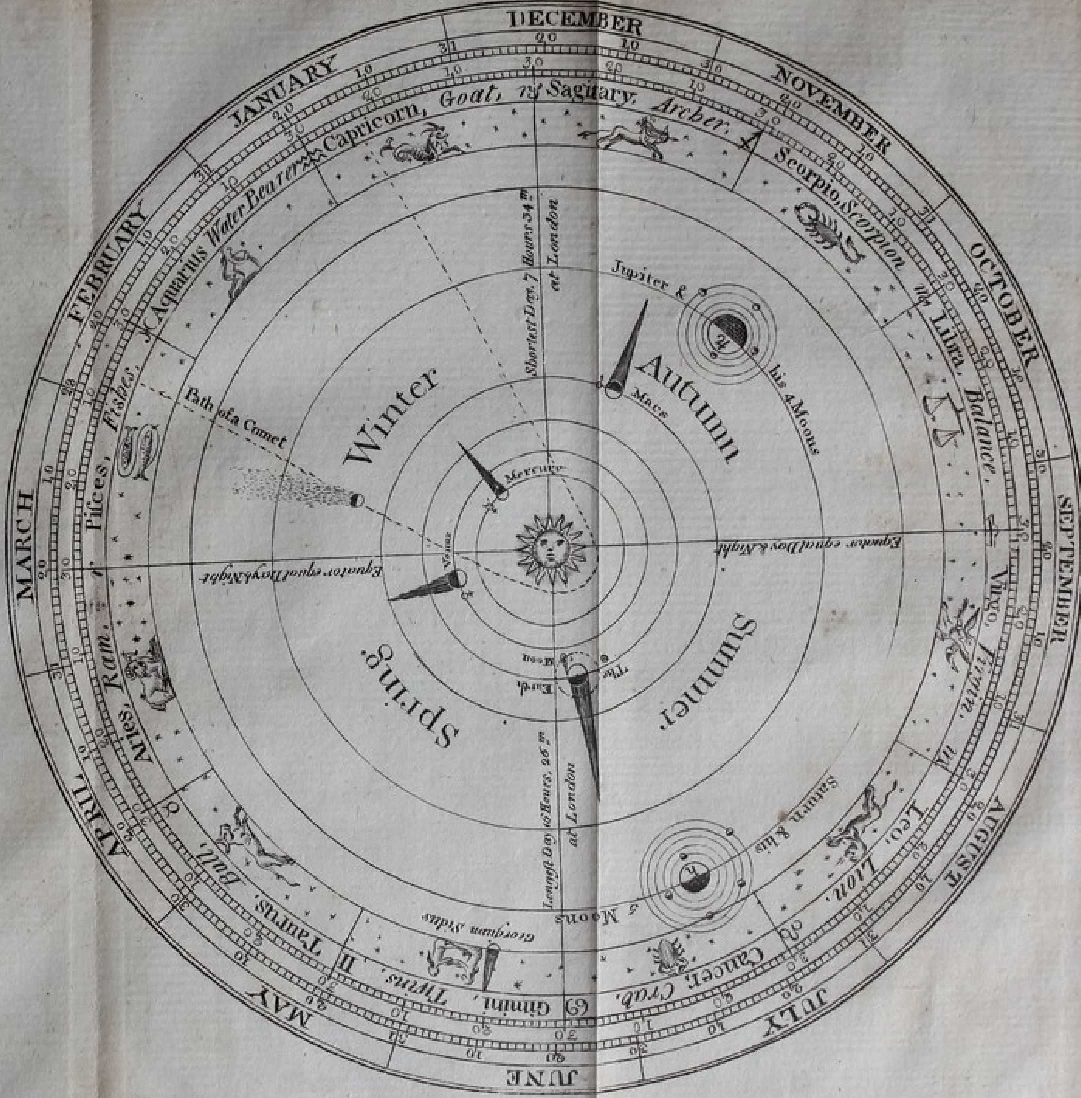
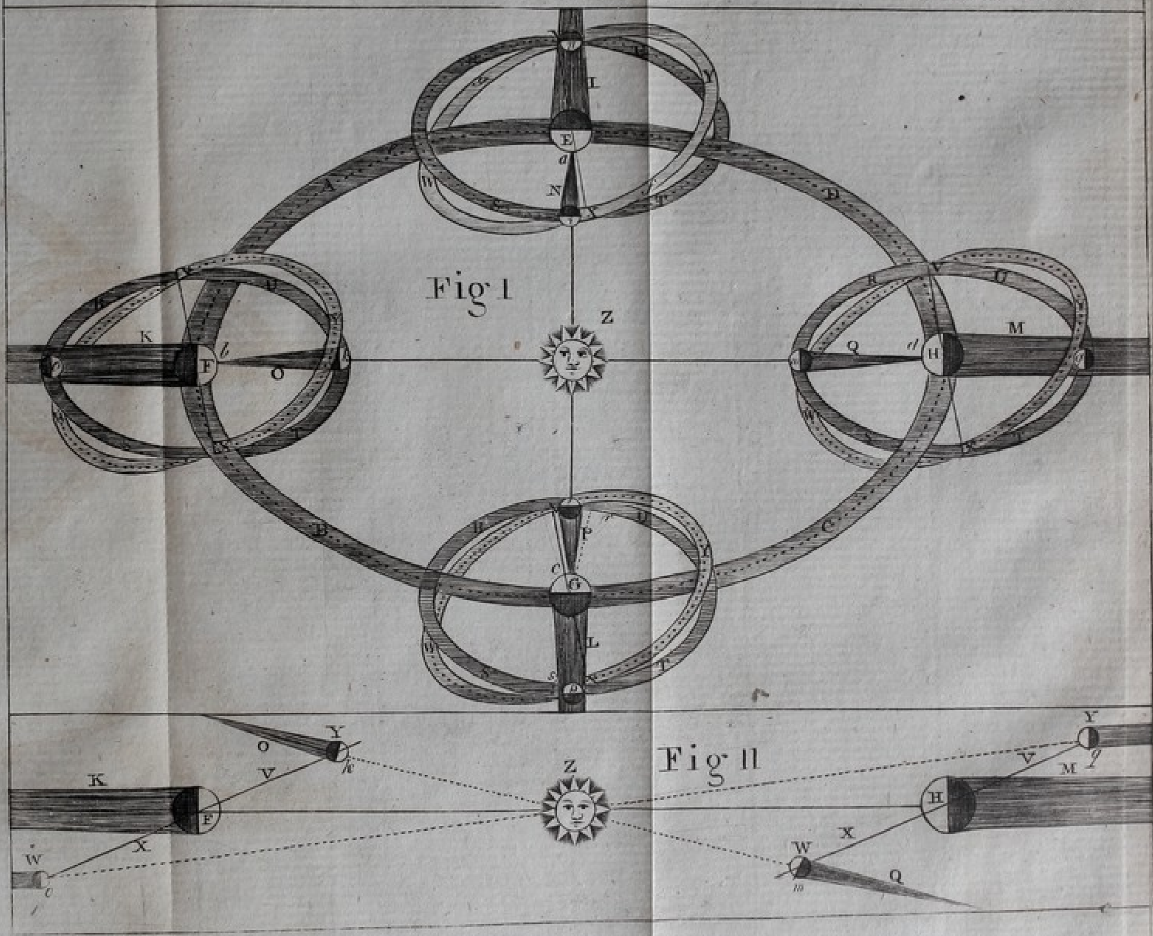
The COPERNICAN *or* SOLAR SYSTEM PLATE XIX



ECLIPSES PLATE XX



138 degrees from the node, and the moon 85 degrees from the ſun.

A period of eclipſes.

But, in 223 mean lunations, after the ſun, moon, and nodes, have been once in a line of conjunction, they return ſo nearly to the ſame ſtate again, as that the ſame node, which was in conjunction with the ſun and moon at the beginning of the firſt of theſe lunations, will be within 28 degrees 12 ſeconds of a degree of a line of conjunction with the ſun and moon again, when the laſt of theſe lunations is compleated. And therefore, in that time, there will be a regular period of eclipſes, or returns of the ſame eclipſe, for many ages.

On the UNIVERSE.

THIS wide machine the univerſe regard,
With how much ſkill is each apartment rear'd?
The ſun a globe of fire, a glowing maſs,
Hotter than melting flint or fluid glaſs.
Of this our ſyſtem holds the middle place,
Mercury the neareſt to the central ſun,
Does in an oval orbit circling run;
But rarely is the object of our ſight,
In ſolar glory ſunk and more prevailing light.

Venus

Venus the next whofe lovely beams adorn,
As well the dewy eve as opening morn,
Does in her orb in beautious order turn.
The Globe terreftrial next with flanting poles,
And all it's pond'rous load unwearied rolls.
Mars next in order, further from the fun,
Does in a more extenfive orbit run.
Then we behold bright planetary Jove,
Sublime in fpace, thro' his wide province move;
Four fecond planets his dominion own,
And round him turn, as round the earth the moon.
Saturn revolving in a higher fphere,
Is by five moons attended thro' his year,
The vaft dimenfion of his path is found,
Five thoufand million Englifh miles around.
Then Georgium Sidus fartheft from the Sun,
In boundlefs fpace does round his orbit turn.

Yet is this mighty fyftem, which contains
So many worlds fuch vaft ætherial planes,
But one of thoufands, which compofe the whole,
Perhaps as glorious, and of worlds as full.
The ftars which grace the high expanfion, bright,
By their own beams and unprecarious light,
Tho' fome near neighbours feem and fome difplay
United luftre in the milky way,
At a vaft diftance from each other lie,
Sever'd by fpacious voids of liquid fky.
All thefe illuftrious worlds and many more,
Which by the tube aftronomers explore:
And millions which the glafs can ne'er defcry
Loft in the wilds of vaft immenfity,

Are

Are ſuns, are centers, whoſe ſuperior ſway,
Planets of various magnitudes obey.

If we with one clear comprehenſive ſight
Saw all theſe ſyſtems all theſe orbs of light;
If we their order and dependence knew,
Had all their motions and their ends in view,
With all the comets which in ether ſtray,
Yet conſtant to their time and to their way,
Would not this view convincing marks impart
Of perfect wiſdom and ſtupendous art!

F I N I S.

E R R A T A

OF THE

Introduction to Uſeful Knowledge.

Page	Line	
3	1	*for* fixed round, *read*, fixed point round.
7	3	*for* is power, *read*, is the power.
8		Second marginal note, *for* Fig. 1. *read*, Fig. 5.
9	14	*inſert* if
12		Firſt marginal note, *inſert*, Fig. 1.
	7	*for* hangs, *read*, hanging.
		In the margin, oppoſite l. 29, *inſert*, Fig. 2.
18	27	*for* argueing *read*, arguing.
34	30	*for* a f d, *read*, a f e.
42	17	*for* leſs perfect, *read*, the leſs perfect.
	27	*for* electri, *read*, electric.
46	3	remove the ſemicolon *from* it, *to* globe;
58	18	*for* G C D, *read*, C G D.
59		bottom line, *for* knobed, *read*, knobbed.
64		laſt marginal note, *read*, Fig. 22.
67	16	*for* rareaction, *read*, rarefaction.
74	9	*for* piſto, *read*, piſtol.
79	18	*for* nor, *read*, not.
80	4	*for* poſiite, *read*, poſite.
99	6	*for* then, *read*, than
103	7	in the parentheſis, *for* Miſcellaneous Articles, *read*, Page 129 of the Introduction to Uſeful Knowledge.
106	16	*for* putrify, *read* putreſy.
	18	*for* putrifying, *read*, putreſying.
	20	*for* putrifying, *read* putreſying.

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E R R A T A.

Page	Line
112	29 *for* ſlider a, *read*, ſlider d S.
116	7 *for* airs, *read*, air.
117	3 in the parentheſis, *inſert*, Plate VII.
120	1 *for* wings, *read* rings.
140	1 *for* D to P, *read*, D to F.
143	18 *for* Fig. 4, *read*, Fig. 5.
144	16 *for* with which, *read*, which with.
144	18 *for* fludity, *read*, fluidity.
151	16 *for* ſuffıcient, *read*, ſufficient.
167	9 *for* contrivance, *read* trivance.
168	23 *for* thrt, *read*, that.
176	4 *for* too, *read*, two.
181	17 *for* viſa, *read*, vice.
193	1 *dele* the.
195	17 *dele* the ſpace betwixt downward.
199	4 *for* ſccnice, *read*, ſcience.
205	11 *for* ray, *read*, rays.
206	11 *for* wiſh, *read*, wiſhes.
211	22 *dele* of.
218	firſt marginal note, *for* Fig. 8. *read*, Fig. 9
224	1 *for* hand, *read*, hind.
229	3 *for* he, *read*, the.
246	13 *for* limb, *read*, line.
253	2 *for* oqject, *read*, object.
256	32 *for* back, *read*, backward.
260	2 in the table, *for* rflecting, *read*, reflecting.
271	5 *for* diſh, *read*, diſk.
272	29 *for* refracting, *read*, reflecting.
276	1 *for* whee, *read*, wheel.
280	11 *dele* of the
287	Antepen. *inſert* 8 mult.
291	ult. *for* dextent, *read*, detent.
295	10 *for* of, *read*, on.
	ult. *for* ferce, *read*, force.
296	3 *for* lift, *read*, lifts.
	12 *for* anſwers, *read*, anſwer.
297	In the margin, *for* Plate XII. *read*, Plate XIX
	Pen. *for* eclipſes, *read*, ellipſes.
302	6 *for* viec, *read*, vice.
303	29 *dele* pro.
312	20 *inſert* theſe.
12	In the index, *for* whed, *read*, when.
14	4 *for* back, *read*, motion.

ERRATA

OF THE

MISCELLANEOUS ARTICLES.

Page.	Line.
12	11 *for* an, *read,* and.
14	27 *for* letharge, *read,* lytharge.
32	24 *for* objeƈt, *read,* objeƈts.
42	9 *dele* is.
	ib. *for* altogether, *read,* all together.
74	2 *dele* it.
78	5 *for* turnſal, *read,* turnſol.
79	12 *for* taſte, *read,* take.
80	21 *inſert* Plate.
85	6 *for* ſoldrr, *read,* ſolder.
	18 *for* biſmouth, *read,* biſmuth.
	29 *for* uſcſel, *read,* uſeful.
86	19 *dele* temper.
88	10 *for* ſtond, *read,* ſtand.
99	28 *for* into, *read,* tin to.
	29 *for* taking, *read,* taken.
109	14 *for* fiugre, *read,* figure.
110	1 *for* laſt, *read,* leaſt.
137	24 *for* peculum, *read,* ſpeculum.
138	8 *for* diaphragm, *read,* diagram.
149	29 *for* biſmouth, *read,* biſmuth.
152	22 *dele* than.
154	26 *for* fire, *read,* fine.
158	2 *for* neatly, *read,* nearly.
	11 *dele* In.
164	Antepen. *inſert* of.

CURIOUS

AND

USEFUL

Miſcellaneous Articles.

ADVERTISEMENT.

THE greateſt part of the publications which have appeared on the ſubjects treated of in Miſcellaneous Articles, after having drawn their readers into much unneceſſary expence, have left them nearly in the ſame ſtate of ignorance as that in which they were found.

This has ariſen partly from the obſcure and perplexed manner in which the ſubjects have been handled; and ſtill more from another cauſe, namely, that the authors themſelves were totally unacquainted with the practical part of the arts they wrote upon. Theory without experiment will ever be liable to error. To obviate both theſe objections is the deſign and intention of this work. Particular attention has been paid to render perfectly clear and eaſy every thing it contains, and the editor's own private experiments have

repeatedly

repeatedly confirmed the truth of every thing it advances. The beſt authors have been conſulted, and neither pains nor expence have been ſpared to render the whole worthy the encouragement and patronage of the public.

CONTENTS

CONTENTS

TO THE

MISCELLANEOUS ARTICLES.

CONTENTS.

A ſolder

REFERENCES to the PLATES.

MISCELLANEOUS PLATES.

CURIOUS AND ENTERTAINING MISCELLANEOUS ARTICLES.

Of laying Gold upon white Earthen Ware.

TAKE japanners gold ſize of the beſt ſort one ounce, which keep in a bottle well corked; the ſame quantity of oil of turpentine, and a book of leaf gold; then with two or three camel hair pencils, you will be ready for the work. All theſe materials may be had at any principal colour-ſhop.

Being thus provided with every thing neceſſary, proceed to work after the following manner:

1ſt. Pour out of the gold ſize bottle, about a ſmall tea ſpoonful into a ſhell, or cup, then with the pencil lay the ground of your deſign upon the pot; but obſerve to keep moiſtening the gold ſize gradually, with the pencil, out of

the turpentine bottle, for the gold ſize being expoſed to the open air, ſoon grows too thick for uſe. A little experience will make it quite eaſy to be underſtood. When the ground is laid according to the deſign, ſet the pot in a clean place to dry leiſurely for the ſpace of one hour, then place it as near the fire as you can but juſt endure the heat with your hand for about four ſeconds of time. In this ſituation let it remain, until by preſſing your finger upon the ground, and taking it ſuddenly off, it will give a ring, then lay the gold on (as directed below) and it will look like burniſhed gold, then with the pencil and gold ſize touch the places you would have ſhadowed, and it is ready to be baked in an oven for two hours, after which it will bear waſhing, and continue bright many years.

This experiment will ſucceed very well upon glaſſes which have figures or ornaments of any kind ground upon them, ſuch as decanters, pints, wine glaſſes, &c. The proceſs of laying on the ſize, and gold, is the ſame as for pots, only obſerve, when you lay the gold on, not to preſs it too hard for fear of breaking the glaſs, which I have ſometimes done before I was well acquainted with the preſſure it would bear, for glaſs is exceeding tender when ground deep. Obſerve, when you lay the ſize on, that you do not daub it upon the poliſhed ſurface of the glaſs; if you do, the work will not look neat; for if the glaſs has a bad figure ground upon it, it will be impoſſible for you to make any amendment. Be careful to lay the ſize on even, after which, put the glaſs in a tin oven before the fire, till by touching the ſize with your finger, and ſuddenly taking it off again, the veſſel will ring as before mentioned, and then it is ready for laying on the gold; in doing which, I have tried ſeveral methods, but ſhall only mention two, and

leave

leave it to your choice to follow which you like, or make further improvement.

Firſt, I took a book of leaf gold, and laid it on the table, then carefully took from the book one of the leaves of paper, and rubbed one ſide of it upon my forehead, which gave it ſuch a clammy moiſture, that when I laid it upon the leaf of gold in the book, and gently ſtroked it over, the gold adhered to it, ſo that I could cut it, along with the paper, into as narrow ſhreds as I pleaſed, for the ſtalks of flowers, &c. likewiſe into ſquares of every dimenſion; I then took ſuch pieces as ſuited me, and laid them upon the ſize (it being in proper order) and gave them a gentle preſſure with my finger, in order to faſten them until ſuch time as I threw the papers away, and gathered up a piece of cotton-wool, with which I preſſed them all over, continuing the ſame operations until the whole was compleated, then wiped off the ſuperfluous gold, and ſhadowed the ornaments in their proper places, putting it into an oven to bake two or three hours, and the work was finiſhed.

I practiſed the above method for ſome time, but experience ſoon convinced me, that the face of the gold had not that bright luſtre which it ought to have had; I therefore procured a cuſhion, and with a knife cut the gold to the dimenſions wanted, and with a piece of cotton-wool took it from off the cuſhion, and laid it on the glaſs, and this ſucceeded to my ſatisfaction.

How to ſilver Looking Glaſſes.

IN order to go compleatly forward, you muſt be prepared with the following articles, viz.

1ſt. A ſquare marble flag, or ſmooth ſtone, well poliſhed, and ground exceeding true, the larger the better, with a frame round it, or a groove cut in its edges, to keep the ſuperfluous mercury from running off. 2d. Lead weights covered with cloth, to keep them from ſcratching the glaſs, from 1 pound weight to 12 pounds each, according to the ſize of the glaſs which is laid down. 3d. Rolls of tinfoil. 4th. Mercury or quickſilver, with which you muſt be well provided. Then proceed as follows:

Cut your tinfoil a little larger than your glaſs every way, and lay it flat upon the ſtone, and with a ſtraight piece of hard wood, about three inches long, ſtroke it every way, that there be no creaſes or wrinkles in it, then drop a little mercury upon it, and with a piece of cotton-wool or hare's foot, ſpread it all over the foil, ſo that every part may be touched with the mercury. (Now here obſerve, that the marble ſlab be nearly level with the horizon) then pour on the mercury all over the foil, and cover it with a fine paper, and lay two weights very near its loweſt end or ſide, to keep your glaſs ſteady, while you draw your paper from betwixt the ſilvered foil and the glaſs, which muſt be laid upon the paper, as you draw the paper, you muſt take care that no air bubbles be left, for they will always appear if left in at the firſt, you muſt likewiſe be ſure to make the glaſs as clean as poſſible on the ſide intended to be ſilvered, and have the paper alſo quite clean, otherwiſe, when you have drawn the paper from under it, dull white ſtreaks will appear, which are very diſagreeable.

After the paper is drawn out, place as many weights upon the glaſs as you conveniently can, in order to preſs out the ſuperfluous mercury, and make the foil adhere to the glaſs,

glaſs. When it has lain ſix or ſeven hours in this ſituation raiſe the ſtone about two or three inches at its higheſt end, that as much of the mercury may run off as poſſible; let it remain two days before you venture to take it up, but before you take the weights off, gently bruſh the edges of the glaſs, that no mercury may adhere to them; then take it up, and turn it directly over with its face ſide downward, and raiſe it by degrees, that the mercury may not drip off too ſuddenly; for if when taken up it is immediately ſet perpendicular, air will get in between the foil and the glaſs at the top, as the mercury deſcends to the bottom, by which means, if you be not exceedingly careful, your labour will be loſt; a very little practice, ſtrictly obſerving the above rules, will ſoon encourage the young artiſt to purſue this pleaſing experiment with pleaſure and profit.

Another method, and which I prefer, is to ſlide the glaſs over the foil without the aſſiſtance of paper, as directed for ſilvering meniſcus glaſſes.

I would adviſe at the firſt to begin with ſmall glaſſes, and ſo proceed to larger ones by degrees.

To foilate Glaſs Globes.

TAKE half an ounce of clean lead, and melt it with an equal weight of pure tin; then immediately add half an ounce of biſmuth, and carefully ſkim off the droſs, then remove the lead from the fire, and before the mixture grows cold, add five ounces of mercury, and ſtir the whole well together; then put the fluid amalgam into a clean glaſs, and it is fit for uſe.

When

When this amalgam is ufed for foiling or filvering, let it firft be ftrained through a linen rag; then gently pound fome ounces thereof into the globe intended to be foiled; the mixture fhould be poured into the globe by means of a glafs or paper funnel, reaching almoft to the bottom of the globe, to prevent its fplafhing to the fides, then dexteroufly inclining (though very flowly) the globe every way, in order to faften the filver; when this is once done, let the globe reft fome hours; then repeat the operation till at length the fluid mafs is fpread even, and fixed over the whole internal furface; as it may be known to be by viewing the globe againft the light; and then the fuperfluous amalgam may be poured out, and the outfide of the globe cleared, and the operation is ended.

In this manner are made thofe fhining fpherical globes appearing like glaffes filled with quickfilver, which we fee hung up in parlours, near the cieling, to invite the flies in fummer from the windows, and other parts of the room, where they might prove more offenfive.

The operator has confiderable advantage, as it can be performed without heat, and is not attended with the danger of poifonous fumes from arfenic, or other unwholefome matters ufually employed for this purpofe, and how far it is applicable to the more commodious foiling of the common looking glaffes and other fpeculums, may deferve to be confidered: I have tried it on feveral irregular furfaces, and it has anfwered exceeding well.

How

How to silver the Convex Side of Meniscus Glasses for Mirrors.

TAKE an earthen plate, on which pour some prepared plaster of Paris, mixed with water, of a proper consistence; then immediately, before it grows too stiff, lay your meniscus with its convex side downward, in the middle of the plate, and press it till it lies quite close to the plaster, in which situation let it remain, until the plaster becomes quite dry; after which, work a groove with your finger round the outside of the meniscus, in order to let the superfluous mercury rest upon it; then cut the tinfoil to a proper size, and press it with the meniscus into the plaster mould, in order to make it lie close; after which cover it with the mercury, and without a paper, (as directed for silvering plain mirrors) slide it over the silvered foil; then place a weight on it, and let it stand two or three days, raising it by degrees, that the mercury may drip off gradually, and you will find it answer your expectation.

After this method common window glass, &c. may be silvered.

To lay Paper Prints on the inside of Glass Globes.

FIRST cut off all the white part of your impression, so that nothing appear but the print; then prepare some strong gum arabic water, or size, with which you must brush over the face side, after which put it into the globe, and with a long small stick, on which a camel hair pencil is fixed, stick it even on, and by this method you may put what quantity of

of prints you pleaſe into the globe; let them dry about twelve hours, then pour ſome prepared plaſter of Paris, either white or tinged whatever colour you pleaſe, and turn the globe eaſily about, ſo that every part be covered, then pour out the ſuperfluous plaſter, and it is finiſhed.

How to take Impreſſions from Medals, &c. in Plaſter of Paris.

AFTER having oiled the ſurface of your mould gently with a little cotton, or a camel hair pencil, dipped in oil of olives, put a hoop of paper round it, exactly to the thickneſs you would chuſe your impreſſion to be made; then take ſome prepared plaſter of Paris, in a tea-cup or baſon, according to the quantity wanted to be at that time uſed, and ſome fair water, to the conſiſtence of a very thick cream, and with a bruſh rub over the ſurface of the mould, and immediately afterwards make it to a ſufficient thickneſs; for rubbing the ſurface, entirely prevents any air holes from appearing on the impreſſion. Let it ſtand about half an hour, and it will in that time grow ſo hard, that you may verv ſafely take it off; then pare it ſmooth on the back, and neatly rouud the edges, and it is done. It ſhould be dried, if in cold or damp weather, before a briſk fire. In this operation, when you have made the impreſſions to a proper thickneſs, you ſhould, while they are wet in the moulds, ſprinkle them with ſome of the powder, which makes them conſiderably harder, and dry ſooner. If you cover the face of the mould with fine plaſter, a coarſer ſort will do to fill it up with, and be a conſiderable ſaving; but I would alſo

adviſe

advife you not to mix more plafter at one time than what you immediately want, becaufe it will be apt to thicken too foon, and fo the fuperfluous quantity will be loft (until it be burnt again, and go through the fame operation as when at firft prepared) for adding water to it to thin it, will quite prevent it from ever fetting hard a fecond time, without burning it afrefh.

To prepare a Plafter Mould fo as to take a Brimftone or Wax Impreffion from it.

LET your plafter mould be quite dry, then dip it in the following mixture, viz.

Take half a pint of boiled linfeed oil, and fpirit of turpentine one ounce, mix them together in a bottle; when wanted, pour the mixture into a plate or faucer, and dip the furface of your mould into it, take your mould out again, and when it has fucked up the oil, dip it again; repeat this till the oil begins to ftagnate upon it; then take a little cotton-wool, hard rolled up, (to prevent the oil from fticking to it) and wipe it carefully off; lay it in a dry place for a day or two, (if longer the better) and the mould will acquire a very hard furface from the effect of the oil; when ufed, it muft be oiled with oil of olives in the fame manner as before directed.

How to caft Brimftone, and give it a metallic Glofs.

TAKE fome ftone brimftone, melt it in an iron ladle over the fire, let it flame for about five or fix minutes, then

take it off, and with a piece of board extinguifh the flame, and let it cool a little fo as not to feel like glue, or run ropy, it is then proper for ufe; and you may pour it into your mould, in which let it ftand five or fix minutes, and you may take it off; pare it as before, and rub the furface of the impreffion over with fome cotton, and the beft powder of black lead, which will give it a very fine metallic glofs.

How to make Sulphur Red or Green, and caft it in Moulds like Marble.

TAKE two ounces of beft clean ftone brimftone, and melt it flowly over a gentle fire, without letting it flame; when it is melted, add one ounce of vermilion, ftir them well together, then pour the compofition over the furface of your mould, and immediately pour it off again, and fill the mould up to a proper thicknefs with common brimftone, let it ftand the fame time as before-mentioned, then pare and rub over the furface with fome clean cotton, which will give it a polifh; the more impreffions you can make at once melting the better, becaufe the brightnefs of the red fades, the oftener it is melted: it may be made green by ufing it in the fame manner, and by adding the fame quantity of the beft fmalt, inftead of vermilion, only it requires more ftirring to mix it properly; it may alfo be made to imitate a beautiful marble, by mixing feveral colours feparately, and made in fmall fquares of equal fizes, which break into exact lengths, and difpofe them according to your fancy, endwife in an iron frame that will open with a joint, after which, melt them together, and the colours will unite in a pleafing manner, and each will appear diftinct. When you melt it be careful not to fhake it, and let it cool by degrees.

How

How to chuse Plaster.

IT is best to chuse plaster in stone, the finest and clearest parts only, for if you have it in powder, it is not to be depended on so well. Take great care that it may be very well burnt, and well pounded; also very white, and sifted through a fine tiffany, then it may be laid up in a box for use. In London this precaution is unnecessary, because it may be procured good (according to the price) of the dealers in this article.

Of colouring Plaster.

PLASTER of Paris may be tinged with several colours when your are casting, by mixing it with Prussian blue, red lead, orpiment, &c. with which you may compose a blue, red, yellow, and green, &c. and it has a very good effect when the raised part is white, red, &c. and the ground of another colour. But it is to be observed, that the coloured impressions take a longer time in becoming hard, than when the plaster is unmixed. But if you sift some plaster upon the top of your cast (when it happens to be a flat figure) it will set the sooner, and the superfluous part may be pared off when thoroughly dried.

To lay Mezzotinto Prints upon Glass.

PROVIDE a clear plate of glass, as straight as possible a little larger than the print, then steep the print flat way, in warm water about an hour, and with a thin knife, spread

Venice turpentine, or varniſh, exceeding thin an even over one ſide of the glaſs, which muſt be kept warm, that the turpentine may ſpread the better; and obſerve that there be not the leaſt ſpeck of the glaſs uncovered with the turpentine. Then take the print out of the water, and lay it on a ſmooth table between two cloths, or ſeveral folds of paper, in order to take out the ſuperfluous water. When this is done, lay the print upon the glaſs by degrees, beginning at one end, and ſtroke outward that part which is faſtened to the glaſs, that no wind or water may lie betwixt, as it will cauſe bliſters, which you muſt be careful to ſtroke out. The print being laid upon the glaſs in the moſt exact manner, proceed to rub it with your finger until all the thickneſs of the paper is come off in little rolls, and nothing is left upon the glaſs but a little film, like a ſpider's web, that is faſt ſtuck to the glaſs by the turpentine, &c. great care muſt be taken in rubbing, that no holes are made in the print, eſpecially in the lights, which are the moſt tender parts. If the print be large, ſo that ſome parts of the paper become dry, while you are rubbing the other, you ſhould, with a little water on your finger. wet them as you ſee occaſion, to keep them moiſt, for the paper will not rub when dry. When you have rubbed the paper till it appears tranſparent on the back, ſet it up to dry for three or four hours: after which varniſh it over with turpentine or maſtic varniſh, two or three times, or till you ſee it tranſparent, and after it has ſtood a day or two to dry, proceed to paint it.

Colours proper for painting upon Glaſs,

ARE beſt procured at colour-ſhops, prepared in little bladders on purpoſe, viz. flake white, lamp black, umber, vermilion,

vermilion, mafticote, Pruffian blue, verdigreafe, &c. Ultramarine (for blue) and carmine (for red) are beft kept in powder, as being leaft liable to wafte in that ftate; and when wanted for ufe, a fmall quantity may be mixed up with a drop or two of nut oil with your pallet knife.

To get the colours out of the bladders, prick a fmall hole near the bottom, and prefs it until you have enough for your prefent ufe; becaufe the colours are apt to dry and fkim over.

With thefe colours you may exactly imitate any colour whatfoever, by different ways and methods of mixing, according to your fancy.

The Method of ufing the Colours.

AS the lights and fhades of your print open, lay the lighter colours firft, on the lighter parts of your print, and the darker over the fhaded parts; and having once laid on the brighter colours, it is not material if the darker forts are laid a little over them; for the firft colour will hide thofe laid on afterwards.

When any colours are too ftrong, they may be lightened to any degree by mixing white with them upon your pallet; or you may darken them as much as you pleafe, by mixing them with a deeper fhade of the fame colour.

The colours muft not be laid on too thick; but if troublefome, thin them before you ufe them with a little oil of turpentine.

Take

Take care to have a pencil for each colour; and never uſe that which you have uſed for green with any other colour, without firſt waſhing it well with oil of turpentine, as that colour is apt to appear predominant when the colours are dry.

Waſh all the pencils after uſing, in oil of turpentine.

To waſh any Powder very fine for Colours.

YOU muſt have four or five large wine glaſſes by you, and two or three quarts of clear water. Fill one of your glaſſes with it, and put in half an ounce of the colour you intend to waſh, ſtir it well about with a knife, and permit it to ſtand about ten ſeconds of time, in order to let the gritty parts ſettle to the bottom before you pour it into another glaſs, which, let it remain until the next day, when it will be quite ſettled, then pour off the water, and the powder will be left very fine, which dry, and paper up for uſe, but ſome powders will require a longer time to ſettle, therefore muſt be treated accordingly.

To make the beſt drying Oil.

MIX a little letharge of gold, with linſeed oil, boil it over a ſlow fire, but not too much, leſt it ſhould prove over thick, and be unſerviceable.

To make Turpentine Varniſh for the above Prints.

PUT one ounce of Venice turpentine in an earthen pot, place it over a ſlow fire, and when it is diſſolved, add

two

two ounces of oil of turpentine; as ſoon as they boil take off the pot, and when the varniſh is cool, keep it in a glaſs bottle; this and all other varniſhes ought to be ſtopped cloſe up, and well ſecured from the air. With this you may varniſh prints on glaſs or other things, to render them tranſparent: if the varniſh ſhould be too thick, you may thin it with the addition of a little oil of turpentine; if too thin add a little more Venice turpentine.

To make Maſtic Varniſh for the above Prints.

TAKE two ounces of the cleareſt gum maſtic you can chooſe, powder it finely, and put it in a bottle with ſix ounces of oil of turpentine, ſtop the bottle cloſe, and ſhake them well together till they are well incorporated. Then hang the bottle in a veſſel of boiling water for half an hour, during which, ſhake it three or four times; if you would have it ſtronger, let it boil a quarter of an hour more, and it will be fit for uſe.

If it ſhould not happen to ſuit your convenience to mix and prepare the colours, varniſhes, &c. yourſelf, they may be had ready for uſe at the colour-ſhops in any quantity.

Inſtructions for the Improvement of Youth in the Art of Drawing.

AS the art of drawing is not only an innocent, and uſeful amuſement for youth; but a qualification highly expedient, if not abſolutely neceſſary; to render the ſtudy and practice of it eaſy and entertaining, will be eſteemed an acceptable ſervice to the public.

Not

Not that this, or any other book of the like nature (however correct) is a sufficient guide of itself. For this accomplishment (like other arts) can never be perfectly acquired, without patience and induftry.

The young practitioner muft be brought forwards by proper gradations; the outlines of a figure muft be his firft care, (as the platform muft be firft laid, before the building can be erected) and he muft be content to copy parts of objects, before he indulges his curiofity too far, and makes the leaft attempt at a finifhed piece, but what he will find here carefully obferved, will be the beft direction for his future progrefs.

He muft not be too hot, or eager after new tranfitions from one plate to another, but muft dwell upon each, and never begin a fecond till he has in fome meafure made himfelf mafter of the firft.

He muft further (if he is curious, and aims at any degree of perfection) be very flow in his firft operations. Hafte feldom produces any thing beautiful or correct; and ill habits, when once contracted, are the moft difficult things in nature to be removed.

He cannot look too often on his original; and the length, breadth, and fimilitude of each object before him, will require his utmoft attention and obfervance. And when once he is able, by care and application, to touch up a piece with any tolerable beauty, practice in a fhort time will make him expeditious, and render his labours advantageous and delightful.

Implements

Implements neceſſary for Drawing.

THE implements neceſſary for drawing are compaſſes, charcoal, ruler, black and red lead pencils, pen knife, port crayons, black, white, and red chalk, crayons, Indian ink, crow-quill pens, camel hair pencils, fitches, paper of ſeveral ſorts, &c.

Charcoal is to be choſen of ſallow-wood, ſplit into the form of pencils, ſharpened to a point; its uſe is to draw lightly the deſign over at firſt, that if any part be amiſs, it may be wiped out and amended. Feathers ought to be of a duck's wing on account of their ſtiffneſs (though others may ſerve well enough) with which you may wipe out any ſtroke of the charcoal where it is drawn amiſs, leſt variety of lines breed confuſion. Black and red lead pencils, are to go over your draught the ſecond time more exactly, becauſe the lead will not wipe out with your hand, when you come to draw with the pen. Pens made of raven or crow-quills (but others may ſerve) are to finiſh the work: here you muſt be very careful and exact, for what is now done amiſs cannot be altered. Rulers are to draw ſtraight or perpendicular lines, triangles, ſquares, or polygons, which, you are to uſe in the beginning, till practice and experience may render them needleſs. Compaſſes with ſteel points, to take in and out, that you may uſe black or red lead at pleaſure; their uſe is firſt to meaſure (by help of a ſcale of equal parts upon the edge of your ruler) your proportions, and whether your work, which is done with the charcoal, is exact; alſo to draw circles, ovals, arches, &c.

Of the Precepts of Drawing in general.

HAVING all the neceſſaries above-mentioned in readineſs, it will be good to practiſe as much as may be without the help of your rule and compaſſes; it is your eye and fancy that ought to judge, without artificial meaſurings.

1. The firſt practice of drawing begins with plain geometrical figures, as lines, angles, triangles, quadrangles, polygons, arches, circles, ovals, cones, cylinders, and the like: for theſe are the foundation of drawing. The circle aſſiſts in all orbicular forms, as in the ſun, moon, &c. the oval in giving a juſt proportion to the face and mouth, the mouth of a pot or well, the foot of a glaſs, &c. the ſquare confines the picture you are to copy, &c. the triangle in the half face; the polygon in ground-plans, fortifications, &c. angles and arches in perſpective; the cone in ſpires, tops of towers and ſteeples; the cylinder in columns, pillars, pilaſters, and their ornaments. Having made your hand fit and ready in moſt general proportions, learn to give every object its due ſhade according to its convexity or concavity, and to elevate or depreſs the ſame, as the object appears either nearer or farther off the light, which is indeed the life of the work.

2. The ſecond practice conſiſts in forming fruits; as apples, pears, cherries, peaches, grapes, ſtrawberries with their leaves, &c. the imitation of flowers; as roſes, tulips, carnations, &c. herbs; as thyme, hyſſop, &c. trees; as oak, fir, aſh, walnut, &c,

3. The third practice imitates, 1. Beaſts, as the lion, horſe, elephant,

elephant, leopard, dog, &c. 2. Fowls; as the eagle, ſwan, parrot, partridge, dove, raven, &c. 3. Fiſhes; as the whale, herring, pike, carp, lobſter, crab, &c. of which variety of prints may be bought at reaſonable rates.

4. The fourth practice imitates the body of a man with all its lineaments, the head, noſe, eyes, ears, cheeks, hands, arms, and ſhadows, all exactly proportionable both to the whole, and to one another, as well in ſituation as magnitude.

5. The fifth practice is in drapery, imitating clothing, and artificially ſetting off the outward coverings, habit and ornaments of the body; as cloth, ſtuff, ſilk and linen, with their natural and proper folds; which though it may ſeem ſomething hard to do, yet exerciſe and imitation of the choiceſt prints will make it eaſy.

In drawing all the foregoing forms, or whatever elſe, you muſt be perfect; firſt in the exact proportions; ſecondly in the general or outward lines before you fall to ſhadowing or trimming your work within In mixed and uncertain forms, where the circle and ſquare will do no good, as in lions, horſes, &c. you muſt work by your own judgment, and ſo obtain the true proportion by daily practice; thus, having the ſhape of the thing in your mind, firſt draw it rudely with your charcoal, and more exactly with your lead pencil; then peruſe it well, and conſider where you have erred, and mend it according to the idea which you carry in your mind; this done, view it again, correcting by degrees the other parts, even to the leaſt jot, ſo far as your judgment will inform you; having done what you can, compare it with ſome excellent pattern or print of the

like kind, uſing neither rule or compaſs, but your own reaſon, in mending every fault, giving every thing its due place, and juſt proportion; by this means you may rectify all your errors, and ſtep an incredible way on to perfection.

Having good patterns and copies to draw by, the young artiſt muſt learn to alter them to other proportions either greater or leſs, and this by many trials, as ſhall be taught hereafter more particularly.

Let the young artiſt now begin to exerciſe in drawing after the life, (for that is the compleateſt, beſt, and moſt perfect copy, which nature has ſet for obſervation) wherein the liberty of imitation is preſented in the largeſt latitude; this will be attained by much practice and diligent exerciſe; but there ought to be a perfection in drawing, before there can be the leaſt thoughts of colours or painting; for all things belonging to theſe, will (in a ſhort time) be eaſily and perfectly underſtood.

Of particular Obſervations in the Art of Drawing.

IN drawing after a print or picture, put it in ſuch a light that the gloſs of the colours may not hinder your ſight, but ſo as that the light and your eye may both fall obliquely upon your piece; which, place at ſuch a diſtance, that at opening your eyes, you may view it all at once; the greater your picture is, the farther off you muſt place it to draw after: which, ſet before you a little reclining. Then obſerve the middle of your picture to be copied, which touch upon your paper with the point of your charcoal: obſerve likewiſe the moſt perſpicuous and uppermoſt figures (if

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more than one) which touch gently in their proper places, thus running over the whole draught, you will fee the fkeleton as it were, of the work.

But if you go on without confidering whereunto your work will tend, you will be forced to draw the fame many times over; and to as little purpofe, if you are not exceeding careful, by which means your ingenuity may be dulled, and you decline all further progrefs.

Take particular care of obtaining a right and true draught, and do not be uneafy becaufe you cannot go quickly forward, for what you think may be done in two or three hours, it will be better to beftow two or three days upon; by this means (though you act leifurely, yet you will act prudently) and you will both fooner and better attain the perfection of what you defire.

We fhall now proceed to the leffons, in regard to which the learner is here particularly defired to perfect himfelf in the practice of the firft, in its feveral branches, before he attempts the fecond; and in the fecond, before he meddles with the third; not endeavouring to become mafter of the whole at once, which will only ferve to perplex his ideas, and make him grow weary in the purfuit of what he will never by this means be likely to attain; whereas, by proceeding gradually from one leffon to another, in the order they here ftand, the rules will be found much more eafy and practicable, and confequently the ftudy infinitely more pleafing and engaging.

LESSON

LESSON I.

Of Drawing the Introductory Lines, with the Features and Limbs separately.

FIRST endeavour to imitate perpendicular or upright lines, and then horizontal or parallel lines, but without using the ruler; if care be taken, a few examples of this sort will do. When you can do this well, proceed to the curved lines, observing carefully their different inclinations; and when you can with ease perform these, proceed to draw the outlines of the features of a human face, as the eyes, nose, mouth, and ears; and from them to the limbs or parts of the body, as the arms, hands, legs, feet, &c. they must be but faintly sketched, so as to be easily rubbed down with bread or Indian rubber, in order to make the necessary alterations before finishing.

LESSON II.

Of Profiles and Ovals.

HAVING become master of the former, you may then, and not before, attempt the profile or side face, being very careful to observe the proportion of the several parts to each other; after this the full or oval face, observing still the bearings of every feature with respect to the rest, and keeping the proportions as exact as possible. Divide the eye seen in the front into three parts; the center is the size of the sight, and the proper opening of the eye, which is one-third of its length. The eye in profile is half the size of the

the eye in front, having only one part and an half. The noſe ſeen in front is in width the length of the eye; and in profile has the ſame dimenſion. See plate I.

The noſtril is in height one-third of the width of the noſe. After proceeding with great care in the above, you may begin the outline of the body.

LESSON III.

Of whole Figures, with the Proportions and Dimenſions of the Human Body.

IF on examination you find yourſelf acquainted with, and can eaſily imitate the different features, and parts of the body, you may then begin the figure in the following manner: ſketch the whole very lightly with your pencil or charcoal, then examine the proportion of the different parts, rubbing down with Indian rubber, and altering where neceſſary; when you have brought it as near as poſſible to your original, proceed to finiſh the figure with the crow-quill pen, and Indian ink, beginning with the head, next the ſhoulders, then the body, after which the arms and hands, then the hips, legs and feet, taking care to correct in the finiſhing any errors in the pencil-ſketch, the remains of which will be eaſily rubbed out with Indian rubber. Uſe no compaſſes till after a very minute inſpection with the eye, and then if the fault cannot be diſcovered, a proper application of them to the copy and original will greatly aſſiſt the pupil in perfecting this branch.

The Proportions and Dimenſions of the ſeveral Parts of the Human Body.

THE beſt method of aſcertaining theſe, is to raiſe a perpendicular on the place you intend for the middle of the figure, and divide it into heads, and from ſuch menſuration form a ſcale, to regulate the proper diſtances from any one part of the body to another: but as it has been more common to divide the figure into ten parts, an example of both theſe, together with the following rules for the illuſtration of each, reſpectively are given:

The Proportion of the Human Body, divided into Eight Heads. *See Plate* II.

THE length of the head (or firſt diviſion of the figure) is from the crown or top of the head to the bottom of the chin. A line ruled through the ſecond diviſion will directly croſs the paps of the breaſts. The third diviſion will fall a little above the navel. The fourth acroſs the privities, which is exactly the middle of the figure. The fifth croſſes the middle of the thigh. The ſixth is juſt below the bend of the knee The ſeventh falls a little below the calf of the leg. And the eighth extends to the bottom of the heel. Obſerve, that when the arms are extended at full length in a direct line, the full extent from the end of the middle finger of the right-hand to that of the left, is exactly the length of the figure: from the middle of the collar bone to the end of the middle finger, is juſt four heads, viz. the firſt to the bend of the ſhoulder, the ſecond to the elbow, the third to the wriſt, and the fourth to the fingers end. From

From ſhoulder to ſhoulder in a man of common ſize, meaſure exactly two heads; there can be no preciſe ſtandard for the breadth of the limbs, which vary according to the bulk of the perſons and the movement of the muſcles.

The Proportion of the Human Body divided into Ten Heads. See Plate II.

THE firſt of theſe diviſions extends from the crown of the head to the under lip. The ſecond a little below the collar bone; and a line drawn through this part of the figure, will preſs over the middle of the ſhoulder. The third diviſion will make a line juſt below the paps of the breaſt. The fourth will reach juſt below the navel. The fifth which is the middle of the figure, directly acroſs the privities. The ſixth will paſs over the middle of the thighs, The ſeventh croſſes the bend of the knee. The eighth directly through the calves of the legs. The ninth reaches half way from the calf, to the bottom of the heel, which determines the tenth and laſt diviſion of the figure.

As the pupil will find the foregoing rules of infinite advantage, it will be again neceſſary, to adviſe him to make due application, till it become ſtrongly impreſſed on his mind, and they will enable him to judge of the productions of nature in the formation of the human body, but it is indiſpenſibly neceſſary that the pupil ſhould have ſome knowledge in anatomy, it being the fundamental part of deſign, which enables him to diſcover the beauties of the antique; it would therefore be neceſſary to recommend the ſtudent to

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pay ſome attention to it, as, ſo much of it as is neceſſary for draughtſmen, is very eaſily retained.

LESSON IV.

Of Drapery.

HAVING drawn the out line of the figure you want to clothe, faintly with charcoal, whiſking out the faulty part with a feather, till the figure appear in the attitude and proportion of the original; ſketch the outline of your drapery lightly, with the ſeveral folds, remembering that they muſt not croſs each other. Due regard muſt likewiſe be paid to the quality of the drapery; as ſtuffs and woollen cloth are more harſh than ſilk, which is always flowing and eaſy. Remember that the drapery muſt not ſtick too cloſe to the body, but let it ſeem to flow eaſy about it, and yet appear ſo that the motion of the figure be free and natural. Be careful that the drapery ſuppoſed to be blown by a breeze of wind all flow one way, and draw the parts next the body before thoſe which fly off. The garments muſt always bend with the figure, and if you make the drapery almoſt cloſe to the body the ſmaller muſt be the folds, and if quite cloſe there muſt be no folds, but only a faint ſhadow, to repreſent that part of the body which it covers; the ſtudent ſhould take every opportunity to improve in this uſeful branch, by remarking the folds as they appear in the drapery of gentlemen and ladies, according to the ſeveral poſitions, by following this unerring rule of nature, the learner will greatly heighten his own ideas, and ſoon attain perfection.

Thus

Thus far might ferve to give the young draftfman a general idea of drapery; but that he may not be at a lofs in perfecting himfelf in this art, a few more general inftructions may not be unneceffary.

1. Be careful to avoid overcharging your figure with a fuperfluity of drapery. 2. Let as much of the form of the body as poffible be fhewn underneath it. 3. When the draperies are large, throw them into as many folds as you can, and let thefe be large and graceful. 4. On the contrary, let thofe which are clofe to the body, be loofened by fmall folds judicioufly placed; it will be the means of avoiding that ftiffnefs, which for want of this caution appears, when the drapery is made to fit too ftrait, and makes the figure feem as if wrapped round with a bandage, inftead of being gracefully clothed. 5. When much drapery is required, let the greater part (if poffible) be thrown into fhadow. 6. Obferve that the folds which fall in the light muft have fuch foft and tender fhadows, as may make them fit hollow from the body, and not feem to girt too clofely to it. 7. Let the folds be properly contrafted, and avoid ftrait lines as much as poffible. 8. A judicious repetition of folds in a circular form greatly contributes to characterife a fore-fhortened limb. 9. In fixed attitudes let the drapery appear motionlefs (unlefs expofed to the air). But the drapery of figures moving with great agility, fhould feem to play as if agitated by the wind, but in proportion only to the velocity of the figures in motion

To conclude this part of the fubject with one ufeful caution, viz. Let the pupil be careful how he ftudies ftatues, and remember that the beft of them are only memorials of thofe great artifts, whofe lives were fpent in en-

deavouring to expreſs their own idea of perfection, which varied according to the different taſte of each, and the nature of the materials upon which they wrought: and let it likewiſe be remembered, that there is a ſtiffneſs which ſhould be ſtudiouſly avoided in a copy (even though a correct one) made after the fineſt ſtatue, which will never convey any idea but that of a ſtatue, whereas there is ſuch a freedom obſervable in the imitations of nature, as evidently diſtinguiſhes them from thoſe taken either from marble or plaſter.

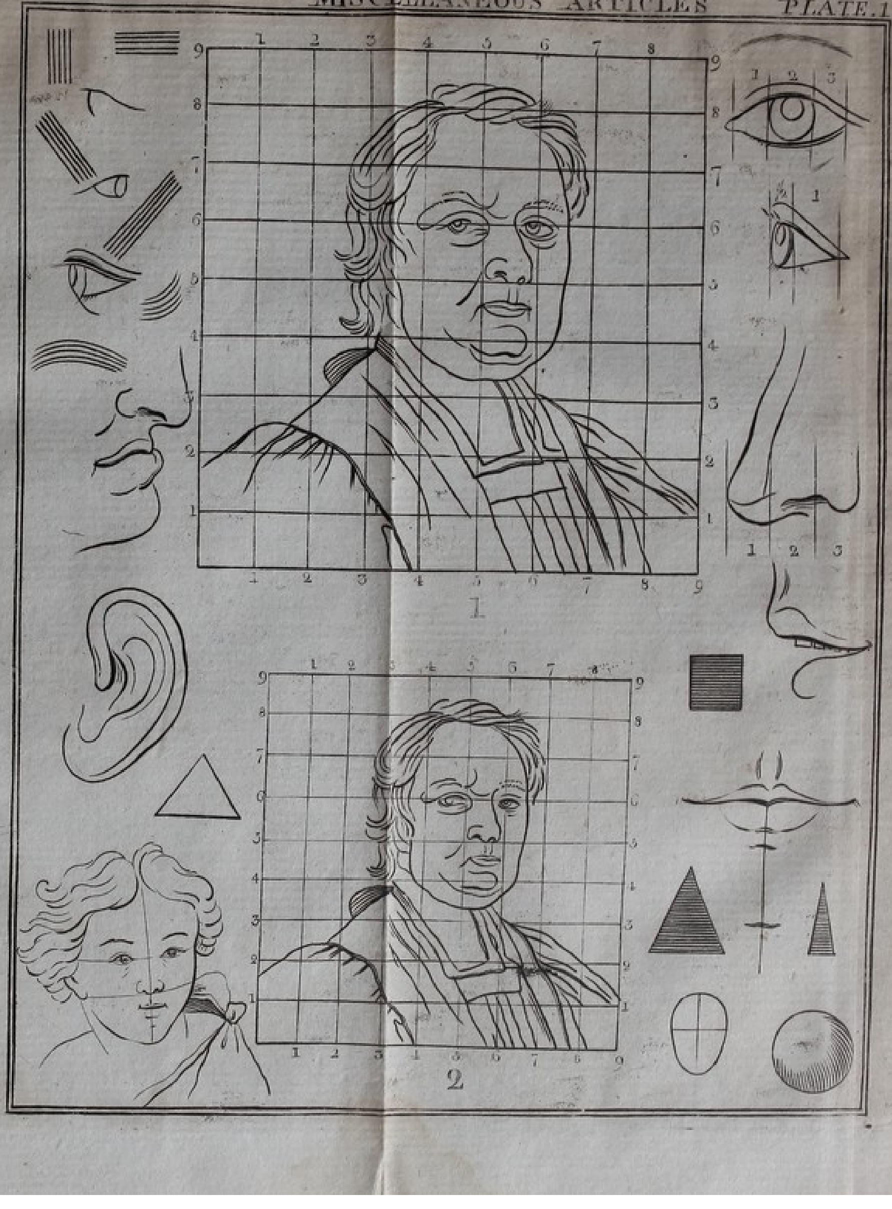
LESSON V.

Of Light and Shade.

HAVING out-lined the folds, and the other parts of drapery, you may next attempt the ſhadowing your figure, obſerving the following method.

Shadow the drawing with the pencil or pen; in which great care is required. Firſt obſerve from which ſide the light comes in, which if natural ought to be from the right or left; for when the light comes in the middle, it is called an artificial light, as proceeding from ſome artificial luminary, as a candle, lamp, &c. Lay your ſhades rather faint at firſt, that you may heighten them at pleaſure where neceſſary.

Remember that your ſhades muſt be all on the ſame ſide of the figure, that is to ſay, if the right ſide of the face be in ſhade, ſo muſt the ſame ſide of the body, arm, leg, &c. Your ſhades muſt be faint as they approach the light, the ſtrength

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ſtrength gradually decreaſing towards the extremities, to prevent a harſh appearance.

A piece of paper, or glove leather, rolled hard and cut almoſt to a point like a pencil is uſeful (if you ſhade with the pencil, red chalk, or crayons) to blend the ſhades, and ſoften them into each other, as alſo where they appear too ſtrong to weaken them. By examining nature you will improve your ideas in light and ſhade, as well as in out-lines, and be enabled to form a right judgment of the truth of your drawing. Indian ink may be prepared for a few different ſhades, by rubbing it more or leſs in water on a marble ſtone cut in hollows, for that purpoſe, reſerving one of the hollows for the water.

To take a perfect Draught of a Picture.

1. TAKE a ſheet of the fineſt white paper you can get, wet it over with clean linſeed oil on one ſide, and wipe the oil off again as clean as you can, then let it ſtand and dry, otherwiſe it will ſpoil a printed picture by the ſoaking thorough of the oil; having thus prepared your paper, lay it on any printed or painted picture, and you may ſee perfectly thorough it; then with a black lead pencil, you may copy with eaſe any picture on the oiled paper, then put it upon a ſheet of clean white paper, and with a little pointed tracer, or burniſher, go over your ſtrokes which you drew upon the oiled paper, and you ſhall have the ſame very neatly, and exactly drawn upon the white paper.

2. HA-

2 HAVING drawn the picture, take the oiled paper, and pin it upon a ſheet of white paper, and prick over the drawing with a pin, then take it off and lay the white paper upon the thing you would draw, and duſt it over with charcoal duſt tied looſely in a rag, and it will leave a true copy of your original, which you may touch up with a black lead pencil; the pricked paper will laſt you longer, and likewiſe be more complete, if it was varniſhed over and made perfectly dry before you prick it.

3. TAKE a piece of fine paper as above, and bruſh it over with oil of turpentine, it will immediately become tranſparent, and may be uſed without loſs of time in drying. It ſhould not be prepared before it is wanted, becauſe as it dries it loſes its tranſparency.

4. TAKE a ſheet of fine white paper and rub it over on one ſide with black lead, or elſe with vermilion, tempered with a little freſh butter, lay the coloured ſide upon a ſheet of white paper, and lay the picture you would copy out upon the other ſide of the coloured paper, and with a ſmall pointed tracer, go over all the ſtrokes of your picture, and the ſtrokes will be drawn on the white paper.

5. TAKE a piece of white lanthorn-horn, and lay it upon your picture, then with a hard nib'd pen, and ink, draw the ſtrokes of your picture upon the horn; and, when it is dry, breathe upon the horn in order to moiſten the ink, then preſs it hard on a piece of white paper a little wetted, and the picture you drew upon the horn will appear upon the paper. You may reverſe your picture by drawing over the other ſide.

6. LAY

6. LAY a paper print upon a bright glafs window, with the back-fide of the print upon the window, then lay a clean paper upon the print, and draw the out-ftrokes upon the paper, which you may vifibly fee, it being fet up againft the light, and by this method you may fhadow it as fine and as exact as you pleafe.

To make Camp Paper, with which a Perfon may write or draw, without Pen, Ink, or Pencil.

TAKE fome hard foap, mix it with lamp black, make it into the confiftence of a jelly, with water; with this, brufh over one fide of your paper, and let it dry: when you ufe it, put it between two fheets of clean paper, with its black fide downward, and, with a pin, or ftick, with a fharp point, draw or write what you pleafe upon the clean paper; and where the tracer has touched, there will be the impreffion upon the lowermoft fheet of paper, as if it had been written or drawn with a pen.

It may be made of any colour by mixing the foap with different colours.

The Method of Enlarging and Contracting,

DIVIDE your original with a pair of compaffes into any number of fquares, and rule them acrofs with a black lead pencil from fide to fide and from top to bottom. Then, having your paper of the fize you intend, divide it into the fame number of fquares, either larger or lefs, as you would enlarge or contract it. and place your original before you,

and draw ſquare by ſquare the ſeveral parts; obſerving to make the part you are drawing fall into the ſame part of the ſquares as it does in your original. To prevent miſtakes, number the ſquares both of the original and copy, as in fig. 1 and 2, plate I. Then outline it with Indian ink, rub out the marks of the pencil with bread, and ſhade it at pleaſure.

Though this is an antient method, yet it is now much practiſed, and is of great help to painters in general.

The Method of Etching Copper Plates.

ETCHING is a manner of engraving on copper, wherein the lines or ſtrokes, inſtead of being cut with a tool or graver, are eaten in with aqua-fortis.

Etching has ſeveral advantages over graving, 1ſt, as being done with more eaſe and expedition; 2d. as requiring fewer inſtruments; and 3d, as repreſenting curious kinds of ſubjects better and more agreeable to nature, as landſcapes, ruins, grounds, and ſmall, faint, looſe, remote object &c.

Of the proper Inſtruments and Materials uſed in Etching.

THE principal inſtruments for etching, are needles, oil-ſtone, bruſh-pencils, burniſher, ſcraper, compaſſes ruler, tracer, and the frame: the materials are the hard and ſoft varniſh, prepared oil, and aqua-fortis.

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The needles are to be chofen of feveral fizes, of a fine grain, and fuch as will break without bending. Thefe are to be fixed in round fticks, of firm wood, about fix inches in length, and of the thicknefs of a large goofe-quill: they are to ftand out of the fticks about a quarter of an inch, or fomething better. Of thefe you fhould have twenty at leaft, which may be fixed in fuch fticks as to have a pencil at the other end.

The ufe of the oil-ftone is for whetting the needles, which, if you would have the points round, muft be whetted fhort upon the ftone, by turning them round; and if you would have them floping, they are firft to be blunted upon the oil-ftone, and then whetted floping on one fide only, till they come to a fhort and roundifh oval.

The brufh-pencil is to cleanfe the work, wipe off duft, and to ftrike the colours even over the ground or varnifh, when laid upon the plate.

The burnifher is a piece of fteel well hardened, fomewhat roundifh at the end, for fmoothing and giving a luftre to the plate.

The fcraper is one of the inftruments fitted for clearing the plate of all deeper fcratches or ftrokes which the burnifher will not take away.

The chief ufe of the compaffes is in meafuring diftances, or ftriking circles, or fome part or portion of them, where you would have your work to be exact.

The ruler is ufed chiefly in drawing all the ftraight hatches or lines of the defign upon the plate; or to mark out dif-tances upon ftraight lines.

The tracer is ufed for drawing through all the outmoft lines or circumferences of the print, pattern, or drawing, which is etching after.

There are two methods of etching, viz. one with hard varnifh or ground, the other with foft. The hard was formerly much ufed, being better accommodated to the intention of imitating the engraving with the tool; as the firmnefs of the body of the varnifh gave more opportunity of reouching the lines, or enlarging them with the oval-pointed needles; but the foft varnifh, has now almoft wholly fuperfeded the ufe of the hard by the free manner of working it admits of.

To make Soft Varnifh for Etching,

TAKE virgin's wax and afphaltum, each two ounces; of black pitch and Burgundy pitch in a new earthen-ware glazed pot; and add to them by degrees, the afphaltum finely powdered. Let the whole boil, till fuch time as that, taking a drop upon a plate, it will break when it is cold, on bending it double two or three times betwixt the fingers. The varnifh being then boiled enough, it muft be taken off the fire, and letting it cool a little, muft be poured into warm water, that it may work the more eafily with the hand, fo as to be formed into balls; which muft be rolled up, and put into a piece of taffety for ufe.

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It muſt be obſerved, firſt, that the fire be not too violent for fear of burning the ingredients; a ſlight ſimmering will be ſufficient: ſecondly, that while the aſphaltum is putting in, and even after it is mixed with them, the ingredients ſhould be ſtirred continually with the ſpatula: and thirdly, that the water, into which this compoſition is thrown, ſhould be nearly of the ſame degree of warmth with it, to prevent a kind of cracking that happens when the water is too cold.

The varniſh ought always to be harder in ſummer than in winter; and it will become ſo if it be ſuffered to boil longer, or if a greater proportion of aſphaltum or brown roſin be uſed. The experiment above-mentioned, of the drop ſuffered to cool, will determine the degree of hardneſs or ſoftneſs that may be ſuitable to the ſeaſon when it is uſed.

The Method of applying the Soft Varniſh to the Plate.

THE plates are to be procured ready for the work, at the braziers, but there are people whoſe buſineſs it is to make them of all ſizes in London. Having a plate according to the ſize you intend, clear it from all greaſineſs by chalk or Spaniſh white, fix a hand vice on the edge of the plate, where no work is intended to be, to ſerve as a handle for managing it when warm: then put it upon a chaffing-diſh in which there is a moderate fire, obſerving to hold it ſo that it may not burn: keep the plate over the fire till it be ſo hot, that the varniſh, being brought into contact with it, may melt: then cover the whole plate over with a thin coat of the varniſh, and while the plate is warm, and the varniſh upon it in a fluid ſtate, dab (or beat) every part of the varniſh

gently with a ſmall ball (or dabber) made of cotton tied up in taffety; which operation ſmooths and diſtributes the varniſh equally over the plate.

When the plate is thus uniformly and thinly covered with the varniſh it muſt be blackened by a piece of flambeau, or large candle, which affords a copious ſmoke; ſometimes two or even four, ſuch candles are uſed together for the ſake of diſpatch, that the varniſh may not grow cold; which if it does during the operation, the plate muſt then be heated again, that it may be in a melted ſtate when that operation is performed: but great care muſt be taken not to burn it, which, when it happens, may be eaſily perceived by the varniſh appearing burnt and loſing its gloſs.

It is proper to be very cautious in keeping the flambeau or candle at a due diſtance from the plate, leſt the wick touch the varniſh, which would both ſully and mark it. If it appear that the ſmoke has not penetrated the varniſh, the plate muſt be again placed for ſome little time over the chaffing-diſh; and it will be found, that in proportion as the plate grows hot, the varniſh will melt and incorporate with the black which lay above it, in ſuch a manner, that the whole will be equally pervaded by it.

Above all things, the greateſt caution ſhould be uſed in this operation, to keep all the time a moderate fire; and to move frequently the plate, and change the place of all the parts of it, that the varniſh may be melted alike every where, and kept from burning. Care muſt alſo be taken, that during this time, and even till the varniſh be entirely cold, no filth, ſparks, or duſt fly on it; for they would ſtick faſt, and ſpoil the work.

To

To make the Hard Varnish for Etching.

TAKE four ounces of fat oil, very clear, and made of good linſeed oil, like that uſed by painters: heat it in a clean pot of glazed earthen ware, and afterwards put to it four ounces of maſtich well powdered, and ſtir the mixture briſkly, till the whole be melted, then paſs the whole maſs through a piece of fine linen, into a glaſs bottle that can be ſtopped very ſecurely; and it is fit for uſe. The method of applying this varniſh, is preciſely the ſame as for the ſoft; being ſpread equally over the warm plate with the taſfety ball, and ſmoked in the ſame manner; only after it is ſmoked, it muſt be baked, or dried over a gentle fire of charcoal, till the ſmoke from the varniſh begins to decreaſe, taking care not to overheat the plate, which would both ſoften it and burn the varniſh.

To make the Soft Wax for the Borders of the Plate, to keep on the Aquafortis.

TAKE four ounces of bees wax, temper it with a little Venice turpentine and tallow to a proper conſiſtence, which will be eaſily found by trial.

General Directions for Etching.

THE method of etching is as follows: the plate being covered over with a peculiar ground or varniſh, as already directed, and that ſide blackened with the ſmoke of a candle, the back of the deſign or draught is laid over the varniſh, being

being firſt rubbed with red chalk: then the deſign being laid on, is to be transferred upon the varniſhed ſide of the plate. This is done by tracing over all the lines and ſtrokes of the draught with a needle or point, not very ſharp, which preſſing the paper cloſe down to the ground, cauſes the wax to lay hold of the red chalk, and thus brings off with it the marks of the ſeveral lines, ſo that at length it ſhews a copy of the whole deſign in all its correctneſs.

In the mean time, it is neceſſary to obſerve, that ſuch parts of the plate as you do not work upon is to be covered with a ſheet of fine white paper, and a ſheet of brown over that; upon this you may reſt your hand, to keep it from the varniſh. If you make uſe of a ruler, lay ſome part of it upon the paper, that it may not rub off the varniſh; and take ſpecial care that no duſt or filth get in between the paper and the varniſh, becauſe that would hurt it.

The draught or deſign being thus chalked, the etcher next proceeds to draw the ſeveral lines with a pointed tool through the ground upon the copper. In doing this, he makes uſe of points of various ſizes, and preſſes them on more ſtrongly or lightly according as the ſeveral parts of the figures &c. require more or leſs ſtrength or boldneſs.

This being done, a rim or border of wax is raiſed round the circumference of the plate, to keep in the aqua-fortis, and prevent it from running off at the edges; and then it is poured on the plate ſo prepared. The ground or varniſh with which the plate is covered, defends it every where from the corroſive quality of the aqua-fortis, except in thoſe lines or hatches cut through the ground with the points, which lying open, the water paſſes through them into the copper and

and eats into it the depth required, which being done it is poured off again.

It is to be obſerved, that the aqua-fortis muſt not continue equally long, or be poured on equally over all the parts of the deſign; and you muſt let it down to a proper ſtrength with water, which no rule but practice can teach, without the ſtrength of the aqua-fortis could be obtained, and likewiſe the goodneſs of the ground; the remote parts muſt firſt be eaten more ſlightly than thoſe nearer to the view. For affecting this, a compoſition of oil and greaſe with which they cover all the parts that are to be eaten no farther, is made uſe of; or elſe this compoſition is at firſt laid on as a defence, and taken off again when they find it proper. In a word, they are every now and then covering or uncovering one or another part of the deſign as occaſion requires.

The management of the aqua-fortis is the principal matter in the whole art of etching, and that on which the effect of the whole chiefly depends. The workman muſt be obſervant as to the ground, that it does not fail or give way in any part to the aqua-fortis; and if in any place it does, to ſtop up that with common varniſh. It muſt be alſo obſerved that a freſh dip of aqua-fortis muſt never be given without firſt waſhing out the plate in fair water, and drying it at the fire.

When the aqua-fortis has performed its part, the ground muſt be taken off and the plate waſhed and dried; after which, the artiſt muſt examine it, and with his graver touch it up, and heighten it where the aqua-fortis, &c. has miſſed.

Particular

Particular Directions for Etching.

IN making lines or hatches, as there muſt be ſome bigger and ſome leſs, ſome ſtraight and ſome crooked, you muſt uſe ſeveral ſorts of needles, bigger or leſs, as the work requires. The large lines are made by leaning hard on the needle, the point being ſhort and thick (but a round point will not cut the varniſh clear), or by making divers lines or hatches very cloſe to one another, and then paſſing over them again with a thicker needle; or by making them with a pretty large needle, and letting the aqua-fortis be longer thereon.

If your lines or hatches ſhould be of an equal thickneſs from end to end, lean on the needle with an equal force; leaning lightly where you would have the lines or ſtrokes fine or ſmall; and heavier where you would have them appear deep or large. If the lines are too ſmall, paſs over them again, with a ſhort, but round point, of ſuch a bigneſs as you would have the line, leaning ſtrongly where you would have it deep.

The manner of holding the needle with oval points, which is moſt proper for making large and deep ſtrokes, much reſembles that of a pen; only the flat ſide whetted is uſually held next the thumb, yet it may be uſed with the face of the oval turned towards the ſide of the little finger.

If you would end with a fine ſtroke, you ſhould draw it with a fine needle; and in uſing the oval points, hold them as upright and ſtraight in your hand as you can, ſtriking

your

your ſtrokes firmly and freely, for that will add much to their beauty and clearneſs.

In etching landſcapes, you muſt uſe ſlender points for faint ſtrokes to thoſe places at the greateſt diſtance from view, as alſo thoſe neareſt the light; and muſt be careful, while at work, to bruſh off all the duſt worked off with the needles.

It is neceſſary to obſerve, that you ought to be ſo far maſter of the art of drawing as to be able to copy any print or painting exactly, and to draw after good heads of plaſter or figures, according to your own fancy, and to ſhadow every thing exactly according to art; and therefore, when you imitate plaſter, be ſure to take the true out-lines or circumferences; and taking notice how the ſhadow falls, to do it very faint, as ſoft as the deſign requires. Therefore it is convenient that you be able to hatch with the pen exactly, after good copies; and when you can do that, to draw after plaſter, and then to draw from the life.

In order to take the out-lines of any drawing or print upon the ground of the plate, you muſt ſcrape a little white-lead on the backſide: then take a feather and rub it over every where alike, and ſhake off that which remains looſe.

Having done this, lay the print on the plate, over that ſide where the lead is, and faſten the four corners of it to the plate with a little ſoft wax: then take the tracer and draw upon the print all the outmoſt lines or circumferences exactly. When you have done this, take off the print from the plate, and all the ſame out-lines and circumferences,

which you drew upon the print with the tracer, will exactly be found upon the ground.

Then you muſt obſerve exactly how your original or pattern is ſhadowed, how cloſe the hatches are joined, how they are laid, and which way the light falls or comes in; this muſt be made to fall one way, and if the light falls ſideways in the print, you muſt hatch that ſide darkeſt which is is fartheſt from the light; and ſo place the lights altogether on one ſide, and not confuſedly, part on one ſide, and part on the other.

Take heed how cloſe all the hatches join, how they incline, and which way they twiſt and wind: this follow as exactly as you can, but before you begin to hatch or ſhadow, you muſt not fail to draw all the out-lines with a needle upon the ground as artificially as you can, and ſhadow it with your different needles according to the original.

In landſcapes, that part next the eye, as was already obſerved is to be hatched darkeſt, and the reſt is to decline in its ſhadows by degrees the farther it is off from view. The ſame method is to be obſerved in etching a ſky, for that which is neareſt to the eye muſt be ſhadowed darkeſt, but in general as ſoft and faint as poſſible, loſing itſelf gradually, as directed before; and, by how much nearer the ſky comes to the ground, by ſo much the more looſe and faint muſt it be made to appear, and where they both meet as it were together, the ſky muſt be quite loſt.

In etching letters, ſcrew the copper-plate in a hand-vice, then hold it over a charcoal fire till it be warm; rub a piece of virgin wax all over the plate, ſpreading it very even with a feather,

feather, and then letting it cool. The letters being written on paper with a black lead pencil, lay the written ſide downwards upon the waxed plate, and faſten the four corners with a little ſoft wax, placing the writing ſo exact, that the lines may run ſtraight. Then rub the backſide of the paper all over with a burniſher, taking care not to miſs any part thereof, and taking the paper off the plate, you will find all the letters written on the paper left exact on the wax. Then draw all the letters through the wax on the plate with a tracer, and afterwards clean the work from the looſe wax with a linen rag or pencil bruſh; and laſtly, pouring on the aqua-fortis, the letters will be etched: all the former operations being performed, waſh the plate with fair water, and ſet it wet upon the fire till the mixture be well melted; then wipe it very clean on both ſides with a linen-cloth till it is thoroughly clear of all the mixture. In the next place, take good charcoal, and pulling off the rind, put fair water on the plate, and rub it with the charcoal, as if you were to poliſh it, and by this operation you will get off the varniſh; only you muſt remember that the charcoal is to be free of all ſorts of knots and roughneſs, and that no ſand or filth fall on the plate. After this, adding two thirds of fair water to one third of common aqua-fortis, dip a linen rag in it, which by rubbing the plate all over, will reſtore it to its former beauty. However, it is neceſſary that the plate be wiped after this, with dry linen-rags, to take off the ſaid water, this is done by holding it a little before the fire, putting on a little olive-oil, and with the fur of an old beaver hat rolled up, rubbing the plate all over before it is wiped with the dry cloth.

Laftly, if any places require to be touched with the graver, as it frequently happens, efpecially where it is to be very deep or black, carefully correct them; and then the plate is fit to be carried to the rolling-prefs.

Of Engraving.

THE tools neceffary for engraving are, the oil-rubber, burnifher, fcraper, oil-ftone, needles, and ruler, already mentioned to be ufed in etching; alfo gravers, compaffes, a fand bag, and fome good charcoal.

Gravers are of two forts, fquare and lozenge; three of each fort fhould be provided. The firft is ufed in cutting the broader ftrokes, the other for the fainter and more delicate. No graver fhould exceed the length of five inches and a half, the handle included, excepting for ftraight lines.

The fand-bag or cufhion, is ufed to lay the plate on, for the conveniency of turning it about. The oil-ftone muft be of the Turkey fort, and may be procured at the iron-mongers.

Of whetting and tempering the Graver.

AS great pains is required to whet the graver nicely, particularly the belly of it, care muft be taken to lay the two angles of the graver, which are to be held next the plate, flat upon the ftone, and rub them fteadily, till the belly rifes gradually above the plate, fo as that, when you lay the graver flat upon it, you may juft perceive the light under the point; otherwife it will dig into the copper, and then

then it will be impoſſible to keep a point, or execute the work with freedom. In order to this, keep your right arm cloſe to your ſide, and place the fore-finger of your left hand upon that part of the graver which lies uppermoſt on the ſtone. When this is done, in order to whet the face, place the flat part of the handle in the hollow of your hand, with the belly of the graver upwards, upon a moderate ſlope, and rub the extremity or face upon the ſtone, till it has an exceeding ſharp point, which you may try upon your thumb nail. The oil-ſtone, while in uſe, muſt never be kept without oil.

When the graver is too hard, as is uſually the caſe when firſt bought, and may be known by the frequent breaking of the point, the method of tempering it is as follows:

Heat a poker red hot, and hold the graver upon it within half an inch of the point, till the ſteel changes to a light ſtraw colour; then put the point into oil to cool: or, hold the graver cloſe to the flame of a candle, till it be of the ſame colour, and cool it in the tallow: but be careful either way not to hold it too long, for then it will be too ſoft; and in this caſe the point, which will then turn blue, muſt be tempered again. Be not too haſty in tempering; for ſometimes a little whetting will bring it to a good condition when it is but a little too hard.

Of holding the Graver.

CUT off that part of the handle which is upon the ſame line with the belly, or ſharp edge of the graver, making that ſide flat, that it may be no obſtruction.

Hold

Hold the handle in the hollow of your hand; and extending your fore-finger towards the point, let it reſt upon the back of the graver, that you may guide it flat, and parallel with the plate.

Take care that your fingers do not interpoſe between the plate and the graver; for they will prevent you from carrying the graver level with the plate, and from cutting your ſtrokes ſo clean as they ought to be.

Of laying the Deſign upon the Plate.

AFTER you have poliſhed the plate fine and ſmooth, heat it ſo as it will melt virgin-wax, with which rub it thinly and equally over, and let it cool. Then the deſign which you lay on, muſt be drawn on paper, with a black lead pencil, and laid upon the plate with its penciled ſide upon the wax, then preſs it to, and with a burniſher go over every part of the deſign, and when you take off the paper, you will find every line which you drew with the black lead pencil upon the waxed plate, as if it had been drawn; then with a ſharp pointed tool, trace all your deſign through the wax upon the plate, and you may then take the wax off, and proceed to work.

Directions for Engraving.

LET the table or board you work at be firm and ſteady; upon which place your ſand bag with the plate upon it; and holding the graver as above directed, proceed in the following manner:

For

For ſtraight ſtrokes, hold your plate firm upon the ſand-bag with your left hand, moving your right hand forwards; leaning lighter where the ſtroke ſhould be fine, and harder where you would have it broader.

For circular or crooked ſtrokes, hold the graver ſtedfaſt, moving your hand or the plate, as you ſee convenient.

Learn to carry your hand with ſuch a ſlight, that you may end your ſtroke as finely as you began it; and if you have occaſion to make one part deeper or blacker than another, do it by degrees: and that you may do it with greater exactneſs, take care that your ſtrokes be not too cloſe, nor too wide.

In the courſe of your work, ſcrape off the roughneſs which ariſes, with the belly of your graver; but be careful, in doing this, not to ſcratch the plate: and that you may ſee your work properly as you go on, rub it with the oil-rubber, and wipe the plate clean, which will take off the glare of the copper, and ſhew what you have done to the beſt advantage.

Any miſtakes or ſcratches in the plate may be rubbed out with the burniſher, and the part levelled with the ſcraper, poliſhing it again afterwards lightly with the burniſher, or charcoal.

Having thus attained the uſe of the graver, according to the foregoing rules, you will be able to finiſh the piece you had etched, by graving up the ſeveral parts to the colour of the original; beginning, as in the etching, with the fainter

parts,

parts, and advancing gradually with the ſtronger, till the whole is compleated.

The dry needle (ſo called becauſe not uſed till the ground is taken off the plate) is principally employed in the extreme light parts of water, ſky, drapery, architecture, &c.

For your firſt practice, copy ſuch prints as are openly ſhaded; the more finiſhed ones being too difficult, till you have gained farther experience.

To prevent any obſtruction from too great a degree of light, the uſe of a ſaſh, made of tranſparent, or fan-paper, paſted on a frame, and placed ſloping at a convenient diſtance between your work and the light, will not only preſerve the ſight, but, when the ſun ſhines, it cannot poſſibly be diſpenſed with.

Of Mezzotinto-Scraping.

THIS art, which is of late date, is recommended to the practice of the ingenious reader, for the amazing eaſe with which it is executed, eſpecially by thoſe who have any notion of drawing.

Mezzotinto prints are thoſe which have no hatching or ſtrokes of the graver, but whoſe lights and ſhades are blended together, and appear like a drawing of Indian ink.

The tools uſed in this art are, the copper-plate, oil-ſtone, grounding-tools, ſcrapers, burniſhers, and needles.

Directions

Directions for laying the Mezzotinto Ground.

MARK off upon the bottom of the plate, the diſtance you intend to leave for the writing, coat of arms, &c. then laying your plate with a piece of ſwanſkin-flannel under it, upon your table, hold the grounding tool in your hand perpendicularly, lean upon it moderately hard, continually rocking your hand in a right line from end to end, till you have wholly covered the plate in one direction: next croſs the ſtrokes from ſide to ſide, afterwards from corner to corner, working the tool each time all over the plate, in every direction, almoſt like the points of a compaſs; taking all poſſible care not to let the tool cut (in one direction) twice in a place. This done, the plate will be full, or, in other words, all over rough alike, and would, if it were printed, appear completely black.

Having laid the ground, take the ſcrapings of black chalk, and with a piece of rag rub it over the plate; or you may with two or three candles ſmoak it, as before directed for etching.

Now, take your print or drawing, and (having rubbed the back with red chalk duſt, mixed with white lake) proceed to trace it on the plate.

Directions for ſcraping the Picture.

TAKE a blunt needle, and mark the outlines only, then with a ſcraper ſcrape off the lights in every part of the

plate, as clean and ſmooth as poſſible, in proportion to the ſtrength of the lights in your picture, taking care not to hurt your outlines: and that you may the better ſee what you do, with the thumb and fore-finger of the left hand hold a piece of tranſparent paper, ſloping, juſt over your right hand, and you will ſoon be a judge of the different tints of the work you are doing; ſcraping off more or leſs of the ground, as the different ſtrengths of light and tints require.

The uſe of the burniſher is, to ſoften or rub down the extreme light parts after the ſcraper is done with, ſuch as the tip of the noſe, forehead, linen, &c. which might otherwiſe, when proved, appear rather miſty than clear.

Another method uſed by mezzotinto ſcrapers, is, to etch the outlines of the original, as alſo the folds in drapery, marking the breadth of the ſhadows by dots which having bit to a proper depth with aqua-fortis; then take off the ground uſed in etching, and having laid the mezzotinto ground, proceed to ſcrape the picture as above.

Four or five days before you think the plate will be ready for proving, wet ſome French paper, as no other will do ſo well for this work, and that time is neceſſary for it to lie wet. Then when the proof is dry, touch it with white chalk where it ſhould be lighter, and with black chalk where it ſhould be darker; and when the print is retouched, proceed as before for the lights, and for the ſhades, uſe a ſmall grounding-tool, as much as you judge neceſſary to bring it to proper colour: and when you have done as much as you think expedient, prove it again, and ſo proceed to prove and touch, till it is entirely to your mind.

Avoid

Avoid as much as poſſible over-ſcraping any part before the firſt proving, as by this caution the work will appear more elegant.

The Method of Etching Copper Plates with Aqua-Tinta.

TAKE a copper plate prepared as before directed for etching, and engraving; lay the etching ground upon it, and etch the outlines of your deſign; take the ground off and clean the plate perfectly well; then ſprinkle gum ſandarach in fine powder very thin and even over the plate, and warm the plate ſo as juſt to faſten the gum ſandarach; but great caution muſt be here obſerved not to melt the gum, if you do the ſpirits of nitre will have no effect, and it will require to be done over again. After it is cold dip a ſmall bruſh pencil in ſpirits of nitre and go over every part you intend to ſhadow for the firſt time; repeat the ſame operation until you have brought it to your ſatisfaction. If your ſpirits be too ſtrong you may mix it with a little water.

Mr. P. Sandby has finiſhed ſome excellent prints by this method, which are held in great eſteem among the admirers of exhibitions of this kind.

This art has been kept as ſecret as poſſible by thoſe who have practiſed it; and I believe this is the firſt hint of the proceſs, that the public has been favoured with.

Crayon

Crayon Painting.

THE elegant arts, of which painting is one of the moſt conſiderable, have ever been held in the higheſt eſtimation by the great and illuſtrious of all ages, not ſolely for private amuſement, but for their beneficial influence in ſociety, in promoting benevolence and inſpiring delicacy of feeling.

This will not appear paradoxical, if we obſerve, that they are evidently contrived to afford innocent pleaſures, diſregarding the inferior ſenſes; in this light they may be conſidered as a rational ſcience, and when cultivated to an eminent degree of refinement, they do honour to mankind.

Every attempt to encourage and improve the elegant arts deſerves great commendation, ſince there is too much reaſon for believing that the intereſts of humanity are not ſo ſtrongly guarded, or ſo firmly ſecured, as eaſily to relinquiſh thoſe ſuccours, or forego thoſe aſſiſtances which they adminiſter to them.

Since painting is an art in which truth of outlines is no leſs neceſſary than juſtneſs of colouring, I apprehend a few hints relative to the former will not (even at this period) be deemed ſuperfluous or unneceſſary; for, ſhould theſe elements fall into the hands of the accompliſhed artiſt, to whoſe judgment I ſubmit them with the higheſt diffidence, I flatter myſelf I ſhall meet with favour and indulgence, ſince I intend this work principally for the uſe of thoſe who are juſt

entering

entering into the world of imitation. To fuch, I hope to make an offering worthy their acceptance, fhould inclination lead them to the ftudy of painting with crayons, by exhibiting the materials ufed in this art, with the methods of making and preparing them for the execution of defign.

I am in hopes of rendering fome fervice to the art of painting with crayons, of fuggefting fome hints which may poffibly give rife to further inquiries refpecting this pleafing ftudy, and of explaining its principles for the benefit of fuch as may prefer the filent amufement of a beautiful art, to the delufive enchantments in the gay circles of pleafures.

I fhall now endeavour to give the ftudent fome directions towards the attainment of excellence in this art.

The ftudent muft provide himfelf with fome ftrong blue paper, the thicker the better, if the grain is not too coarfe and knotty, though it is almoft impoffible to get any entirely free from knots. The knots fhould be levelled with a pen-knife or razor, otherwife they will prove exceedingly troublefome. After this is done, the paper muft be pafted very fmooth on a linen cloth, previoufly ftrained on a deal frame, the fize according to the artift's pleafure: on this the picture is to be executed; but it is moft eligible not to pafte the paper on till the whole fubject is firft dead coloured. The method of doing this is very eafy, by laying the paper with its dead colour on its face, upon a fmooth board or table, when, by means of a brufh, the backfide of the paper muft be covered with pafte; the frame, with the ftrained cloth, muft then be laid on the pafted fide of the paper, after which turn the painted fide uppermoft, and lay a piece of clean paper upon it, to prevent fmearing; this being done, it may

may be ſtroked gently over with the hand, by which means all the air between the cloth and the paper will be forced out.

When the paſte is perfectly dry, the ſtudent may proceed with the painting. The advantages ariſing from paſting the paper in the frame, according to this method (after the picture is begun) are very great, as the crayons will adhere much better than any other way, which will enable the ſtudent to finiſh the picture with a firmer body of colour, and greater luſtre.

When painters want to make a very correct copy of a picture, they generally make uſe of a tiffany, or black gauze, ſtrained tight on a frame, which they lay flat on the ſubject to be imitated, and with a piece of ſketching chalk, trace all the out-lines on the tiffany. They then lay the canvas to be painted on flat upon the floor, placing the tiffany with the chalked lines upon it, and with an handkerchief bruſh the whole over: this preſents the exact out-lines of the picture on the canvas.

The crayon-painter may alſo make uſe of this method, when the ſubject of his imitation is in oils, but in copying a crayon picture, he muſt have recourſe to the following method on account of the glaſs.

The picture being placed upon the eſel, let the out-lines be drawn on the glaſs with a ſmall camel's-hair pencil dipped in lake, ground thin with oils, which muſt be done with great exactneſs: after this is accompliſhed, take a ſheet of paper of the ſame ſize, and place it on the glaſs, ſtroking over all the lines with the hand, by which means the

the colours will adhere to the paper, which muſt be pierced with pin-holes pretty cloſe to each other. The paper intended to be uſed for the painting muſt next be laid upon a table, and the pierced paper placed upon it; then with ſome fine pounded charcoal, tied up in a piece of lawn, rub over the perforated ſtrokes, which will give an exact out-line. Great care muſt be taken not bruſh this off till the whole is drawn over with ſketching chalk, which is a compoſition made of whiting and tobacco-pipe clay, rolled like crayons, and pointed at each end.

When the ſtudent paints immediately from the life, it will be moſt prudent to make a correct drawing of the out-lines on another paper, the ſize of the picture he is going to paint, which he may trace by the preceding method, becauſe erroneous ſtrokes of the ſketching chalk (which are not to be avoided without great expertneſs) will prevent the crayons from adhering to the paper, owing to a certain greaſy quality in the compoſition.

The ſtudent will find the ſitting poſture, with the box of crayons in his lap, the moſt convenient method for him to paint. The part of the picture he is immediately painting ſhould be rather below his face, for, if it is placed too high, the arm will be fatigued. Let the windows of the room where he paints be darkened at leaſt to the height of ſix feet from the ground, as before directed, and the ſubject to be painted ſhould be ſituated in ſuch a manner, that the light may fall with every advantage on the face; avoiding too much ſhadow, which ſeldom has a good effect in portrait painting, eſpecially if the face he paints has any degree of delicacy. Before he begins to paint, let him be attentive to his ſubject, and appropriate the action or attitude

proper

proper to the age of the ſubject: if a child, let it be childiſh; if a young lady, expreſs more vivacity than in the majeſtic beauty of a middle-aged woman, who alſo ſhould not be expreſſed with the ſame gravity as a perſon far advanced in years. Let the embelliſhments of the picture, and introduction of birds, animals, &c. be regulated by the rules of propriety and conſiſtency.

The features of the face being carefully drawn with chalk, let the ſtudent take a crayon of pure carmine, and carefully draw the noſtril and edge of the noſe, next the ſhadow, then with the fainteſt carmine tint lay in the ſtrongeſt light upon the noſe and forehead, which muſt be executed broad. He is then to proceed gradually with the ſecond tint, and the ſucceeding ones, till he arrives at the ſhadows, which muſt be covered brilliant, enriched with much lake, carmine a little broken, with brilliant-green. This method, will, at firſt, offenſively ſtrike the eye, from its crude appearance, but, in finiſhing, it will be a good foundation to produce a pleaſing effect, colours being much more eaſily ſullied when too bright, than when the firſt colouring is dull, to raiſe the picture into a brilliant ſtate. The ſeveral pearly tints, diſcernable in fine complexions, muſt be imitated with blue verditer and white, which anſwers to the ultramarine tints uſed in oils. But if the parts of the face where theſe tints appear are in ſhadow, the crayons compoſed of black and white muſt be ſubſtituted in their place.

Though all the face when firſt coloured ſhould be laid in as brilliant as poſſible, yet each part ſhould be kept in its proper

proper tone, by which means the rotundity of the face will be preſerved.

Let the ſtudent be careful when he begins the eyes to draw them with a crayon inclined to the carmine tint, of whatever colour the iris are of; he muſt lay them in brilliant, at firſt, not loaded with colour, but executed lightly: no notice is to be taken of the *pupil* yet. The ſtudent muſt let the light of the eye incline very much to the blue caſt, cautiouſly avoiding a ſtaring, white appearance, (which, when once introduced, is ſeldom overcome) preſerving a broad ſhadow thrown on its upper part, by the eye-laſh. A black and heavy tint is alſo to be avoided in the eye-brows; it is therefore, beſt to execute them like a broad glowing ſhadow at firſt, on which, in the finiſhing, the hairs of the brows are to be painted, by which method of proceeding, the former tints will ſhew themſelves through, and produce the moſt pleaſing effect.

The ſtudent ſhould begin the lips with pure carmine and lake, and in the ſhadow uſe ſome carmine and black; the ſtrong vermilion tints ſhould be laid on afterwards. He muſt beware of executing them with ſtiff, harſh lines, gently intermixing each with the neighbouring colours, making the ſhadow beneath broad, and enriched with brilliant crayons. He muſt form the corner of the mouth with carmine, brown oker, and greens, variouſly intermixed. If the hair is dark, he ſhould preſerve much of the lake and deep carmine tints therein; this may be eaſily overpowered by the warmer hair tints, which, as obſerved in painting the eyebrows, will produce a richer effect when the picture is finiſhed; on the contrary, if this method is unknown or neglected, a poverty of colouring will be diſcernable.

After the ſtudent has covered over, or as artiſts term it, has dead-coloured the head, he is to ſweeten the whole together by rubbing it over with his finger, beginning at the ſtrongeſt light upon the forehead, paſſing his finger very lightly, and uniting it with the next tint, which he muſt continue till the whole is ſweetened together, often wiping his finger on a towel to prevent the colours being ſullied. He muſt be cautious not to ſmooth or ſweeten his picture too often, becauſe it will give riſe to a thin and ſcanty effect, and have more the appearance of a drawing than a ſolid painting, as nothing but a body of rich colours can conſtitute a rich effect. To avoid this (as the ſtudent finds it neceſſary to ſweeten with the finger) he muſt continually repleniſh the picture with more crayon.

When the head is brought to ſome degree of forwardneſs, let the back-ground be laid in, which muſt be treated in a different manner, covering it as thin as poſſible, and rubbing it into the paper with a leather-ſtump. Near the face the paper ſhould be almoſt free from colour, for this will do great ſervice to the head, and by its thinneſs, give both a ſoft and ſolid appearance. In the back-ground alſo, crayons which have whiting in their compoſition ſhould be uſed, but ſeldom or never without caution; but chiefly ſuch as are the moſt brilliant and the leaſt adulterated. The ground being painted thin next the hair, will give the ſtudent an opportunity of painting the edges of the hair over in a light and free manner when he gives the finiſhing touches.

The ſtudent having proceeded thus far, the face, hair, and back-ground being entirely covered, he muſt carefully view the whole at ſome diſtance, remarking in what reſpect it is

out

out of keeping, that is, what parts are too light, and what too dark, being particularly attentive to the white or chalky appearances, which muſt be ſubdued with lake and carmine. The above method being properly put into execution will produce the appearance of a painting principally compoſed of three colours, viz. carmine, black, and white, which is the beſt preparation a painter can make for the producing a fine crayon picture.

The next ſtep, is to compleat the back-ground and the hair; as the duſt, in painting theſe, will fall on the face, and would much injure it, if that was compleated firſt. From thence proceed to the forehead, finiſhing downward till the whole picture is compleated.

Back grounds may be of various colours; but it requires great taſte and judgment to ſuit them properly to different complexions: in general a ſtrong coloured head ſhould have a weak and tender tinted ground, and on the contrary a delicate complexion ſhould be oppoſed with ſtrong and powerful tints, by which proper contraſt between the figure and the back-ground, the picture will receive great force, and ſtrike the ſpectator much more than it could poſſibly do was this circumſtance of contraſt not attended to.

Young painters often treat the back-ground of pictures as a matter of very little or no conſequence, when it is moſt certain great part of the beauty and brilliancy of the picture, eſpecially the face, depends upon the tints being well ſuited, the darks kept in their proper places, and the whole being perfectly in ſubordination to the face. Thus a ſimple back-ground requires attention, but the difficulty is

is ſtill greater when a variety of objects are introduced, ſuch as hills, trees, buildings, &c. in theſe caſes one rule muſt be ſtrictly attended to, that each grand object be diſpoſed ſo as to contraſt each other; this is not meant merely reſpecting their forms, but their colour, their light, ſhade, &c. For inſtance, we will ſuppoſe the figure receiving the ſtrongeſt light; behind the figure, and very near at hand, are the ſtems of ſome large trees, theſe muſt have ſhade thrown over them, either from a driving cloud, or ſome other interpoſing circumſtance; behind theſe ſtems of trees, and at a diſtance are ſeen trees on a riſing ground, theſe ſhould receive the light as a contraſt to the former, &c. If an architectural back-ground be choſen, the ſame rule muſt be applied; ſuppoſe a building at a moderate diſtance is placed behind the figure receiving the light, a column, or ſome other object in ſhadow ſhould intervene, to preſerve proper decorum in the piece, or what will have the ſame effect, a ſhadow muſt be thrown over the lower part of the building, which will give equal ſatisfaction or repoſe to the eye. It muſt be remembered, the light muſt be always placed againſt the dark, and the weak againſt the ſtrong, in order to produce force and effect, and *vice verſa*.

In painting over the forehead the laſt time, begin the higheſt light with the moſt faint vermilion tint, in the ſame place where the faint carmine was firſt laid, keeping it broad in the ſame manner. In the next ſhade ſucceeding the lighteſt, the ſtudent muſt work in ſome light blue tints, compoſed of verditer and white, intermixing with them ſome of the deeper vermilion tints, ſweetening them together with great caution (this direction is for the fineſt complexions, but the ſtudent muſt vary his colouring ac-

cording

cording to his ſubject) inſenſibly melting them into another increaſing the proportion of each colour as his judgment ſhall direct. Some brilliant yellows may alſo be uſed, but ſparingly; and towards the roots of the hair, ſtrong verditer tints, intermixed with greens, will be of ſingular ſervice. Cooling crayons, compoſed of black and white, ſhould ſucceed theſe, and melt into the hair. Beneath the eyes, the pleaſing, pearly tints are to be preſerved, compoſed of verditer and white, and under the noſe, and on the temples, the ſame may be uſed; beneath the lips, tints of this kind alſo are proper, mixing them with the light greens and ſome vermilion.

The introduction of greens and blues into the face, in painting, has often given ſurpriſe to thoſe who are unacquainted with the art, but there is reaſon ſufficient for their introduction (though it may appear ſtrange at firſt) in order to break and correct the other colours.

The carmine predominating in the dead colour, is, as has been obſerved, the beſt preparation for the ſucceeding tints; the crudeneſs of this preparation muſt be corrected by variouſly intermixing greens, blues, and yellows, which of theſe are to be uſed is to be determined by the degree of carmine in the dead colour, and the complexion intended. The blue and yellow are of a nature diametrically oppoſite, and ſerve to correct the reds, and oppoſe one another; the greens being compounded of both theſe colours, are of peculiar uſe in many caſes where the tranſition is not to be ſo violent.

The ſtudent attentively conſidering nature, will diſcover a pleaſing variety of colours on the ſurface, and diſcernable through a clear and tranſparent ſkin; this variety will be

ſtill

ftill increafed by the effect of light and fhade; he will perceive one part inclining to the vermillion red, another to the carmine or lake, one to the blue, this to the green, and that to the yellow, &c. In order to produce thefe different effects he will apply thofe colours to which the tints are moft inclined; yet in crayon painting it is often beft to compound the mixed colours upon the picture, fuch as blue and yellow inftead of green; blue and carmine inftead of purple; red and yellow inftead of orange; in other circumftances the compounds already mixed fhould be ufed: but in this cafe there can be no abfolute rule given, it muft be left to the experience and difcretion of the painter, though the ftudent may be greatly affifted in the commencement of his ftudies, by an able mafter to direct and point out thebeft method to treat circumftances of this nature, as they occur in practice, which may at firft appear obfcure and myfterious, but will foon, to a good capacity, become demonftrably clear upon certain and fure principles: the circumftances that require different treatment are fo various and fo many, as to render it impoffible for me here to defcend to every particular.

In finifhing the cheeks, let the pure lake clear them from any duft contracted from the other crayons; then with the lake may be intermixed the bright vermillion; and laft of all, (if the fubject fhould require it) a few touches of the orange coloured crayon, but with extreme caution; after this, fweeten that part with the finger as little as poffible, for fear of producing a heavy, difagreeable effect on the cheeks: as the beauty of a crayon picture confifts in one colour fhewing itfelf through, or rather between another; this the ftudent cannot too often remark,

it

it being the only method of imitating beautiful complexions.

The eye is the moſt difficult feature to execute in crayons, as every part muſt be expreſſed with the utmoſt nicety, to appear finiſhed; at the ſame time the painter muſt preſerve its breadth and ſolidity while he is particularizing the parts. To accompliſh this, it will be a good general rule for the ſtudent to uſe his crayon in ſweetening as much, and his finger as little as poſſible. When he wants a point to touch a ſmall part with, he may break off a little of his crayon againſt the box, which will produce a corner fit to work with in the minuteſt parts. If the eye-laſhes are dark he muſt uſe ſome of the carmine and brown oker, and the crayon of carmine and black; and with theſe he may alſo touch the iris of the eye, (if brown or hazel) making a broad ſhadow, cauſed by the eye-laſh. Red tints of vermilion, carmine, and lake, will execute the corners of the eye properly, but if the eye-lids are too red, they will have a diſagreeable ſore appearance. The pupil of the eye muſt be made of pure lamp-black; between this and the lower part of the iris, the light will catch very ſtrong, but it muſt not be made too ſudden, but be gently diffuſed round the pupil till it is loſt in ſhade. When the eye-balls are ſufficiently prepared, the ſhining ſpeck muſt be made with a pure white crayon, which ſhould be firſt broken to a point, and then laid on firm; but as it is poſſible they may be defective in neatneſs, they ſhould be corrected with a pin, taking off the redundant parts, by which means they may be formed as neat as can be required.

The difficulty, with reſpect to the noſe, is to preſerve the lines properly determined, and at the ſame time ſo artfully blended

blended into the cheek, as to expreſs its projection, and yet no real line to be perceptible upon a cloſe examination; in ſome circumſtances it ſhould be quite blended with the cheek, which appears behind it, and determined entirely with a ſlight touch of red chalk. The ſhadow cauſed by the noſe is generally the darkeſt in the whole face, partaking of no reflection from its ſurrounding parts. Carmine and brown oker, carmine and black, and ſuch brilliant crayons, will compoſe it beſt.

The ſtudent having before prepared the lips with the ſtrongeſt lake and carmine, &c. muſt, with theſe colours, make them compleatly correct, and, when finiſhing, introduce the ſtrong vermilions, but with great caution, as they are extremely predominant: this, if properly touched, will give the lips an appearance equal, if not ſuperior, to thoſe executed in oils, notwithſtanding the ſeeming ſuperiority the latter has, by means of glazing, of which the former is entirely deſtitute.

When the ſtudent paints the neck, he ſhould avoid expreſſing the muſcles too ſtrong in the ſtem, nor ſhould the bones appear too evident on the cheſt, as both have an unpleaſing effect, denoting a violent agitation of the body, a circumſtance ſeldom neceſſary to expreſs in portrait painting. The moſt neceſſary part to be expreſſed, and which ſhould ever be obſerved (even in the moſt delicate ſubjects), is a ſtrong marking juſt above the the place where the collar bones unite, and if the head is much thrown over the ſhoulders, ſome notice ſhould be taken of the large muſcle that riſes from behind the ear, and is inſerted into the pit between the collar bones. All inferior muſcles ſhould be, in

general,

general, quite avoided. The ſtudent will find this caution neceſſary, as moſt ſubjects, eſpecially thin perſons, have the muſcles of the neck much more evident than would be judicious to imitate. As few necks are too long, it may be neceſſary to give ſome addition to the ſtem, a fault on the other ſide being quite unpardonable, nothing being more ungraceful than a ſhort neck. In colouring the neck, let him preſerve the ſtem of a pearly hue, and the light not ſo ſtrong as on the cheſt. If any part of the breaſt appears, its tranſparency muſt alſo be expreſſed by pearly tints, but the upper part of the cheſt ſhould be coloured with beautiful vermilions delicately blended with the other.

Of Drapery.

PAINTING the drapery is commonly thought to be a very inferior branch of the art: this is, moſt certainly, a miſtake. A very great painter being aſked what part of the picture he thought moſt difficult to execute, anſwered, the drapery. Whether we allow this to be abſolutely true or not, we may venture to affirm, that it is a very difficult part to execute with taſte; merely to give the effect of ſilk, ſatin, or cloth, &c. is not the point; this, the ſervile copyiſt, by the mere dint of labour, may effect, and may even deceive the vulgar eye, ſo that the imitation may be taken for reality; but to make the folds give grace and dignity to the figure, to cloath it uninfluenced by prejudice, faſhion, or caprice, ſo as to bear the teſt of ages, requires the fulleſt exertion of true genius, and the ſtudy of a man's life; therefore, a full deſcription here would be too prolix, ſo I ſhall leave the ſtudent to perfect it with great diligence and care.

Of the Materials.

THE perfection of the crayons confifts, in a great meafure, in their foftnefs, for it is impoffible to execute a brilliant picture with them if they are otherwife, on which account great care fhould be obferved in the preparing them, to prevent their being hard. In all compofitions, flake-white, and white-lead fhould be wholly rejected, becaufe the flighteft touch with either of thefe will unavoidably turn black.

The ufual objection to crayon paintings is, that they are fubject to change; but whenever this happens, it is intirely owing to an injudicious ufe of the above-mentioned whites, which will ftand only in oils. To obviate the bad effects arifing from the ufe of fuch crayons, let the ftudent make ufe of common whiting prepared in the following manner:

Take a large veffel of water, put the whiting into it, and mix them well together; let this ftand about half a minute, then pour off the top into another veffel, and throw the gritty fediment away; let what is prepared reft about a minute, and then pour it off as before, which will purify the whiting and render it free from all dirt and grittinefs. When this is done, let the whiting fettle, and then pour the water from it; after which, lay it on the chalk to dry, and keep it for ufe, either for white crayons, or the purpofe of preparing tints with other colours, for with this, all the other tints may be fafely prepared. If the ftudent chufes to make crayons of the whiting immediately after it is wafhed, it is not neceffary to dry it on the chalk,

chalk, for it may be mixed inſtantly with any other colour, which will ſave conſiderable trouble. All colours of a heavy, or gritty nature, eſpecially blue verditer, muſt be purified by waſhing after this method.

The ſtudent muſt be provided with a large, flexible pallet-knife, a large ſtone and muller to levigate the colours, two or three large pieces of chalk to abſorb the moiſture from the colours after they are levigated, a piece of flat glaſs to prevent the moiſture from being abſorbed too much, till the colours are rolled into form, and the veſſels for water, ſpirits, &c. as neceſſity and convenience ſhall direct.

R E D S.

Carmine and Lake.

IT is rather difficult to procure either good carmine or good lake. Good carmine is inclined to the vermilion tint, and ſhould be an impalpable powder, and good lake to the carmine tint. The carmine crayons are prepared in the following manner:

As their texture is inclinable to hardneſs, inſtead of grinding and rolling them, take a ſufficient quantity of carmine, lay it upon a grinding-ſtone, mix it with a levigating knife with ſpirits of wine, till it becomes ſmooth and even; yet the leſs friction produced by the knife the better. The chalk-ſtone being ready, lay the colour upon it to abſorb the ſpirit, but be careful that it is laid on in a proper ſhape for painting. If it is levigated tooth in, the crayons will be too flat, and if too thick, it will occaſion a waſte of colour, by their ad-

hering to the pallet-knife; but practice will render the proper degree of consistency familiar.

When thus made, if the carmine crayons should prove too hard, they must be reduced to an impalpable powder in a mortar, and again mixed in the same manner till soft enough for use, which will not be if the carmine be ground by the muller with any fluid.

The simple colour being prepared, the next step is to compose the different tints by a mixture with whiting; the proportion to be observed consisting of twenty gradations to one, which may be clearly understood by the following directions: take some of the simple colour, and levigate it with spirits of wine, adding about one part of washed whiting to three parts of carmine, of which, when properly incorporated, make two parcels. The next gradation should be composed of equal quantities of carmine and whiting, of which four crayons may be made. The third composition should have one fourth carmine, and three fourths whiting, of this make six crayons, which will be a good proportion with the rest. The last tint should be made of whiting, very faintly tinged with carmine, of which make about eight crayons, which will compleat the above-mentioned proportion. As these compound tints are levigated, they are to be laid immediately upon the chalk that the moisture may be absorbed to the proper degree of dryness for forming into crayons, which may be known by its losing the greatest part of its adhesive quality when taken into the hand: if the consistency is found to be right, it may be then laid upon the glass, which having no pores, will prevent the moisture from becoming too dry, before it is convenient to form it into crayons, otherwise the crayons

would

would be full of cracks and very brittle, which will be a great inconvenience when they are ufed in painting.

N.B. Though thefe tints made with whiting may be rolled, yet the pure carmine will not bear it, but muft be left on the chalk-ftone till perfectly dry.

Lake,

IS a colour very apt to be hard, to prevent which the ftudent muft obferve the following particulars:

Take about half the quantity of lake intended for the crayons, and grind it very fine with fpirits of wine; let it dry, and then pulverize it, which is eafily done if the lake is good; then take the other half, and grind it with fpirits, after which mix it with the pulverized lake, and lay it out directly in crayons on the chalk. The colour will not bear rolling. The fimple colour being thus prepared, proceed with the compound crayons, as directed before, and in the fame degrees of gradation as the carmine tints. If thefe fhould prove too hard when made, let them be again pulverized and treated as the carmine.

Vermilion.

THE beft is inclined to the carmine tint. To prepare this colour mix it on the ftone with foft water or fpirits, after which it may be rolled into crayons. It is fometimes, indeed, inclined to be fo very foft as to return again to powder, and cannot be held in the fingers, which may be remedied

medied by mixing it up with thin water-gruel well ſtrained, which will give ſufficient coheſion. The different tints are produced by a mixture of the ſimple colour with whiting, according to the proportions already given.

BLUES.

Pruſſian Blue,

IS a colour very apt to bind, and is rendered ſoft with more difficulty than carmine and lake. The ſame method of preparation is to be followed with this as directed with reſpect to lake, only it is neceſſary to grind a larger quantity of the pure colour, as it is chiefly uſed for painting draperies. The different tints may be made according to neceſſity, or the fancy of the painter.

Blue Verditer,

IS a colour naturally gritty, and therefore it is neceſſary to waſh it well. Its particles are ſo coarſe as to require ſome binding matter to unite them, otherwiſe the crayons will never adhere together. To accompliſh this, take a quantity ſufficient to form two or three crayons, to which add a piece of ſifted plaſter of Paris about the ſize of a pea; mix theſe well together, and form the crayons upon the chalk. This blue is extremely brilliant, and will be of great uſe in heightening draperies, &c. The tints muſt be formed with whiting, as directed in the former inſtances, and are highly ſerviceable for painting fleſh, to produce thoſe pearly tints ſo beautiful in crayon pictures. It is not neceſſary

neceſſary to mix the compounds with ſpirits, as clear water will be ſufficient.

GREENS.

BRILLIANT greens are produced with great difficulty, which may be procured of thoſe who make it their buſineſs to prepare them, yet the following compoſitions will be found uſeful.

Theſe brilliant crayons will be neceſſary for the ſtudent to compleat his ſet with, of which he will find great want both in the browns and deep reds, as well as in the greens; but in general he ſhould be careful what white or light crayons he uſes, that they are not compounded by the maker with flake-white, a trial may be made of one of them thus: bruiſe the crayon to a powder between the finger and thumb, and mix it with an equal quantity of charcoal-duſt, put this into a crucible, which muſt be placed in a fierce fire, till the charcoal-duſt is conſumed, and if the crayon be made with flake-white, the lead will return to its original metallic ſtate, conſequently theſe light crayons are not fit for uſe in this climate, as the leaſt damp will make them turn black, yet notwithſtanding the dark colours will be perfectly good, and may be uſed without danger.

Take yellow oker, and after grinding it with ſpirits, mix it with the powder of Pruſſian blue, then temper it with a knife, and lay the crayons on the chalk, without rolling them: beſides this, uſe king's yellow mixed with Pruſſian blue, brown oker and Pruſſian blue. Roman oker and Pruſſian blue mixed in different proportions will be uſeful.

The

The crayons made of theſe laſt may be rolled. Various tints may be produced by theſe colours, according to fancy or neceſſity; ſome to partake more of the blue, and others of the yellow.

Y E L L O W S.

King's-Yellow,

I S the moſt uſeful and moſt brilliant, levigated with ſpirits of wine, to compoſe the different tints as before directed. Yellow oker and Naples yellow, ground with ſpirits, will make uſeful crayons.

Orange,

I S produced by King's-yellow and vermilion, ground together with ſpirits, and the tints formed as in other caſes, but no great quantity of them is required.

B R O W N S.

Cullens-Earth,

I S a fine dark brown. After ſix or eight of the ſimple crayons are prepared, ſeveral rich compound tints may be produced from it, by a mixture with carmine, in various degrees; black, carmine, and this colour, mixed together, make uſeful tints for painting hair; ſeveral gradations may be produced from each of theſe by a mixture with whiting Roman, and brown oker are excellent colours, either ſimple or compounded with carmine. Whiting tinged, in ſeveral degrees,

degrees, with either of theſe, will prove very ſerviceable in painting; common ſea-coal, ground and mixed with carmine, is a fine brown.

Umber

MAY be treated in the ſame manner as above, only it is neceſſary to levigate it with ſpirits of wine.

PURPLES.

PRUSSIAN blue ground with ſpirits, and mixed with pulverized lake, will produce a good purple. Carmine thus mixed with Pruſſian blue, will produce a purple ſomething different from the former. Various tints may be made from either of theſe compounds, by a mixture with whiting.

BLACK.

Lamp-Black

IS the only full black that can be uſed with ſafety, as all others are ſubject to mildew; but as good lamp-black is very ſcarce, the ſtudent will, perhaps, find it moſt expedient to make it himſelf, the proceſs of which is as follows:

Provide a tin cone, fix it over a lamp at ſuch a height, that the flame may juſt reach the cone for the ſoot to gather

within it. When a ſufficient quantity is collected, take it it out, and burn all the greaſe from it in a crucible. It muſt then be ground with ſpirits, and laid on the chalk to abſorb the moiſture. Various grey tints may be formed from this by a mixture with whiting, as mentioned in former inſtances. Black chalk ground, is a very good blue black.

Carmine and black is another good compound, of which five or ſix gradations ſhould be made, ſome partaking more of the black, and others having the carmine moſt predominant, beſides ſeveral tints by a mixture with whiting.

Cinabar and black is alſo a very uſeful compound, from which ſeveral different tints ſhould be made.

Pruſſian blue and black is another good compound, and will be found of ſingular ſervice in painting draperies.

It is impoſſible to lay down rules for the forming every tint neceſſary in compoſing a ſet of crayons, there being many accidental compoſitions, entirely dependent on fancy and opinion. The ſtudent ſhould make it a rule to ſave the leavings of his colours, for of theſe he may form various tints, which will occaſionally be uſeful.

N, B. The Cologn or Cullen's earth, yellow oker, brown oker, Roman oker, Naples yellow, umber, black chalk, and ſea coal duſt, are all ſubject to throw out a white kind of ſalt, which will injure the picture, if the following method of treating them be not ſtrictly obſerved: grind them extremely fine with water, and ſeparately put them into a large glazed veſſel, filled with boiling water. After

the

the colour has been well ſtirred, leave it to precipitate; then pour off the water, which will take away the ſalts, and leave the colour excellently prepared for making crayons after it has been dried on the chalk-ſtone and pulverized.

Of rolling the Crayons, and diſpoſing them for Painting.

THE different compoſitions of colours muſt be cut into a proper magnitude after they are prepared, in order to be rolled into paſtils for the convenience of uſing them. Each crayon ſhould be formed in the left hand with the ball of the right, firſt formed cylindrically, and then tapered at each end. If the compoſition is too dry, dip the finger in water; if too wet the compoſition muſt be laid upon the chalk again, to abſorb more of the moiſture. The crayons ſhould be rolled as quick as poſſible; and when finiſhed, muſt be laid upon the chalk again, to abſorb all remaining moiſture. After the gradation of tints from one colour are formed, the chalk and the grinding-ſtone ſhould be well ſcraped and cleanſed with water before it is uſed for another colour.

When the ſet of crayons is compleated according to the rules preſcribed, they ſhould be arranged in claſſes for the convenience of painting with them. Some thin drawers, divided into a number of partitions, is the moſt convenient method of diſpoſing them properly. The crayons ſhould be depoſited according to the ſeveral gradations of light. The bottom of the partitions muſt be covered with bran, as a bed for the colours, becauſe it not only preſerves them clean, but prevents their breaking.

 The

The box made ufe of when the ftudent paints, fhould be about a foot fquare, with nine partitions. In the upper corner, on the left hand, (fuppofing the box to be in the lap when he paints) let him place the black and grey crayons, thofe being the moft feldom ufed; in the fecond partition, the blues; in the third, the greens and browns; in the firft partition on the left hand of the fecond row, the carmines, lakes, vermilions, and all deep reds; the yellows and orange in the middle, and the pearly tints next; and as thefe laft are of a very delicate nature, they muft be kept very clean, that the gradations of colour may be eafily diftinguifhed: in the loweft row, let the firft partition contain a piece of fine linen rag to wipe the crayons with while they are ufing; the fecond, all the pure lake and vermilion tints; and the other partition may contain thofe tints, which, from their complex nature, cannot be claffed with any of the former.

Receipts for thofe who paint in Water-Colours.

Two Methods to make Gum-Water.

1. DISSOLVE one ounce of pure white gum-arabic, and half an ounce of double-refined fugar, in a quart of fpring water; ftrain it through a fine fieve or a piece of muflin, and bottle it off for ufe, keeping it free from duft.

2. Take fome gum-arabic of the whiteft fort, bruife it, and tie it up in a piece of woollen-cloth, and fteep it in fpring water in a glafs or earthen veffel, till it be diffolved. If it be too ftiff, add more water; and if too thin, more gum.

With

With this water you may temper moſt of your colours; uſing ſuch a quantity, that being touched when dry, the colour will not come off. If the colour ſhines, there is too much gum in it.

To make Liquid Gold for Vellum Painting, &c.

GRIND the fineſt leaf-gold with ſtrong gum-water very fine, adding as you grind it more gum-water as you ſee neceſſary. When you have ground it as fine as you can, waſh it in a large ſhell; then temper it with a little mercury-ſublimate, bind it in the ſhell with a little diſſolved gum, ſhake and ſpread it equally all over the ſhell, and uſe it with fair water only. Thoſe who do not chuſe to make, may buy the ſhells ready prepared, at the colour ſhops, at a very low price.

To make Liquid Silver for the ſame Purpoſe.

THE proceſs for this is the ſame with that of liquid gold, only obſerving in the uſing it to temper it with glare of eggs inſtead of water.

To make the Glare of Eggs.

TAKE the whites, and beat them with a ſpoon till they riſe in a foam; let them ſtand all night, and they will be clarified into good glare.

Of Colours proper for washing Maps.

COLOURS for washing maps may be made by boiling different kinds of wood, and staining substances, as logwood, Brazil, cochineal, madder, turnsal, &c.

To keep the Colours from sinking.

BOIL four ounces of roach-allum in a pint of spring water, till it is thoroughly dissolved; then filter it through brown paper, and keep it for use.

Before you lay on your colours, take a sponge, and wet the back of your paper with this water while it is hot. This will not only prevent the colours from sinking, but will likewise give them an additional beauty and lustre, and preserve them from fading. If your paper is not good, it must be washed three or four times with this water, drying it every time.

To make Size for painting Scenes, and other Candle-Light Pieces,

STEEP a quarter of a pound of the cuttings of white glove-leather in water for some time: then take them out, and boil them in three quarts of water, till it wastes to a pint, and strain it through a cloth into an earthen pan. When the size is cold, if it feel firm under your hand, it is strong enough. You may prepare any colours in this size while it is warm, and it will take of the glare which would

appear

appear upon them by candle-light, if mixed with gum-water.

How to make a Compoſition to waſh Braſs ſo as to look like Silver.

TAKE ſilver, or gold-lace, half an ounce, add thereto one ounce of double refined aquafortis, put them in an earthen pot, and place them over a gentle fire till all be diſſolved, which will happen in about five minutes; then taſte it off, and mix it in a pint of clear water, after which, pour it into another clean veſſel to free it from grit or ſediment; and then add a ſpoonful of ſalt, and the green water will immediately let go the ſilver particles, which will form themſelves into a white curd; then pour off the water, and throw it away, for it is of no further uſe. The white curd muſt then be mixed with two ounces of ſalt of tartar, half an ounce of whiting, and a large ſpoonful of ſalt, more or leſs, according as you find it for ſtrength. Mix it well up together, and it is ready for uſe.

How to Silver Braſs, &c.

HAVING well cleared the braſs from all ſcratches (otherwiſe it will ſpoil its appearance) rub it over with a piece of old hat and rotten-ſtone, to clear it from all greaſineſs, then rub it with ſalt and water with your hand; then take a little of the before-mentioned compoſition on your finger, and rub it over where the ſalt has touched, and it will adhere to the braſs, and appear as well as ſilver; after which, waſh and ſteep it in plenty of clear water, to kill the

the aquafortis which remained in the compofition; and, when dried with a clean hot rag, it is then ready to be varnifhed.

To make white Varnifh for Brafs.

TAKE fpirits of wine (highly rectified) one pint, which, divide into four parts; then mix one part with half an ounce of gum maftic, in a phial by itfelf, one part fpirits, and half an ounce of gum fandarach in another phial, one part fpirits, and half an ounce of the whiteft parts of gum benjamin; then mix and temper them to your mind. No rule can further inftruct you, unlefs the quality of the gums and fpirits could be afcertained. It would not be amifs to add a very little bit of white rofin, or clear Venice turpentine, in the maftic bottle, it will affift in giving a glofs: if your varnifh fhould prove ftrong and thick, add clear fpirits, if too hard, pour from the maftic bottle, if too foft, a little from the fandarach, or benjamin. When you have brought it to a proper temper and ready for ufe, warm the filvered (if a clock face, not too hot as to melt the wax) before the fire, or upon a hot heater, and with a flat camel's-hair brufh, or clean linen rag lapped up, and dipped in the varnifh, ftroke it quickly over, until no white fhades appear, and it will preferve the filver on many years.

To make Pulvis Fulminans, or Thunder Powder.

MIX three parts of falt petre, two parts of falt of Tartar, and one part of flowers of fulphur well together; put the

the compofition into a bottle and cork it well to prevent the air from fpoiling it, and it is ready for ufe.

When you ufe it, take as much as will lay upon a fhilling, and putting it upon a fire fhovel over a gentle fire, it will prefently begin to ferment, and will make a horrible explofion like that of a gun. This experiment generally produces much diverfion, efpecially when ignorant perfons are employed to hold the fhovel. I never knew an inftance of its doing any harm, when no more than the above quantity was ufed at once.

To cleanfe Mercury by Aquafortis.

PUT your mercury in a ftrong glafs bottle, with a little clean fand, and fhake it well for fome time, after which pour it into a bafon, and add thereto as many half ounces of double refined aquafortis, as you have pounds of mercury; let the aquafortis evaporate away, and it is then fit for ufe.

To refine Mercury if mixed with other Metals.

MAKE an iron ball A, as reprefented Plate IV. Fig. 1. that is hollow, and will fcrew in two halves in the middle; to one half muft be fixed a pipe B, bended for the convenience of going into a veffel of water, then put your metal in, and fcrew it up, and place it on the fire, and the mercury will evaporate from the ball along the pipe into the veffel of water C, and leave all the dregs behind.

A general deſcription of making Thermometers.

1. BEING well provided with tubes, with bottles at the end of them, provide ſome good ſpirits of wine, with alkanate root, and put it in the baſon, Fig. 2; then take the inſtrument, Fig. 3, which is a large iron tube, heat it red hot, and with a pair of tongs lay hold of it at A, and immerſe the ball A, and tube, Fig 2, into it while hot, and it will drive the air out of the ball; then immediately immerſe it into the baſon, and the ſpirits will aſcend into the ball and fill it. If it ſhould not be quite full the firſt operation; it may be done a ſecond or third time.

How to fill a Tube with Mercury.

TAKE a tube, Fig. 4, and lap a paper funnel on the top of it, and pour mercury into it, until it covers the top B; then heat it as before, with the mercury in it, and the air will aſcend, and, as it were, ſeem to boil through the mercury; when obſerve as ſoon as it has done boiling, take it out of the inſtrument, Fig. 3, and the mercury will deſcend into the ball, until it be quite full; after which ſet it to cool, to ſuch a degree of denſity, that the mercury will not ſettle into the ball in extreme froſt; then, by heating it a little, you may throw out as much ſuperfluous mercury as you find ſufficient; afterwards hermetically ſeal it with your blow-pipe and lamp, and it is ready to be applied to a ſcale.

Farenheit's ſcale is moſt generally in uſe, and the remarkable periods of heat are as follows: 212 water boils, 175 ſpirits of wine boils, 112 fever heat, 98 blood heat,

76 fummer heat, 55 temperate, 32 water freezes, 27 vinegar freezes, 20 ftrong wines freezes, 0 the degree of cold produced by mixing fnow and falt, (fee fcale Fig. 5) When you have filled your ball and tube to your fatisfaction, before you hermetically feal the end, put the ball into boiling water and obferve how high it rifes; which part you muft mark with a file, to a very great exactnefs; then let it fettle to froft, or (if froft cannot be obtained) to the greateft degree of cold you can, according to another good thermometer; which point alfo mark exactly; after which divide the intermediate points, and continue them downwards as in the fcale, according to their refpective places, then heat the mercury in the ball, until it has forced all the air out of the tube, at which time inftantly feal it by a blow pipe and lamp. In order to facilitate the procefs of fealing the tube, it will be neceffary to obferve, that the end of the tube fhould be drawn out as fmall as a hair, by means of a blow-pipe and lamp; when the mercury is forced by heat up to that fmall part, applying the flame of a candle to the end at that time, will feal it without the help of a blow-pipe.

Thofe who defire a more accurate defcription of the different fcales, may be well inftructed in Martine's treatife on the fcales of thermometers; it would be quite too copious to be inferted here.

To make Silver Solder.

MELT fine filver two parts, brafs one part; don't keep them long in fufion, left the brafs fly away in fumes.

Another for coarser Silver.

MELT four parts of fine ſilver, and three of braſs, throw in a little borax, and pour it out as ſoon as it is melted.

A Solder for Gold.

MELT copper one part, fine ſilver one part, and gold two parts; add a little borax when it is juſt melted, then pour it out immediately.

The Method of Soldering Gold or Silver.

AFTER the ſolder is caſt into an ingot, it would be more ready for uſe if you were to draw it into ſmall wire, or flat it between two rollers; after that cut it into little bits, then join your work together with fine ſoft iron wire, and with a camel's-hair pencil dipt in borax, finely powdered, and well moiſtened with water, touch the joint intended to be ſoldered; placing a little ſolder upon the joint, apply it upon a large piece of charcoal, and with a blow pipe and lamp, blow upon it through the flame until it melts the ſolder, and it is done.

To cleanſe Silver after it is Soldered.

MAKE it juſt red hot, and let it cool, then boil it in allum water, in an earthen veſſel, and it will be as clean

clean as when new. If gold, boil it in urine, and ſal-armoniac.

A Soldrr for Lead.

TWO parts lead and one part tin, its goodneſs is tried by melting it, and pouring the bigneſs of a crown piece upon the table; for if it be good, there will ariſe little bright ſtars in it. Apply roſin when you uſe this ſolder.

A Solder for Tin.

TAKE four parts pewter, one of tin, and one of biſmouth, melt them together, and run them into narrow thin lengths, and it is done.

A Solder for Iron.

NOTHING here is neceſſary but good tough braſs, with borax applied, mixed with water, to the conſiſtence of paſte.

A Cement uſeful for Turners.

TAKE roſin one pound, pitch four ounces, melt theſe together, and while boiling hot, add brick-duſt, until by dropping a little upon a ſtone you perceive it hard enough; then pour it into water, and immediately make it up in rolls, and it is fit for uſe.

Another

Another finer than the laſt.

TAKE roſin one ounce, pitch two ounces, add red oker, finely powdered, until you perceive it ſtrong enough, and it is done.

Either of theſe cements are of excellent uſe to turners, by applying to the ſide of a chock, and making it warm before the fire, you may faſten any thin piece of wood, which will hold while you have turned it, by the cement: when you want it off again, ſtrike it on the top with your tool, and it will drop off immediately.

A Cement for broken Pots, Glaſſes, &c.

TAKE quick lime, glare of eggs, and old thick varniſh; grind and temper temper well together, and it is ready for uſe.

A ſtrong Cement for Electrical Purpoſes.

MELT one pound of roſin in a pot or pan, over a ſlow fire, add thereto, as much plaſter of Paris, in fine powder, as will make it hard enough, which you may ſoon know by trial; then add a ſpoonful of linſeed oil, ſtirring it all the time, and try if it be hard and tough enough for your purpoſe, if it is not ſufficiently hard, add more plaſter of Paris, and if not tough enough, a little more linſeed oil.

N. B.

N. B. I believe this to be as good a cement as is poſſible to be made for fixing the necks of globes, or any thing which is wanted ſtrongly fixed, for it is not very eaſy to melt again when cold.

Another ſofter than the former.

TAKE roſin, one pound, bees-wax one ounce, add thereto as much red oker as will make it of a ſufficient ſtiffneſs, pour it into water, and make it into rolls, and it is fit for uſe. This cement is uſeful in cementing braſs hoops on glaſſes, or any other mounting of electrical apparatus.

A Cement for Glaſs-Grinders.

TAKE pitch and boil it, add thereto, and keep ſtirring it all the while, fine ſifted wood aſhes, until you have it of a proper temper; the addition of a little tallow may be added as you find neceſſary.

Another for ſmall Work.

TAKE ſix parts roſin, and one of bees-wax, melt them together, and if too ſoft, add more roſin, if too hard, add more bees-wax, &c.

A Cement or Glue, that will hold very ſtrongly, either againſt Heat or Moiſture.

MIX and boil linſeed oil and quick lime together, till they become very thick; then pour them out, and make them into rolls or cakes, and they will prove very uſeful, applied to many purpoſes.

A good Glue for Sign Boards, or any Thing that muſt ſtand the Weather.

MELT common glue with water, to a proper conſiſtence; then add linſeed oil, with a little red lead, more or leſs, as you ſee occaſion, and it will anſwer the purpoſe exceeding well.

To make a fine Glue, wherewith you may caſt curious Medals.

STEEP iſinglaſs in brandy, and when it is diſſolved, boil it together with water, and ſpread it over any medal, and when dry, it will appear perfect. It muſt be of a tolerable thick conſiſtence, much like common glue.

To ſtain Wood Red.

TAKE archal one pound, add 1-4th oil of vitriol, and it is ready for uſe; to make it ſtrike deeper, add a little more oil of vitriol.

To Stain Blue.

DISSOLVE indigo, well bruiſed, one ounce, in a pound of oil of vitriol, ſet it near the fire for two or three days, keep ſtirring it about with a ſtick, then let it down to what ſtrength you pleaſe with water.

Yellow.

GAMBOGE or turmeric diſſolved in oil of vitriol.

A black Stain for Wood.

HEAT a ſteel-bar very hot, take it out of the fire, and ſmear it over with brimſtone, which will diſſolve a part of the ſurface; ſcrape it off, and repeat this operation till all the ſteel is quite diſſolved (or at leaſt as much as you intend to uſe) then beat it to a fine powder, and incorporate it with very ſtrong alegar or vinegar; add thereto blue nut galls, and a little copperas and allum; but before you lay the ſtain on, it will be proper to ſtrike it over with boiling hot logwood water.

To ſtain Green.

DISSOLVE gamboge in water; add of the blue ſtain to it as you ſee occaſion. N. B. All the wood muſt be very white.

Blue Ink.

A little of the blue ſtain tempered with water, with the addition of a little gum arabic.

To make a good common Ink.

IN four parts of water or beer let a pound of bruiſed galls be infuſed twenty-four hours without boiling; to this add ſix ounces of gum arabic; and when the gum is diſſolved, ſix ounces of green vitriol, which will ſoon give it the black colour; the liquor is then to be ſtrained through a hair ſieve.

Inks of all colours may be made by uſing a ſtrong decoction of the ingredients uſed for dying, mixed with a little allum and gum arabic. For example, a ſtrong decoction of brazil wood, with as much allum as it can diſſolve, and a little gum arabic to give it body and ſome conſiſtence, forms a beautiful red ink; other ingredients may be added, viz. ſpirits to keep it from freezing, &c.

A Compoſition for Ornaments.

TAKE pounded chalk, what quantity you pleaſe, add thereto as much thin glue as will make it into paſte, which mix well together; then put it into moulds, being a little oiled, and preſs it well in, after which, take it out, and it will grow as hard as ſtone. N. B. You muſt make no more of the compoſition than you want for preſent uſe,

for

or if it be left till it grows hard, it cannot be worked again.

To prove Spirits of Wine, whether they are fit for Varniſh.

TAKE ſome in a ſpoon, and put a little gunpowder in it, after which ſet it on fire with a candle or lighted paper; and if it fire the gunpowder when it has burnt itſelf dry, it may be depended on as good; if not, it is not fit for varniſh at all. The leſs of watery parts are in the varniſh, the ſooner it dries, and is fit for poliſhing; it alſo is more permanent, and will come to a better gloſs.

To make Seed-lac Varniſh.

TAKE ſpirits of wine, one quart; put it in a wide mouthed bottle, and add thereto eight ounces of ſeed-lac, which is large grained, bright, and clear, free from dirt and ſticks; let it ſtand two days or longer in a warm place, often ſhaking it. Strain it through a flannel into another bottle, and it is fit for uſe.

To make Shell-lac Varniſh.

TAKE good ſpirits of wine one quart, eight ounces of the thinneſt and moſt tranſparent ſhell-lac, which, if melted in the flame of a candle, will draw out in the longeſt and fineſt hair; mix and ſhake theſe together, and let them ſtand in a warm place for two days, and it is ready for uſe. This varniſh is ſofter than that which is made of ſeed-lac,

therefore is not ſo uſeful; but may be mixed with it for varniſhing wood, &c.

To make a Lacker for Braſs.

TAKE eight ounces of ſpirits of wine, and one ounce of arnotto, well bruiſed, mix this in a bottle by itſelf; then take one ounce of gamboge, and mix it in like manner to the ſame quantity of ſpirits: alſo bruiſed ſaffron, ſteeped in ſpirits to nearly the ſame proportion; after this take ſeed-lac varniſh, what quantity you pleaſe, and you may brighten it to your mind by the above mixture: if it be too yellow, add a little more from the arnotto bottle; and if it be too red, add a little more from the gamboge or ſaffron bottle; if too ſtrong, add a little ſpirits of wine, &c. thus you may temper lacker or varniſh to what degree of perfection you pleaſe.

To caſt Vegetables, Inſects, ſmall Birds, Frogs, Fiſh, &c. in Plaſter Moulds.

PROVIDE a trough of boards, nailed together ſo as not to let water run through the joints; ſuſpend in the trough by thread or Holland twine in ſeveral places, the vegetable plant, inſect, &c. which you would caſt; which being performed, mix four parts plaſter of Paris and two parts of fine brick duſt with common water to the conſiſtence of cream, and with this cover the thing intended to be caſt, obſerving not to diſtort it from its natural poſition if poſſible; when you have filled your trough, let it harden by placing it near the fire by degrees, till you can make it red hot; then let it

cool

cool, and with a pair of bellows, blow and ſhake as much of the aſhes out of the mould as you can: you muſt now put a ſmall quantity of quickſilver into the mould, and ſhake it in order to looſen every part of the aſhes therein, alſo to make a paſſage through where the ſtrings were tied in order to let the air out, when you pour in your metal.

To prepare a Metal for the above Work.

TAKE of grain tin 6, biſmuth 2, and lead 3 ounces; melt them together in an iron ladle, and you may caſt in the above mould to your ſatisfaction.

You may combine the above ingredients in ſuch proportions as to compoſe a metal which will melt in boiling water.

To caſt Convex or Concave Moulds of Medals on Tinfoil with Plaſter of Paris.

TAKE a medal, &c. and cover it with very thin tinfoil, which preſs as cloſe to the medal as you can; go over every part with a bruſh, laying on tolerably hard, in order to preſs the tinfoil into every cavity of the medal, after which you may pour prepared plaſter upon it; and when it is hard, take the medal out, leaving the tinfoil in the plaſter; then with a little fine olive oil, anoint the tinfoil and the plaſter where it muſt part, and pour more plaſter upon the tinfoil, which alſo let harden; you may then ſeparate them, and take out the tinfoil, and you will have both a convex and concave mould.

Chemical

Chemical Tranſcolourations.

AMONG the moſt pleaſing as well as ſurpriſing phenomena of nature may be juſtly ranked the tranſcolourations produced by chemiſtry, and thoſe are the more pleaſing in general which are moſt eaſily executed.

Colours produced by the Mixture of colourleſs Fluids.

Red. Spirits of wine mixed with ſpirit of vitriol.

Orange. Solution of mercury mixed with oil of tartar.

Yellow. Solution of ſublimate and lime water.

Green. Tincture of roſes and oil of tartar.

Purple, Solution of copper and ſpirit of ſal ammoniac.

Blue. Tincture of roſes and ſpirit of wine.

White. Solution of ſublimate and ſpirit of ſal ammoniac.

Black. Solution of ſugar of lead and ſolution of vitriol.

Colours

Colours produced by the mixture of coloured Fluids.

Green. Tincture of ſaffron, which is yellow, mixed with tincture of red roſes.

Crimſon. Tincture of violets, which is blue, and ſpirit of ſulphur, which is brown.

Blue. Tincture of red roſes, which is red, and ſpirit of hartſhorn, which is browniſh.

Purple. Tincture of violets, which is blue, and ſolution of Hungarian vitriol, which is blue.

Violet. Tincture of violets, which is blue, and ſolution of copper, which is green.

Green. Tincture of cyanus (blue bottle flower) which is blue, and ſpirit of ſal ammoniac coloured blue.

Yellow. Solution of Hungarian vitriol, which is blue, and lixivium, which is brown.

Black. Solution of Hungarian vitriol, which is blue, and tincture of red roſes.

Red. Tincture of cyanus, which is blue, and ſolution of copper which is green.

Colours

Colours changed and reſtored.

SOLUTION of copper, which is green, is made colourleſs by ſpirit of nitre; and is reſtored again by oil of tartar.

Limpid infuſion of galls is made black by a ſolution of vitriol, and *tranſparent* again by oil of vitriol; and then black again by oil of tartar.

Tincture of red roſes is made black by a ſolution of vitriol, and becomes red again by oil of tartar.

A ſlight tincture of red roſes, by ſpirit of vitriol, becomes a fine red; then, by ſpirit of ſal ammoniac turns green; and then by oil of vitriol becomes red again.

Solution of verdegris which is green, becomes colourleſs by ſpirit of vitriol; then by ſpirit of ſal ammoniac becomes purple; and then by oil of vitriol becomes colourleſs again.

Take antimony and grind it to powder, and it will become black. Let it be calcined with aqua regia, and it will be of a greeniſh yellow; and when ſublimed with ſal ammoniac it will be white, red, yellow, greeniſh, and black; of an uniform red, when freed from its ſalt by water; but white when fixed with thrice its weight of nitre. Thus may be ſeen almoſt all the colours in one ſolid body.

Mercury

Mercury diſſolved by aquafortis, and diſtilled in a glaſs retort, affords likewiſe in different parts of the glaſs, a variety of colours.

To turn an almoſt limpid liquor blue: pour ſpirits of ſal-ammoniac to a ſolution of verdegris in vinegar, and dilute it with water till it be almoſt limpid. To turn that blue liquor pellucid, add an acid to it, till the acid predominant.

To turn a very green liquor of a beautiful *violet* colour: to a high green ſolution of copper in vinegar, drop ſpirit of of ſal-ammoniac till the alkali predominate.

To produce numerous *blues* and *greens* between a *deep* blue and a *deep* green: put a ſtrong and hot ſolution of copper in ſal-ammoniac, into a clean cylindrical glaſs, and add thereto, ſlowly, ſpirits of nitre, drop by drop. A different colour between the two degrees, will appear upon the addition of each drop.

Several of the above compoſitions when put in glaſs globes, and placed in a window with lamps behind them make beautiful illuminations.

Sympathetic Inks.

By ſympathetic inks is meant thoſe ſort of liquors with which any characters being written they remain inviſible, till ſome method is uſed to give them a colour. There are a great number of compoſitions for performing

the above, but I ſhall only mention a few, ſufficient to give a general idea of their nature and uſe.

1. Take one ounce of litharge of lead, incorporate it with twice the quantity of ſtrong diſtilled vinegar, and let it ſtand twenty four hours. Then ſtrain it off, and let it remain till it be quite ſettled. Preſerve this liquor in a bottle.

2. Take one ounce of orpiment in powder, add thereto two ounces of quick lime, put the ingredients into a pint bottle with as much water as will ſtand two fingers above them. Place the bottles in a warm place, and in twenty four hours the water will be ſtrongly impregnated; then pour the liquor gently off, and put it in a bottle well corked, and it is ready for uſe.

In preparing theſe liquors you muſt take care that they have no communication; for the vapour of the latter is ſufficient to deſtroy the limpidity of the former, and thereby render it unfit for uſe.

When you write with the former ink the letters will be inviſible, until you expoſe the vapours of the ſecond; thus you may read what was written as plain as if written with ink.

Another Sympathetic Ink.

1. Diſſolve green vitriol in common water, and add a ſmall quantity of nitrous acid, to prevent that yellowiſh precipitation that will otherwiſe be formed. The charecters wrote in this diſſolution with a new pen will be inviſible.

2. Infuſe

2. Infuſe in three fourths of a pint of water, or white wine, two ounces of ſmall aleppo galls, and at the end of two or three days pour the infuſion off: thus by drawing a pencil dipped in this infuſion over the letters wrote with the laſt diſſolution, they will appear of a beautiful black, eſpecially if the infuſion be ſtrong.

The letters wrote with the laſt diſſolution will become a fine blue; if they be wetted with water ſaturated with Pruſſian blue: and letters wrote with this water, which will be inviſible, will likewiſe turn to a fine blue, by being wetted with the above diſſolution.

Directions for making the beſt Compoſitions for the Metal of reflecting Teleſcopes; together with a Deſcription of the Proceſs for grinding, poliſhing, and giving the great Speculum the true parabolic curve.

THE perfection of the metal of which the ſpeculum ſhould be made, conſiſts in its hardneſs, whiteneſs, and compactneſs: for upon theſe properties, the reflective powers and durability of the ſpeculum depend.

The beſt compoſition for the Specula of reflecting Teleſcopes is as follows:

Take good Swediſh copper two pounds, and when melted, add fourteen ounces and a half of grain into it; then having taken off the ſcoria, caſt it into an ingot. This metal muſt be a ſecond time melted to caſt a ſpeculum; but it will fuſe in the compound ſtate with a ſmall heat, and therefore will not calcine the tin into putty; it ſhould be poured off as ſoon as it is melted, giving it no more

heat that is abfolutely neceffary. It is to be obferved, however, that the fame metal, by frequent melting, lofes fomething of its hardnefs and whitenefs; when this is the cafe, it becomes neceffary to enrich the metal by the addition of a little tin, perhaps in the proportion of half an ounce to a pound. And indeed when the metal is firft made, inftead of adding the fourteen ounces and a half of tin to the two pounds of melted copper, about one ounce of the tin were to be referved and added to it in the fucceeding melting, before it is caft off into the moulds the compofition would be more beautiful, and the grain of it much finer: this I know by experience to be the cafe.

The beft method for giving the melted metal a good furface is this: the moment before it is poured off, throw into the crucible a fpoonful of charcoal duft; immediately after which, the metal muft be ftirred with a wooden fpatula, and poured into the moulds.

The metal being caft, there will be no occafion for a complicated apparatus for grinding and polifhing it. Four tools are all that are neceffary, viz. the rough grinder to work off the rough face of the metal, a brafs convex grinder, on which the metal is to receive its fpherical figure; a bed of hones which is to perfect that figure, and to give the metal a fine fmooth face; and a concave tool or bruifer with which both the brafs grinder, and the hones are to be formed. A polifher may be confidered as an additional tool; but as the brafs grinder is ufed for this purpofe, and its pitchy furface is expeditioufly, and without difficulty formed by the bruifer, the apparatus is therefore not enlarged.

Of

Of Rough Grinding the Speculum.

THE tool by which the rough ſurface of the metal is rendered ſmooth and fit for the hones, is beſt made of lead, ſtiffened with about a fifth or ſixth part of tin. This tool ſhould be at leaſt a third more in diameter than the metal which is to be ground; and for one of any ſize not leſs than an inch thick. It may be cemented upon a block of wood, in order to raiſe it higher from the bench.

This leaden tool being caſt, it muſt be fixed in the lathe, and turned as true as it is poſſible, by the gage, to the figure of the intended ſpeculum, making a hole or pit in the middle as a lodgment for the emery, of about an inch diameter for a metal of four inches: when this is done, deep grooves muſt be cut acroſs its ſurface with a graver, in the manner repreſented. Plate XVII, of the Introduction to Uſeful Knowledge, Fig. 3.

Theſe grooves will ſerve to lodge the emery, and by their means the tool will cut a great deal faſter. There is no occaſion to fear any alteration in the convexity of this tool by working the metal upon it, for the emery will bed itſelf in the lead, and ſo far arm the ſurface of it, that it will preſerve its figure and cut the metal very faſt. Any kind of a low handle, fixed on the back of the metal with ſoft cement will be ſufficient; but it ſhould cover two thirds of its back to prevent its bending. This way of working will cut the metal tolerable faſt, and with more truth than any other method yet deſcribed.

When

When all the ſand-holes and irregularities on the face of the metal are ground off, and the whole ſurface is ſmooth and regularly figured, the ſpeculum is then ready for the braſs grinder, and muſt be laid aſide for the preſent.

The Manner of forming the Braſs grinding Tool.

Procure a round ſtout piece of Hamburgh braſs, at moſt, a ſixth part larger than the metal to be poliſhed, and let it be well hammered into a degree of convexity (by the aſſiſtance of a gage) ſuitable to the intended ſpeculum. Having done this, ſcrape and clean the concave ſide ſo thoroughly, that it may be well tinned all over; then caſt upon it, after it has been preſſed a proper depth into the ſand, the former compoſition of tin and lead, in ſuch quantity, that it may (for a ſpeculum of four inches diameter), be at leaſt an inch and an half thick, and with a baſe conſiderably broader than the top, in order that it may ſtand firmly upon the bench, in the manner hereafter to be deſcribed. This being done, it muſt be fixed and turned in the lathe with great care, and of ſuch a convexity as exactly to ſuit the concave gage, which we ſuppoſe already made. It will be neceſſary to be more careful in forming this than the former tool, and eſpecially that no rings be left from the turning, nor will the ſucceeding hone tool require ſo much exactneſs, as any defects in turning, will, by a method hereafter mentioned, be eaſily remedied; but any inequality or want of truth in the braſs tool, will occaſion a great deal of trouble before it can be ground out by the emery. This tool muſt have a hole (ſomewhat leſs than that of the metal to be worked upon it), in the middle, quite through to the bottom.

When

When this tool is finifhed off in the lathe, its diameter fhould be one eighth wider than the metal.

How to form the Bed of Hones, or third Tool.

HAVING chofen the beft blue-ftone, fuch as clock-makers ufe in polifhing up their work (taking great care that there be no red veins in it, for fuch veins are generally hardeft, therefore, will prevent its wearing equal) it muft be then cemented to a piece of ftone, or metal; if the blue-ftone cannot be procured, as large as is required, in one piece, it may be joined together with cement, the fize required; after which, you muft faw it into $\frac{3}{8}$ inch fquares, and about one eighth of an inch below the face of the ftone, in order to carry off what wears off the ftone, and likewife what grinds off the metal. The bed of hones fhould be one fourth part larger than the metal which is ground upon it, and turned as true as poffible to the gage in a turner's lathe.

The Manner of forming the Bruifer, the fourth and laft Tool.

THIS tool fhould be likewife made of thick ftout brafs, like the former, perfectly found, about a quarter of an inch thick, and hammered as near to the gage as poffible. It fhould be then fcraped, cleaned, and tinned on the convex fide, as the former tool was on the concave, and the fame thicknefs of lead and tin caft upon it. The general fhape of this fhould differ from the former; for as that increafed in diameter at the bottom for the fake of ftanding firmly,

fo

ſo this ſhould be only as broad at bottom as at top, as it is to be uſed occaſionnally in both theſe poſitions. When this tool is fixed in the lathe, and turned off concave to the convex gage with great truth; its diameter ought likewiſe to be the middle ſize between the hones and the poliſher.

Having with the lathe roughly formed the convex braſs grinder, the beds of hones, and the concave bruiſers, the convex and concave braſs tools, and the metal, they muſt be wrought alternately and reciprocally upon each other, with fine emery and water, ſo as to keep them as nearly to the ſame figure as poſſible, in order to which, ſome waſhed emery muſt be procured. This is beſt done by putting it into a phial, which muſt be half filled with water, and well ſhaken up, ſo that, as it ſubſides, the coarſeſt may fall to the bottom firſt, and the fineſt remain at the top: and whenever freſh emery is laid on the tools, the beſt method (which we ſhould always obſerve with the putty in poliſhing), will be to ſhake the bottle gently, and pour out a ſmall quantity of the turbid mixture.

Of grinding the Speculum, the Braſs Tool, and the Bruiſer together.

All the tools being ready, upon a firm poſt in the middle of a room, you are to begin to grind the convex tool with the bruiſer upon it, working the latter croſs-ways with ſtrokes ſometimes acroſs its diameter, at others a little to the right and left, and always ſo ſhort, that the bruiſer may not paſs above half an inch within the ſurface of the braſs tool, either way, ſhifting the bruiſer round its

axis

axis every half dozen ſtrokes, or thereabouts. You muſt likewiſe every now and then, ſhift your own poſition, by walking round, and working at different ſides of the braſs tool, at the times the ſtrokes ſhould be carried round and round, but not much over the tool: in ſhort, they muſt be directed in ſuch a way, and the whole grinding conducted in ſuch a manner, and with ſuch equability, that every part of both tools may wear equally. This habit of grinding, as well as the future one of poliſhing, may be ſoon acquired.

When you have wrought in this manner about a quarter of an hour with the bruiſer upon the tool, it will be then neceſſary to change them, and, placing the bruiſer upon its bottom, to work the convex tool upon that in the ſame manner.

When by working in this equable manner alternately with the bruiſer and tool, and occaſionally adding freſh emery, you have nearly got out all the veſtiges of the turning tool, and brought them both nearly to a figure, it will be then time to give the ſame form to the metal. This muſt be done by now and then grinding it upon the braſs tool with the ſame kind of emery, taking care however, by working the two former tools frequently together, to keep all three exactly in the ſame curve. The beſt kind of handle for the metal is made of lead, a little more than double its thickneſs, and ſomewhat leſs in diameter, of about three pounds weight, with a hole in the middle a little larger than that in the metal: this handle ſhould be cemented on with pitch. The upper edge of this weight muſt be rounded off, that the fingers may not be hurt; and a groove

 about

about the bignefs of the little finger, be turned round juft below it, for the more conveniently holding and taking the metal off the tools.

The Manner of figuring the Metal upon the Hones.

WHEN the bruifer, brafs tool, and metal, are all brought to the fame figure, and have all a good furface, the next part of the procefs is to give a correct fpherical figure, and a fine face to the metal, upon the hones. It will be neceffary to premife, however, that the hones fhould be placed in a veffel of water, with which they fhould be quite covered for at leaft an hour before they are ufed, otherwife they will be perpetually altering their figure when the metal comes to be ground upon them. The fame precaution is alfo neceffary, if you are called off from your work while you are grinding the metal, for if they be fuffered to grow dry, the fame inconvenience will arife.

In order to give a proper figure to the hones, and exactly fuitable to that of the brafs tool, bruifer, and metal when the hones are fixed down to the block, fome common flour of emery (unwafhed), with a good deal of water, muft be put upon them, and the bruifer being placed upon the hones, and rubbed thereon with a gentle ftroke and a light hand, the inequalities of the ftone will be quickly worn off; but as a great deal of mud will be fuddenly generated, it muft be wafhed off every quarter of a minute, with a great deal of water. By a repetition of this two or three times, the hones (being of a foft and friable fubftance), will be cut down to the figure, without much wearing or altering

altering the bruifer. Though bufinefs may be quickly done, and can be continued but for a few ftrokes at a time; I need not fay, that it is neceffary that thofe ftrokes be carried in the fame direction, and with the fame care which was obferved in grinding the two former tools together.

As foon as the hones have received the general figure of the bruifer, and all the turning ftrokes are worn out from them, the emery muft be carefully wafhed off; in order to which, it will be neceffary to clear it from the joints, with a brufh, under a ftream of water. The bruïfer and metal muft be likewife cleared in the fame manner, and with equal care, from any lurking particles of emery.

The hones being fixed down to the block, you now begin to work the bruifer upon them, with very cautious, regular, fhort ftrokes, forward and backward, to the right and left, turning the axis of the bruifer in the hand while you move round the hones, by fhifting your pofition, and walking round the block. Indeed the whole now depends upon a knack in working, which fhould be conducted nearly in the following manner: having placed the bruifer on the center of the hones, flide it in an equable manner forward and backward with a ftroke or two directly acrofs the diameter, a little on one fide, and fo on the other; then fhifting your pofition an eighth part round the block, and having turned the bruifer in your hand about as much, give it a ftroke or two round and round, but not far over the edges of the hones, and then repeat the crofs ftrokes as before: thofe round ftrokes (which ought not to be above two or three at moft) are given every time you fhift your

own pofition, and that of the metal, previous to the crofs ones, in order to take out any ftripes either in the hones or bruifer, which may be fuppofed to be occafioned by the ftraight crofs ftrokes .During the time of working, no mud muft be fuffered to collect upon the hones, fo as to deftroy the perfect contact between the two tools; and therefore they muft every now and then be wafhed clean, by throwing fome water upon them. When by working in this manner, all the emery ftrokes are ground off from the bruifer, and it has acquired a good figure and clean furface, you may then begin with the metal upon the hones, in the fame cautious manner, wafhing off the mud as faft as it collects, though that will be much lefs now than when the bruifer was ground upon them. Every now and then, however, the bruifer muft be rubbed gently and lightly upon the hones, which will as it were, by fharpening them, and preventing too great fmoothnefs, occafion them to cut the metal much fafter.

When, after having fome time cautioufly wrought in the manner before defcribed, the hone pavement has uniformly taken out all the emery ftrokes, and given a fine face and true figure to the metal, which will be pretty well known by the great equality there is in the feel while you are working, and by which an experienced workman will form a pretty certain judgment; having proceeded thus far, I fay, you may then try your metal, ,and judge of its figure by this more certain manner.

Work the hone-pavement quite clean; then put the metal upon the center of it, and give two or three light ftrokes round and round only, not carrying, however, the

edges

edges of the metal much over the hones; this will take out the order of ſtraight ſtrokes; then having again waſhed the hones, and placed the ſpeculum upon their center, with a gentle preſſure, ſlide it towards you, till its edge be brought a little over that of the hones; then carry it quite acroſs the diameter as far as the other ſide, and having given the metal a light ſtroke or two in this direction, take it off the tool. The metal being wiped quite dry, place it upon a table at a little diſtance from a window; ſtand yourſelf as near the window at ſome diſtance from the metal, and looking obliquely on its ſurface, turn it round its axis, and you will ſee at every half turn the grain given by the laſt croſs ſtrokes flaſh upon your eye at once, over the whole face of the metal. This is a certain proof of a true ſpherical fiugre For as there is nothing ſoft or elaſtic, either in the metal or in the hones, this glare is a certain proof of a perfect contact in every part of the two ſurfaces; which there could not be, if the ſpheres were not both perfect and preciſely the ſame.

Indeed there is one accidental circumſtance which neceſſarily affords its aid in this and every buſineſs of the like ſort; and this is, that a concave and convex ſurface ground together, though ever ſo irregular at firſt, will (if the working be uniform and proper, conſiſting, eſpecially at laſt, of croſs ſtrokes in every direction acroſs the diameter) be formed into portions of true and equal ſpheres; had it not been for this lucky neceſſity, it would have been impoſſible to have produced that correctneſs which is eſſential in the ſpeculum of a good reflecting teleſcope by any mechanic contrivance whatever. For when it is conſidered that the errors in reflection are four times as great as in refrac-

tion

tion, and that the laſt defect in figure is magnified by the powers of the inſtrument ; any thing ſhort of perfection in the figure of the ſpeculum, would be evidently perceived by a want of diſtinctneſs in the performance.

I muſt not, however, quit this article without obſerving, that I all along ſuppoſe, both in forming the tools, and at laſt figuring the metal (and indeed the ſame muſt be obſerved in the future proceſs of poliſhing), that no kind of preſſure is uſed that may endanger the bending, or irregularly grinding them ; they ſhould, therefore, be held with a light hand, and looſely between the fingers, and the motion given ſhould be in an horizontal direction, with no more preſſure than their own dead weight.

Having now finiſhed the metal on the hones, and rendered it both in point of figure and ſurface, fit for the laſt and moſt eſſential proceſs, viz. that of poliſhing, I will deſcribe it in the beſt manner I can ; though many little circumſtances which are unavoidably omitted (and which, at the ſame time, are frequently eſſential to the ſucceſs of a mechanic proceſs) can only be ſupplied by actual experience.

The poliſhing of the ſpeculum is the moſt difficult and eſſential part of the whole proceſs ; for every experienced workman knows, to his vexation, that the moſt trifling error here will be ſufficient to ſpoil the figure of his metal, and render all his preceding caution uſeleſs.

I ſhall explain a method not only of giving the metal a parabolic figure, but alſo of recovering it when it happens

to

to be injured; both to be effected in the act of poliſhing, and the former as certainly as the ſpherical figure is given upon the hones.

Indeed, if we conſider rightly, poliſhing will be perceived to be but a kind of grinding with a finer order of ſtrokes, and with a powder infinitely finer than what was before uſed in what was commonly called the grinding.

How to poliſh the Speculum.

IT is neceſſary to obſerve, that in order to avoid the detrimental intruſions of any particles of emery, it would not be right to poliſh in the ſame room where the metal and tools were ground, nor in the ſame clothes which were worn in the former proceſs; at leaſt, it would be neceſſary to keep the bench quite wet, to prevent any duſt from riſing.

Having then made the poliſher by coating the braſs convex tool equally with pitch, which we ſuppoſe ſmoothed and finiſhed with the braſs tool in the manner before deſcribed, and which is a very eaſy proceſs; the whole operation is begun and finiſhed in the following manner:

The leaden weight or handle upon the back of the metal ſhould be divided into eight parts, by ſo many deep ſtrokes of a graver upon the upper ſurface of the lead, making each ſtroke with the numbers 1, 2, 3, 4, and ſo on, that the turns of the metal in the hand may be known to be uniform and regular.

To

To prevent any miſchief from coarſe particles of putty, I always waſh it immediately before uſing: in order to this, put about half an ounce of putty into an ounce phial, and fill it two thirds with water; then having ſhaken the whole, let the putty ſubſide, and ſtop the bottle with a cork.

In a tea-cup, with a little water, there ſhould be a full-ſized camel's-hair bruſh, and a piece of dry clean ſoap in a gally-pot: a ſoft piece of ſponge will alſo be neceſſary. Theſe, as well as the metal bruiſer and poliſher, ſhould be conſtantly covered from duſt.

The poliſher being fixed down, and the camel's-hair bruſh, being firſt wetted and rubbed a little over the ſoap, let every part of the tool be bruſhed over therewith; then work the bruiſer with ſhort, ſtraight, and round ſtrokes, lightly upon the tool, and continue to do ſo, now and then turning it, till the poliſher have a good face, and be fit for the metal. Then having ſhaken up the putty in the phial, and touched the poliſher in five or ſix places with the cork wetted with that and the water, place the bruiſer upon the tool, and give a few ſtrokes upon the putty to rub down any gritty particles; after which, having removed it, work the metal lightly upon the poliſher round and round, carrying the edges of the ſpeculum, however, not quite half an inch over the edge of the tool, and now and then with a croſs ſtroke.

The firſt putty, and indeed all the ſucceeding applications of it, ſhould be wrought with a conſiderable while; for if time be not given for the putty to bed itſelf in the pitch, and any

any quantity of it lie loofe upon the polifher, it will accumulate into knobs, which will injure the figure of the metal: and therefore as often as fuch knobs arife, they muft be carefully fcraped off with the point of a penknife, and the loofe ftuff taken away with a brufh. After the putty is well wrought into the pitch, fome more may be added in the fame manner, but never much at a time, always remembering to work upon it firft with the bruifer, for fear any gritty particles may find their way upon the polifher. If the bruifer be apt to ftick, and do not flide fmoothly upon the pitch, the furface of either tool may be occafionally brufhed over with the foap and water, but it muft be remembered, that the wet brufh muft be but flightly rubbed upon the foap.

In the beginning of this procefs little effect is produced, and the metal does not feem to polifh faft, in fome meafure owing to its taking the polifh in the middle, and perhaps becaufe neither that nor the bruifer move evenly upon the polifher: but a little perfeverance will bring the whole into a good temper of working; and when the pitch is well defended by the coating of the putty, the procefs will advance apace, and the former acquiring poffibly fome little warmth, the metal moves more agreeably over it, with an uniform and regular friction. All this while the metal muft have no more preffure than that which it derives from its own weight, and that of the handle; and the polifher muft never be fuffered to grow dry, but as often as it has a tendency to do fo, the edges of it muft be moiftened with the hair pencil; and now and then, even when frefh putty is not laid on, the furface of the polifher fhould be touched with the brufh to keep it moift.

When the poliſh of the metal nearly reaches the edge (for it always, as I ſaid before, begins in the middle) you muſt alter your method of working; for now the round ſtrokes muſt be gradually altered for the ſhort and ſtraight ones. Suppoſing then you are juſt beginning to alter them; after having put on freſh putty, and gently rubbed it with two or three ſtrokes of the bruiſer, you place the metal on the tool, and after a ſtroke or two round and round, give it a few forward and backward, and from ſide to ſide, but with the edges very little over the tool; then having turned the metal one eighth round in your hand, and having moved yourſelf as much round the block (which muſt be remembered through out the whole proceſs), you go on again with a ſtroke or two round, to lead you only to the croſs ſtrokes, which are now to be principally uſed, and with more boldneſs. After this has been done ſome time, the metal will begin to move ſtiffly as the friction now increaſes, and the ſpeculum poliſhes very beautifully and faſt; and the whole ſurface of the poliſhing tool will be equally covered over with a fine metallic bronze. The tool even now muſt not be ſuffered to become dry; a ſingle round ſtroke in each of your ſtations and turnings of the metal will be ſufficient, and the reſt muſt all be croſs ones, for we are completing a circular figure. You muſt now be very diligent, for the poliſher drying, and the friction increaſing very faſt, the buſineſs of the ſpherical figure is nearly at an end. As the metal wears much, its ſurface muſt be now and then cleaned with a piece of ſhammy leather, from the black ſtuff which collects upon it; and the poliſher likewiſe from the ſame matter, with a ſoft piece of wet ſponge. You will now be able to judge of the perfect ſpherical figure of the metal and tool, when there is a perfect correſpondence between the ſurfaces, by the fine equable feel there is in working

working, which is totally free from all jerks and inequalities. Having proceeded thus far, you may put the laſt finiſhing to this figure of the metal by bold croſs ſtrokes, only three or four in the directions of each of the eight diameters, turning the metal at the ſame time: this muſt be done quickly, for it ought, in this part of the proceſs particularly, to be remembered, that if you permit the tool to grow quite dry, you will never be able, with all your force, to ſeparate that and the metal, without deſtroying the poliſher by heat.

The metal has now a beautiful poliſh and a true ſpherical figure, but will by no means make a ſharp diſtinct image in the teleſcope: for the ſpeculum (if it be tried in the manner hereafter recommended) will not be found to make parallel rays converge without great aberration; indeed, the deviation will be ſo great, as to be very ſenſibly perceived by a great indiſtinctneſs in the image.

It is here neceſſary to remark, that there muſt be a hole through the middle of the poliſher, a little leſs than the hole in the metal, otherways the hole in the metal would collect the pitch towards the middle, and hence it would be impoſſible to make a good figure.

How to give the Parabolic Figure to the Metals.

In order then to give the ſpeculum the laſt and finiſhing figure, which is done by a few ſtrokes, it muſt be particularly remarked, that by working the metal round and round, the ſphere of the poliſher by this means growing leſs, it wears faſteſt in the middle: and as a ſegment of the ſphere may

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become parabolic, by opening the extremes gradually from within outwards, ſo it may be equally well done by increaſing the curvature in the middle, in a certain ratio, from without inwards.

Suppoſing then the metal to be now truly ſpherical, ſtop the hole in the poliſher, by forcing a cork into it underneath, about an inch, ſo that it do not reach quite to the ſurface; and having waſhed off any mud that may be on the ſurface of the tool with a wet ſoft piece of ſponge, whilſt the ſurface of it is a little moiſt, place the center of the metal upon the middle of the poliſher; then having, with the wet bruſh, lodged as much water round the edge of the metal as the projecting edge will hold, fill the hole of the metal and its handle with water, to prevent the evaporation of the moiſture, and the conſequent adheſion between the ſpeculum and poliſher, and let the whole reſt in this ſtate two or three hours: this will produce an intimate contact between the two, and by parting, with any degree of warmth they may have acquired by the vicinity of the operator, they will grow perfectly cold together.

By this time you may puſh out the cork from the poliſher, to diſcharge the water, and give the metal the parabolic figure in the following manner:

Move the metal gently and ſlowly at firſt, a very little round the center of the poliſher (indeed after this reſt it will move ſtiffly) then increaſing by degrees the diameter of theſe ſtrokes, and turning the metal frequently round its axis, give it a larger circular motion, and this without any preſſure but its own weight, and holding it looſely between the

the fingers: this manner of working may safely be continued about two minutes, moving yourself as usual round the block, and carrying the round strokes in their increased and largest state, not more than will move the edge of the metal half an inch or five-eighths over the tool. The speculum must not all this while be taken off from the polisher; and consequently no fresh putty can be added. It will not be safe to continue this motion longer than the time above-mentioned; for if the parabolic tendency be carried the least too far, it will be impossible to recover a true figure of that kind, but by going through the whole process for the spherical one in manner before described, by the cross strokes upon the polisher, which takes a great deal of time. However, when there is occasion, it may be done; and I have myself several times recovered the circular figure, when I had inadvertently gone too far with the parabolic, and ultimately finished the metal on the polisher without the use of the hones.

To try the true Figure of the Metal.

IT will now be proper to try the figure of the peculum, and that is always best done by placing it in the telescope it is intended for. In order to this, I use the instrument as a kind of microscope, placing the object however, at such a distance that the rays may be nearly parallel. At about twenty yards a watch-paper, or some such object, on which there are some very fine hair strokes of a graver is fixed up. The lead must be then taken off from the back of the speculum, which is best done by placing the edge of a knife at the junction of the lead and metal, when,

by

by ftriking the back of it with a flight blow, the pitch immediately feparates, and the handle drops off; the remaining pitch may be fcraped off with a knife, taking care that none of the duft ftick to the polifhed face of the metal.

Having placed the fpeculum in the cell of the tube, and directed the inftrument to the object, make an annular kind of diaphragm with card paper, fo as to cover a circular portion of the middle part of the metal between the hole and the circumference, equal in breadth to about an eighth part of the diameter of the fpeculum: this paper ring fhould be fixed in the mouth of the telefcope, and remain fo during the whole experiment, for the part of the metal covered by it, is fuppofed to be perfect, and therefore unemployed.

There muft likewife be two other circular pieces of card-paper cut out, of fuch fizes, that one may cover the center of the metal by completely filling the hole in the laft defcribed annular piece; and the other, fuch a round piece as fhall exactly fit into the tube, and fo broad, as that the inner edge juft touch the outward circumference of the middle annular piece. It would be convenient to have thefe two pieces fo fixed to an axis, that they may be put in their places, or removed from thence fo eafily, as not to difplace or fhake the inftrument. All thefe pieces therefore, together, will completely fhut up the mouth of the telefcope.

Let the round piece which covers the center of the metal, or that which has no hole in it, be removed; and by a nice adjuftment of the fcrew, let the image (which is now formed by the center of the mirror) be as fharp and diftinct as poffible. This being done, every thing elfe remaining

maining at reſt, replace the central piece, and remove the outſide annular one, by which means the circumference only of the ſpeculum will be expoſed, and the image now formed will be from the rays reflected from the outſide of the metal. If there be no occaſion to move the ſcrew and little metal, and the two images formed by theſe two portions of the metal be perfectly ſharp, and equally diſtinct, the ſpeculum is perfect, and of the true parabolic curve; or at leaſt the errors of the great and little ſpeculum, if there be any, are corrected by each other.

If, on the contrary, under the laſt circumſtance, the image from the outſide of the metal ſhould not be diſtinct, and it ſhould become neceſſary, in order to make it ſo, that the little ſpeculum be brought nearer, it is plain that the metal is not yet brought to the parabolic figure; but if, on the other hand, in order to procure diſtinctneſs, you be obliged to move the little ſpeculum farther off, then the figure of the great ſpeculum has been carried beyond the parabolic, and hath aſſumed an hyperbolic form. When the latter is the caſe, the circular figure of the metal muſt be recovered (after having fixed on the handle with the ſoft pitch) by bold ſoft ſtrokes upon the poliſher; indeed, a very few of them in the manner before deſcribed make in effect a greater difference in the ſpeculum than would be at firſt imagined. If a metal of a true ſpherical figure were to be tried in the above-mentioned manner in the teleſcope (which I have frequently done) the difference of the foci of the two ſegments of the metal would be ſo conſiderable, as to require two or three turns of the ſcrew to adjuſt them; ſo very great is the aberration of a ſpherical figure of the ſpeculum, and ſo improper to procure that

ſharpneſs

ſharpneſs and preciſion ſo neceſſary to a good reflecting teleſcope.

This is by no means the caſe with the object glaſſes of the refractors; for beſides that they are in fact never ſo diſtinct as well finiſhed reflectors, the apertures of them are ſo exceedingly ſmall, compared to the latter, and the number of the degrees employed ſo very ſmall, that the inconvenience of a ſpherical figure is not ſo much perceived. Accordingly we obſerve in the generality of reflectors (whoſe ſpecula, unleſs by accident, are always ſpherical) that the only true rays which form the diſtinct image ariſe from the middle of the metal: and unleſs the defect be remedied by a conſiderable aperture, which deſtroys much light, the falſe reflection from the inſide of the metal produces a greyiſh kind of hazineſs, which is never ſeen in in Mr. Short's, or indeed in any good teleſcopes.

Suppoſing that the two foci of the different parts of the metal perfectly coincide, and that, by the union of them when the apertures are removed, the teleſcope ſhews the objects very ſharp and diſtinct, you are not however even then to conclude that the inſtrument is not capable of farther improvement; for you will perceive a ſenſible difference in the ſharpneſs of the image, under different poſitions of the great ſpeculum with reſpect to the little one, by turning round the great metal in its cell, and oppoſing different parts of it to different parts of the little metal, correcting by this means the error of one by the other. This attempt ſhould be perſevered in for ſome time, turning round the great ſpeculum about one ſixteenth at a time, and careſully obſerving the moſt diſtinct ſituation each time the eye piece is ſcrewed on: when by trying and turning the

the great metal all round, the diſtincteſt poſition is diſcovered, the upper part of the metal ſhould be marked with a black ſtroke, in order that it may always be lodged in the cell in the ſame poſition. This is the method Mr. Short always uſed; and the caution is of ſo much conſequence, that he thought it neceſſary to mention it very particularly in his printed directions for the uſe of the inſtrument.

And farther, Mr. Short frequently corrected the errors of the great by the little metal in another way. If the great ſpeculum did not anſwer quite well in the teleſcope, he cured that defect ſometimes by trying the effect of ſeveral metals ſucceſſively, by this means correcting the errors of one by the other; for in ſeveral of his teleſcopes which have paſſed through my hands, when the ſizes and powers have been the ſame, I have found that the great metals, though very diſtinct in their proper teleſcopes, yet have, when taken out and changed from one to the other, ſpoiled both teleſcopes, rendering them exceedingly indiſtinct, which could ariſe from no other circumſtance.

To return: a little uſe in working will make the whole of the proceſs of grinding and poliſhing very eaſy and certain; for though I have endeavoured to be as particular as I can (I am almoſt afraid too much ſo), it is yet ſcarcely poſſible to ſupply a want of dexterity, ariſing from habit only, by the moſt laboured and minute deſcription. And though the above account may appear irkſome to the reader, as it lies cold before the eye, I am very ſure, whoever attempts to make the inſtrument, will not complain of it as tediouſly particular.

I will, however, farther remark, that when the metal begins to move ftiffly upon the polifher, and particularly when the figure is almoft brought to the parabolic form, it will be neceffary to fix the elbows againft the fides, in order to give momentum and equability to the motion of the hand by that of the whole body.

The fame polifher will ferve for feveral metals, if it be fomewhat warmed when you begin to ufe it.

There is another circumftance, and a material one too, which muft not be omitted; it is this: for the very fame reafon that the pitch fhould not be too hard or foft, the work will not proceed well in the heat of fummer, or cold of winter: in the latter, it may be poffible to remedy the defect by having the room warmed with a ftove; and in the fummer, the other inconvenience may perhaps be avoided by ufing a harder kind of pitch; but I much doubt in either cafe whether the work will go on fo kindly; I have myfelf always wrought in fpring and autumn.

The procefs of polifhing, and indeed grinding upon the hones, will not go on fo well if it be not continued uninterruptedly from beginning to end; for if the work of either kind be left but for a quarter of an hour, and you then return to it again, it will be fome time before the tool and metal can get into a kindly way of working; and till they do you are hurting what was done before.

I cannot conclude without indulging myfelf in an obfervation on the amazing fagacity of Sir Ifaac Newton in every fubject upon which he thought fit to employ his attention.

tention. It was he who firſt propoſed, and indeed practiſed the poliſhing with pitch; a ſubſtance which, at firſt ſight, perhaps every one but himſelf would have thought very improper, from its ſoftneſs, to produce that correctneſs of figure ſo neceſſary upon theſe occaſions; yet, he poliſhed ſeveral object glaſſes for refracting teleſcopes, and mended many more with it; and I do believe, that it is the only ſubſtance in nature that is perfectly well calculated for the purpoſe; for, at the ſame time that it is ſoft enough to ſuffer the putty to lodge very freely on its ſurface, and for that reaſon to give a moſt tender and delicate poliſh; it is likewiſe totally inelaſtic, and therefore, never from that principle, ſuffers any alteration in the figure you give it. If the firſt makers of the inſtrument, therefore, had given proper credit to, or had ſimply followed the hint Sir Iſaac gave, it would have ſaved them infinite trouble, and they would have produced much better inſtruments; but the pretended refinement of drawing a tincture from pitch, with ſpirits of wine, affords you only the reſinous, hard, and untractable part of the pitch, diveſted of all that part of its original ſubſtance which is neceſſary to give it that accommodating pliability in which its excellence conſiſts.

It is needleſs to ſwell this account with a detail of the proceſs for poliſhing the little ſpeculum, as it muſt be conducted in the ſame manner which has been already deſcribed in that of the large one; only obſerving, that as the little metal has an uninterrupted face, without a hole, ſo there is no occaſion for one in the poliſher; and likewiſe that, as a ſpherical figure is all that need here be practically attempted, ſo the difficulty in finiſhing is infinitely ſhort of that of the other.

As it is always neceſſary to ſolder to the back of the little ſpeculum a piece of braſs, as a fixture for the ſcrew to adjuſt its axis, I ſhall juſt hint a ſafe and neat method of doing it, which may be very uſeful to the optical or mathematical inſtrument-maker upon other occaſions. Having cleaned the parts to be ſoldered very well, cut out a piece of tinfoil the exact ſize of them; then dip a feather into a pretty ſtrong ſolution of ſal ammoniac in water, and rub it over the ſurfaces to be ſoldered; after which, place the tinfoil between them as faſt as you can (for the air will quickly corrode their ſurfaces, ſo as to prevent the ſolder taking) and give the whole a gradual and ſufficient heat to melt the tin. If the joints to be ſoldered have been made very flat, they will not be thicker than a hair: though the ſurfaces be ever ſo extenſive, the ſoldering may be conducted in the ſame manner, only that care muſt be taken, by gentle preſſure, to keep them cloſe together. In this manner, for inſtance, a ſilver graduated plate may be ſoldered on to the braſs limb of a quadrant, ſo as not to be diſcernable by any thing but the different colours of the metals.

A Deſcription of the Grinding Tools, and the Apparatus for aſcertaining the true Figure of the Speculum.

THE grinder for working off the face of the metal. The black ſtrokes repreſent deep grooves made with a graver. Fig. 3.

The bed of hones, which is to complete the ſpherical figure of the ſpeculum, and to render its ſurface fit for the poliſher. Fig. 4,

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An apparatus for examining the parabolic figure of the ſpeculum. Fig. 5.

A A, the mouth of the teleſcope, or edge of the great tube.

B B, a thin piece of wood, faſtened into, and fluſh with the end of the tube; to which is permanently fixed, the annular piece of paſteboard C C, intended to cover, and to prevent the action of the correſponding part of the ſpeculum.

D, another piece of paſteboard, fixed by a pin to the piece of wood B B, on which it turns on a center; ſo that the great annular opening H H, may be ſhut up by the ring F F, or the aperture G G, by the imperforate E, in ſuch manner, that in the firſt inſtance, the reflection may be from the center, and, in the latter, from the circumference of the great ſpeculum.

To grind and poliſh Concave Lenſes, for Proſpect Glaſſes, &c.

PLACE an arbor or mandrill in a turner's lathe, whereon you can fix leaden wheels of what dimenſion you pleaſe, ſuppoſe one, two, or three inches diameter, and three-eighths, or half an inch thick (which are common ſizes for making the above-mentioned inſtruments), you then prepare the glaſs by chipping it round with a pair of large ſciſſars, or ſmall ſhears, to the ſize you want it, and either cement it to the end of a little ſhort block of wood made for that purpoſe, or hold it looſe in your fingers upon the edge of the wheel, it having emery and water conſtantly

conſtantly applied to it all the while you are grinding. In holding the glaſs, you muſt preſs moderately upon it, and keep turning it backward and forward all the time, ſo that it may have a true figure. When you have ground it deep enough, and you can obſerve no defect in its ſpherical figure, you muſt apply no more emery, but ſtill keep working it upon the tool with a very light hand; it would ſtill be much better if you had another wheel of the ſame diameter, on which, you might apply a little ground pumice ſtone, in order to take out the ſtrokes, or ſcratches, made by the emery. When you perceive it to be in a proper ſtate for poliſhing, which you may do by examining it through a magnifying glaſs, and if no ſcratches, nor holes appear, it is then ready for the poliſhing wheel, which is made of wood, the exact ſize of the wheel on which it was ground, and a piece of clean linen cloth faſtened double round its edge; then apply putty, moiſtened with water, and work it in the ſame manner as when you ground it; and, in a few minutes, you will perceive it to have an excellent poliſh.

To grind Convex Lenſes for Microſcopic Object Glaſſes, Eye Glaſſes, &c.

Firſt, provide an upright ſpindle, at the bottom of which, a pulley is fixed, which muſt be turned by a wheel by means of a cord, and handle. At the top of the ſpindle, make a ſcrew, the ſame as a lathe ſpindle, whereon you may ſcrew chocks of different ſorts, which may be made in the following manner:

Make

Make a hole in a piece of wood, juſt to fit tight upon the collar of the ſpindle, and turn it to one inch long, and one inch larger in diameter than the hole ; place it on the collar at the chock end of the ſcrew, and lap a piece of paſteboard round the wood, ſo that it may ſtand an inch above the top of the ſcrew; then pour melted lead upon it till the paper is full, and when cold, you may unſcrew it, and fix it in a lathe ; ſcrew the chock on again, and turn it true on the end ; take it off, and ſolder a piece of thick braſs upon it, with ſoft ſolder, afterwards turn the braſs to the concavity you intend it, as true as poſſible with the turning tool, after which apply it upon the edge of a wheel of the ſame radius of a ſphere as the gage you turned it by ; and, by grinding it a little in the ſame manner as you grind concave glaſſes, it will be ready for uſe. Next prepare the glaſs, by chipping it to the ſize you want it, and cement it on the end of a block of wood of the ſame diameter, and one, two, or three inches long, ſo as to hold it eaſily between your two fingers and thumb ; make a concave gage of thin braſs, the ſame radius of a ſphere as the pan, and grind the edges of the glaſs upon a rough grinding-ſtone, till it fits the gage ; then it is ready for its ſpherical figure.

The next thing neceſſary is to prepare the emery, which is done in the following manner: provide at leaſt, ſix earthen veſſels, that will hold two or three quarts each (take care they are quite clean when uſed), fill the firſt with water, and put one pound of fine emery in it, and ſtir it well about with a ſtick, after which, let it ſtand about three ſeconds of time, and then pour it into another veſſel, which let ſtand ten ſeconds, then pour it off again into the ſeveral veſſels until the water is quite clear ; and, by this means,

means, you will obtain emery of as many degrees of fineneſs as you pleaſe; which muſt be kept ſeparate from one another, and worked in their proper order, beginning at the firſt, and working off all the marks of the grinding-ſtone; then take of the ſecond and third, &c. holding the glaſs upon the pan with a light hand, when it comes to be nearly fit for poliſhing; a little experience will make the practitioner quite perfect.

The poliſhing is performed as follows: after the glaſs is brought, by grinding with emery, to a fine ſurface, grind ſome pumice-ſtone, by rubbing it with a little water upon a ſtone, and what rubs off muſt be uſed in the pan (this is called bottoming), work it off with this, till it is almoſt poliſhed, which will eaſily be perceived; then tie a piece of linen rag about the pan, and, with putty, moiſtened with water, continue the grinding motion, and in a little time there will be an excellent poliſh.

What has been ſaid on grinding ſpeculums for reflectors, will be as eaſily adapted to the grinding of object glaſſes for refractors; for what is called the bruiſer there, will, in this caſe, be called a pan, and the convex tool will become the bruiſer.

There have been contrived a number of different compoſitions for the metals of reflecting teleſcopes; among which, the following appear to be very good.

1. Take of clean new copper twenty-four ounces; melt it in a crucible, ſkim off the *ſcoria*; let the fire abate a little, and add ten ounces of the pureſt grain tin rolled up in brown paper; when the tin is melted ſtir it with a

wooden

wooden ſpatula, and having your moulds ready, pour the metal into them.

The regulation of the fire in making the above metals, ſhould be particularly attended to; for if a violent fire be uſed after the tin is added, the tin will evaporate, and the metal will be full of air-holes, which will prevent its acquiring a fine poliſh. Therefore, when the copper is in perfect fuſion and the ſcoria taken off, the fire ſhould be diminiſhed, the tin added, and no more heat ſhould afterwards be uſed than is ſufficient to melt the whole, ſo as to give the metal its proper form when poured off into the mould.

The Rev. Mr. *Edwards* has taken a great deal of pains to diſcover the beſt compoſition for the metals of reflecting teleſcopes, alſo to give them a fine poliſh and the true parabolic figure.

Theſe teleſcopes have been tried by Dr. *Maſkeline*, and found greatly to excel in brightneſs, and to equal in other reſpects, thoſe made by the beſt artiſts; they ſhew a white object perfectly white, and all objects of their proper colour, much different from the common reflecting teleſcopes.

After having combined the following metals and ſemi-metals, ſuch as ſilver, platina, iron, copper, braſs, lead, tin, antimony, biſmouth, zinc, arſenic, &c. he found, that 32 ounces of copper, with 15 or 16 ounces of grain tin, (according to the purity of the copper) with the addition of one ounce of braſs, one of ſilver, and one ounce of arſenic,

 will

will form a metal, capable, when poliſhed in a proper manner, of reflecting more light than any other metal yet made public.

When it is ſaid that the proportion of tin is from 15 or 16 to 32 ounces of copper, it ſhould be underſtood that the proportion of tin will not always be accurately the ſame, as copper will take more or leſs tin to perfectly ſaturate it according to its purity; it might be of uſe previouſly to purify the copper as much as poſſible; but a very little experience in theſe matters will enable any one exactly to know when the copper is compleatly ſaturated; as the compoſition will, if broken, appear of a moſt beautiful bright, and glaſſy nature, very much reſembling the fine face of quickſilver; the method to aſcertain that point exactly, is to melt 32 ounces of copper, and to add to it, when ſufficiently fuſed, 15 ounces of tin, and to pour the mixture into an ingot; then to a certain known portion of this compoſition add a very ſmall, but known, portion of tin, and thus by a few trials one may eaſily obtain the point of complete ſaturation, and the maximum of perfection; having then aſcertained what portion of tin is added to the above known quantity of the compoſition, add the proportional quantity of tin to the whole, when melted a ſecond time. Thus if I find I muſt add 1 quarter of an ounce to 1 pound of the compoſition, ſo as to obtain the utmoſt brilliancy; then I know, that when I ſhall melt the remainder of the metal a ſecond time, in order to caſt the ſpeculum, I muſt add 1 ounce of grain tin to 4 pounds of the compoſition made according to the proportion of 32 ounces of copper to 15 ounces of tin.

The

The beſt method poſſible to make this compoſition to the greateſt advantage, is to melt the copper as fluid as poſſible, and flux it with the *black-flux*, which is made by mixing 2 parts of *tartar*, with 1 of *nitre*; to melt the tin in a ſeparate crucible by itſelf; to take the two crucibles out of the fire, and pour the melted tin into the fluid copper, and ſtir it inſtantly with a wooden ſpatula, and pour the whole immediately into a large quantity of cold water. The ſudden chill from the cold water divides the melted maſs into an infinite number of ſmall particles, and by that means cools it inſtantaneouſly, and conſequently prevents the tin from calcining ſenſibly; and hence it was always found, that in the ſecond melting the compoſition was entirely free from pores, even though no arſenic had been employed. Yet the addition of arſenic ever rendered it much more compact, and indeed ſpecifically heavier, as well as more brilliant and beautiful; for the ſpecific gravity of the compoſition itſelf is 8.78; but with the addition of 1 ounce of arſenic, to 1 pound of metal it is 8.89.

After having made the brilliant compoſition of copper and tin, melt the proportionable quantity of ſilver and braſs in a ſmall crucible by itſelf. When you put the compoſition a ſecond time into the crucible, add alſo the lump of braſs and ſilver melted before in a ſeparate crucible, and when the whole is fluid, add the proportionable quantity of arſenic, and then pour it off into the flaſks after the *ſcoria* is taken off, and a little powdered roſin is thrown into it. In other words, it is better not to add the braſs to the copper in the firſt melting, as the heat of the copper calcines the *Lapis Calaminaris* in the braſs, which renders the metal not ſo good, as if the braſs and ſilver were melted together, (as ſilver melts with a leſs heat than braſs) and then added to

the metal in the fecond melting. As copper requires a much greater heat to melt it than brafs, it gives too great a heat to the brafs when it is added to it, which by calcining the lapis calaminaris in the brafs will fometimes caufe the metal to be in a fmall degree porous. By purfuing the above method it will never be porous in the leaft degree. We are not to imagine it porous becaufe it breaks up with the emery. It will always do fo with the fineft emery; but thefe break-ups are taken out by the bed of hones. If the common blue hones are ufed, a little water muft be applied at a time, to make them cut the metal. Having faid fo much relative to the compofition of the metal, which is indeed a capital article, we will pafs on to,

The Manner of cafting this Metal.

THE fand moft proper for the purpofe of cafting fpeculums, is the common Highgate fand generally ufed by the *London* Founders; it fhould be as little wet as may be, and well beaten, but not too hard. The flafks fhould be at leaft 2 inches wider than than the metal intended to be caft; for if the fand is not of a fufficient thicknefs, it will inftantly become dry when the hot fluid metal is poured into it, and confequently will contract, and of courfe the fluid metal will run out of the flafks. A proper thicknefs of fand will however prevent this accident. The metal or pattern muft be made of brafs or hard pewter, and muft be a little thicker than the fpeculum intended to be caft from it, as the thing caft is always a little lefs than the pattern, owing to its contracting a fmall degree in cooling. A wooden pattern will not quit the fand near fo well as one made of metal; befides wood will always warp by the moifture of the fand,

fand, and confequently will give a falfe figure or form to the intended fpeculum, and fo create more labour.

As the compofition here given for the fpeculum is the hardeft, and the moft brittle of any metal yet known, fo it is the moft difficult to caft: the common manner of cafting other fpecula will not avail in the leaft degree *here*, and it was a confiderable time, before a certain and infallible way to caft them free from faults or flaws in the face down-downwards, was found out.

The *ingate* fhould be at the back of the metal, and at the very edge of it, its breadth, where it joins the metal, fhould be at leaft half the diameter of the metal, and its thicknefs muft be half the thicknefs of the metal at the edge; and the upper part of the git fhould contain as much metal at leaft, or even more, than the fpeculum itfelf.

When the pattern with its ingate is taken out of the fand, ten or a dozen fmall holes fhould be made through the fand at the back of the mould, with a fmall wire or common knitting-needle, to permit the air to efcape as the metal is poured into the mould. It is found by experience that feveral fmall holes are infinitely better for that purpofe than one large hole.

When the metal is melted a fecond time, which muft be done with as fmall a degree of heat as poffible, and the proportionable quantity of crude arfenic in coarfe powder is added, ftir it with a wooden fpatula; when the fumes are gone off, take the metal off the fire, take away the drofs, and add half an ounce or an ounce of powdered rofin, or equal parts of powdered rofin and nitre, in order to give the metal a good

face,

face, ſtir it well with a ſtick and pour it immediately into the flaſks. When the git is filled up with the fluid metal, ſtrike the flaſks gently, ſo as to ſhake or jog the metal in them in a ſmall degree; this will prevent any flaws in the face, from any air bubbles being lodged there. When the metal has remained in the flaſks for a few minutes, ſo as to become entirely ſolid, open the flaſks when the metal is red hot (it cannot crack in this ſtate, though it is expoſed to the air, as all metals are malleable when they are red hot) and take out the ſpeculum with a pair of tongs, laying hold of it by the git, but take care to keep the face downwards to prevent it from ſinking; force out the ſand from the hole in the middle of the mirror with a piece of wood or iron, and place the ſpeculum in an iron pot with a large quantity of hot aſhes, or ſmall coals, ſo as to bury the ſpeculum in them a ſufficient depth; if the ſand is not forced out of the hole in the manner above directed, the metal by ſinking as it cools will embrace the ſand in the middle of the ſpeculum, ſo tight, as to cauſe it to crack before it becomes entirely cold; and if the metal is not taken out of the ſand, and put in a pot with hot aſhes to anneal it, the moiſture from the ſand will always break the metal. Let the ſpeculum remain in the aſhes till the whole is become entirely cold. The git may eaſily be taken off, by marking it round with a common fire half-round file, and giving it then a gentle blow; the metal is then to be ground and figured.

Of rough grinding and figuring the Speculum.

THE beſt method found to rough grind the ſpeculum, is to grind the ſurface of it quite bright upon the common

mon grind-ſtone, made nearly to the figure or focus of the ſpeculum, by a gauge. Take it then to a convex tool made of lead and tin, or elſe of pewter, and grind the metal upon it with fine emery; which, however fine it may be, will break up the metal very much. This tool, or rough grinder, ſhould be of an elliptical form, and not circular, and of ſuch dimenſions that the ſhorteſt diameter of the ellipſe ſhould be equal in breadth to the diameter of the mirror, and the longeſt diameter of the elliptical tool ſhould be to the ſhorteſt diameter in the proportion of 10 to 9 accurately.

When the metal is brought to a true figure, it muſt be brought to a convex tool formed with ſome ſtones from a place called *Edgdon*, in *Shropſhire*, ſituate between *Ludlow* and *Biſhops-Caſtle*; theſe ſtones or hones are of a fine grain, and will eaſily cut the metal, and bring it to a fine face. The bed of hones ſhould be of a circular figure, and but very little larger than the metal intended to be figured upon it, viz. about 2-tenths of an inch, but not more for a ſpeculum of 4 or 5 inches diameter. If the tool is made conſiderably larger than the metal, it will grind the metal perpetually into a larger ſphere, and by no means of a good figure; if the metal and tool are of the ſame ſize exactly, the metal will work truly ſpherical, but it is apt to ſhorten the focus leſs and leſs, unleſs the metal and tool are worked alternately upwards: it had better be made a little (about 1-twentieth part) greater in diameter, larger than the mirror, when it will not ſo much alter its focus. Too much water ſhould not be uſed at a time upon the hone pavement, or the figure will be very bad; which may eaſily be ſeen by the face of the metal appearing of different degrees of brightneſs in different parts of it. When the metal is brought

brought to a very fine face and figure by the bed of hones, it is then ready to receive a poliſh; but before we give directions concerning the manner of poliſhing it, a circumſtance or two inadvertently paſſed over muſt be mentioned. The metal muſt not be caſt too thick, or it will never take the parabolical figure intended to be given to it: the beſt proportion found for this purpoſe is a metal of 4 ½ inches diameter, and 18 inches focus; it ſhould be 4-tenths of an inch thick at the edge of it: the back of the mirror ſhould be convex to ſtrengthen it, and to cauſe it to ſpring and adhere to the poliſher uniformly, its convexity ſhould be equal to its concavity on the face, that the metals may be every where of an equal thickneſs. The handle ſhould be made of lead, of the ſame convexity and concavity as the metal; its thickneſs about double that of the metal; and its diameter 3-fourths of that of the ſpeculum; it ſhould have a hole in the middle, with a copper or iron ſcrew on it, ſo as to put it together with the mirror, to which it is faſtened with pitch, on a collar lathe, in order to ſmooth and finiſh the edge of the metal, which may be done by holding a fine file to it, when in the lathe at firſt, and afterwards one of the above-mentioned ſtones.

Of poliſhing the Metal, and giving it the true parabolic Figure.

THE rough grinder of an elliptical form is now to be covered with common pitch. The pitch for this purpoſe is generally made by boiling tar in a ladle, over a ſlow fire, till it becomes of the conſiſtence required, for there is a great nicety in the degree of hardneſs of the pitch. The

harder

harder the pitch is, the better figure it will give to the metal, as it does not alter its figure in working, as soft pitch does; besides the metal will acquire a lustre upon a polisher moderately hard, so as to shew objects reflected from it as vivid and as near their natural colour as possible; but if the pitch is too soft, some of its finest particles will always adhere to the face of the metal, and form a very fine and thin cuticle or covering upon its surface. This circumstance is rendered very evident by viewing any white object in the metal, when that fine cuticle or covering upon the surface of the speculum will cause it to shew the object of a dingy brown colour, and not of its genuine whiteness.

Pitch may be easily made harder by adding to it a proper quantity of rosin. I often use equal quantities of pitch and rosin, so as to make the mixture just so hard when cold as to receive an impression from a moderate pressure of my nail. A polisher made with pitch and rosin has this advantage, viz. though it is hard yet it is not so brittle as when pitch only is used, and made hard by boiling it; and consequently not so liable to break or chip off at the edges, and thereby scratch the metal. Pour the melted pitch and rosin, when pretty cool, upon the elliptical tool, made previously warm, so as to cover it every where when spread upon it with an iron spatula about the thickness of a half crown piece. If the covering is too thin, it will continually alter its figure, by the heat it acquires in working the metal upon it, and thereby give a bad figure also to the speculum; when it is somewhat cool, lay a piece of writing paper upon the surface of the pitch, and gently press the mirrour upon the paper; instantly pull the paper off from the pitch, after you have pressed the mirrour upon it, else

it might adhere to the pitch, and you will find the poliſher will be neatly figured to the form of the ſpeculum. If it has not taken an exact figure every where, which would appear by the fine marks of the paper upon the pitch, gently warm the ſurface of the pitch, and repeat the operation as before, till you have formed it of the exact figure of the metal.

With a penknife now take away all the ſuperfluous pitch from the edge of the poliſher; and with a convenient piece of wood form the hole in the middle, accurately round. In In other words, let the pitchy ſurface be every where of the exact ſize and ſhape as the lead tool which is under it.

It may be neceſſary to mention that the hole in the middle of the poliſher ſhould go quite through the tool, and ſhould be made of the ſame ſize, or ſomewhat leſs than the hole in the middle of the ſpeculum. This is a neceſſary caution; and indeed it has always been found that ſmall mirrours without any hole in the middle will poliſh much better, and the figure will be more correct, if the poliſher has a hole in the middle of it. The powder to which the preference is given, to give a moſt exquiſite luſtre, is colcothar of vitriol, and not putty. Putty gives metals a white luſtre, or, as the workmen call it, *a ſilver hue*; but good colcothar of vitriol will poliſh with a very fine and high black luſtre, ſo as to give the metal poliſhed with it the complexion of poliſhed ſteel. To know if the colcothar is good, put ſome of it in your mouth, and if you find it diſſolved away it is good; but if you find it hard and cranch between your teeth it is bad; good colcothar of vitriol is of a deep red or deep purple colour, and is ſoft and

oily

oily when rubbed between the fingers: bad colcothar is of a light red colour and feels harſh and gritty. The colcothar of vitriol ſhould be levigated between two ſurfaces of poliſhed ſteel, and wrought with a little water; when it is worked dry, you may add a little more water to carry it down to what degree you pleaſe. When the colcothar has been wrought dry 3 or 4 times it will acquire a black colour; and will be low enough, or ſufficiently fine, to give an exquiſite luſtre: this levigated colcothar of vitriol put in a ſmall phial, and pour ſome water upon it, and afterwards uſe it for poliſhing the metals in the ſame manner that waſhed putty is directed to be made uſe of for that purpoſe in the former part of this treatiſe. Put on a large quantity of waſhed colcothar of vitriol at once, ſo as to ſaturate the pitch, and form a fine coating of the colcothar, and you will very rarely need to make uſe of a ſecond application. If a ſecond or third application of colcothar ſhould be found neceſſary to bring the metal to a fine luſtre, or to take out any ſcratches upon its face, uſe it very ſparingly, or you will deſtroy the poliſh you have already attained. When the metal is nearly poliſhed, it will always generate ſome black mud upon the ſurface of the mirror, and alſo upon the tool. Wipe it now away from the face of the metal with ſome very ſoft waſh leather; though if too much of the mud be taken away, it will not poliſh ſo well; indeed a little experience in theſe matters will better ſuffice than a volume written upon the ſubject.

In regard to the parabolic figure to be given to the metal, no particular caution is required in the poliſhing; the elliptic tool will always cauſe the ſpeculum to work into an accurate parabolic figure, ſuppoſing the tranſverſe and conjugate diameters bear the true proportion to each other, and

the metal is not too thick to prevent it always from adhering firmly, and uniformly to the polisher. Should the pitch prove too soft it will give way, and alter the figure a little. This circumstance will render the figure of the mirror sometimes a small degree short of the parabola, and sometimes a very little beyond it, but by a little perseverance the correct figure is easily acquired.

To convince any one of the certainty of my assertions; let him polish a metal 2 $\frac{1}{2}$ inches diameter, and 9 $\frac{1}{2}$ inches focus upon an elliptical tool whose diameters are 2 $\frac{1}{2}$ and 3 inches, and I can assert he will always find the metal when polished (if it is not too thick) beyond the Parabola, or it will prove hyperbolical. If he polishes it upon a circular tool in the common way with cross strokes in every direction possible, using first a few round strokes, every time he changes his position, he will find it always prove spherical and consequently short of the parabola. A very little experience in these matters will convince any one of the ease and certainty of giving the great speculum a parabolic figure by polishing it in a common manner with cross strokes in every direction possible, upon an elliptical tool of the proper dimensions, in which (for common foci and apertures, viz. 2 $\frac{1}{2}$ to 9 $\frac{1}{2}$ focus, or 3.8 inches diameter, to 18 inches focus) the diameters should be 10 to 9. The shortest diameter of the ellipse being exactly the same, as the diameter of the metal, and the longest diameter of the ellipse to the shortest diameter as 10 to 9.

Magnetism.

Magnetiſm.

Though the phenomena of the magnet have, for many ages, engaged the attention of natural philoſophers, not only by their ſingularity and importance, but alſo by the obſcurity in which they are involved; yet very few additions have been made to the diſcoveries of the firſt enquirers upon the ſubject. The powers of genius which have been hitherto employed in proſecuting this ſubject, have not been able to frame an hypotheſis, that will account, in an eaſy and ſatisfactory manner, for all the various properties of the magnet, or point out the links of the chain which connect it with the other phænomena of the univerſe. Though it is certain that both natural and artificial electricity will give polarity to needles, and even reverſe; from whence it would appear, that there is a conſiderable affinity between the electric and magnetic fluid, but how it acts when producing magnetiſm, is entirely unknown.

It is known by the works of *Plato* and *Ariſtotle*, that the antients were acquainted with the attractive and repulſive powers of the magnet; but it does not appear, that they knew of its pointing to the pole, or the uſe of the compaſs. As they were not acquainted with the true method of philoſophiſing, and contented themſelves with obſervation alone, their knowledge of nature was confined within very narrow limits, and did not afford any conſiderable advantage to ſociety. Modern philoſophers, by combining experiment with obſervation, ſoon extended the boundaries of ſcience, and diſcovered the polarity of the loadſtone, a property

property which in a manner conftitutes the bafis of naviga- tion, and gives being to commerce.

The loadftone, leading ftone, or natural magnet, is an iron ore, of all forms and fizes, and of various colours. It is endowed with the property of attracting iron; and of both pointing itfelf, and alfo enabling a needle, touched upon it, and duly poifed, to point towards the poles of the world.

Two Methods of communicating the Powers or Properties of the Magnet to Iron and Steel.

TO give a detail of the various proceffes which have been fuggefted, for the touching or communicating the properties of the magnet to iron or fteel, would alone fill a volume; I fhall therefore only give on account of two ge- neral and good methods which I prefume will be found adequate to every common purpofe.

1. Place two magnetic bars A B, (Plate IV. Fig. 6.) in a line, with the north, or marked end of one, oppofed to the fouth, or unmarked end of the other, but at fuch a dif- tance from each other, that the magnet to be touched may reft with its marked end on the unmarked end of A, and its unmarked end on the marked end of B, then apply the north end of the magnet D, and the fouth end of E to the middle of the bar C, the oppofite ends being elevated as in the figure; draw D and E afunder along the bar C, one towards A, the other towards B, preferving the fame ele- vation, remove D and C a foot or two from the bar when they are off the ends, then bring the north and fouth poles of

of theſe magnets together, and apply them again to the middle of the bar C as before; repeat the ſame proceſs five or ſix times, then turn the bar, and touch the oppoſite ſurface in the ſame manner, and afterwards the two remaining ſurfaces, and by this means the bar will acquire a ſtrong fixed magnetiſm.

2. Place the two bars which are to be touched parallel to each other, and then unite the ends by two pieces of ſoft iron called ſupporters, in order to preſerve, during the operation, the circulation of the magnetic matter; the bars are to be placed ſo that the marked end D, (Fig. 7,) may be oppoſite the unmarked end B, then place the two attracting poles G and I on the middle of one of the bars to be touched, raiſing the ends ſo that the bars may form an obtuſe angle of 100 or 120 degrees; the ends G and I of the bars are to be ſeparated two or three tenths of an inch from each other. Keeping the bars in this poſition, move them ſlowly over the bar A B, from one end to the other, going from end to end about fifteen times. Having done this, change the poles of the bars, that is the marked end of one is always to be againſt the unmarked end of the other, and repeat the ſame operation on the bar C D, and then on the oppoſite faces of the bars; the touch, thus communicated, may be farther increaſed, by rubbing the different faces of the bars with ſets of magnetic bars diſpoſed as in Fig. 8.

It ſeems, that in order to render ſteel magnetical, we muſt ſo diſpoſe the pores, that they may form contiguous tubes parallel to each other, capable of receiving the magnetic fluid, and then propagating and perpetuating its motion, ſo that the magnetic ſtream may enter with eaſe, and be

be made to circulate through it with the greateft force: to this end, it is neceffary to be particularly attentive in the choice of the fteel which is to be touched; the grain fhould be equal, fmall, homogeneous, and without knots, that it may prefent a number of equal and uninterrupted channels to the fluid, from one end to the other: this is more immediately important in the choice of the fteel for the needles of fea compaffes, for if the fteel is impure, or the mode of touching improper, the needle may have different poles communicated to it, which will more or lefs impede the action of the principal needle according to their ftrength and fituation.

The fteel fhould be well tempered, that the pores may preferve a long time the difpofition they have received, and and better refift thofe changes in their direction, to which iron and foft fteel are liable. The difference in the nature of fteel is exceeding great, and is eafily proved by touching in the fame manner, and with the fame bars, two pieces of fteel of equal fize but of different kind.

Steel that is hardened, receives a more perfect magnetifm than foft fteel, though it does not appear that they differ from each other in any thing but the arrangement of the parts; perhaps the foft fteel contains phlogifton in its largeft pores, while hardened fteel contains it in the fmaller. Iron, or fteel, have very little air incorporated in their pores; when they are feparated from the ore, they are expofed to a moft intenfe degree of heat, and moft of the changes to which they are afterwards fubmitted, are effected in a red hot ftate. A piece fpring-tempered fteel will not retain as much magnetifm as hard fteel, foft fteel ftill lefs, and iron fcarce retains any. From fome experiments of

Mr.

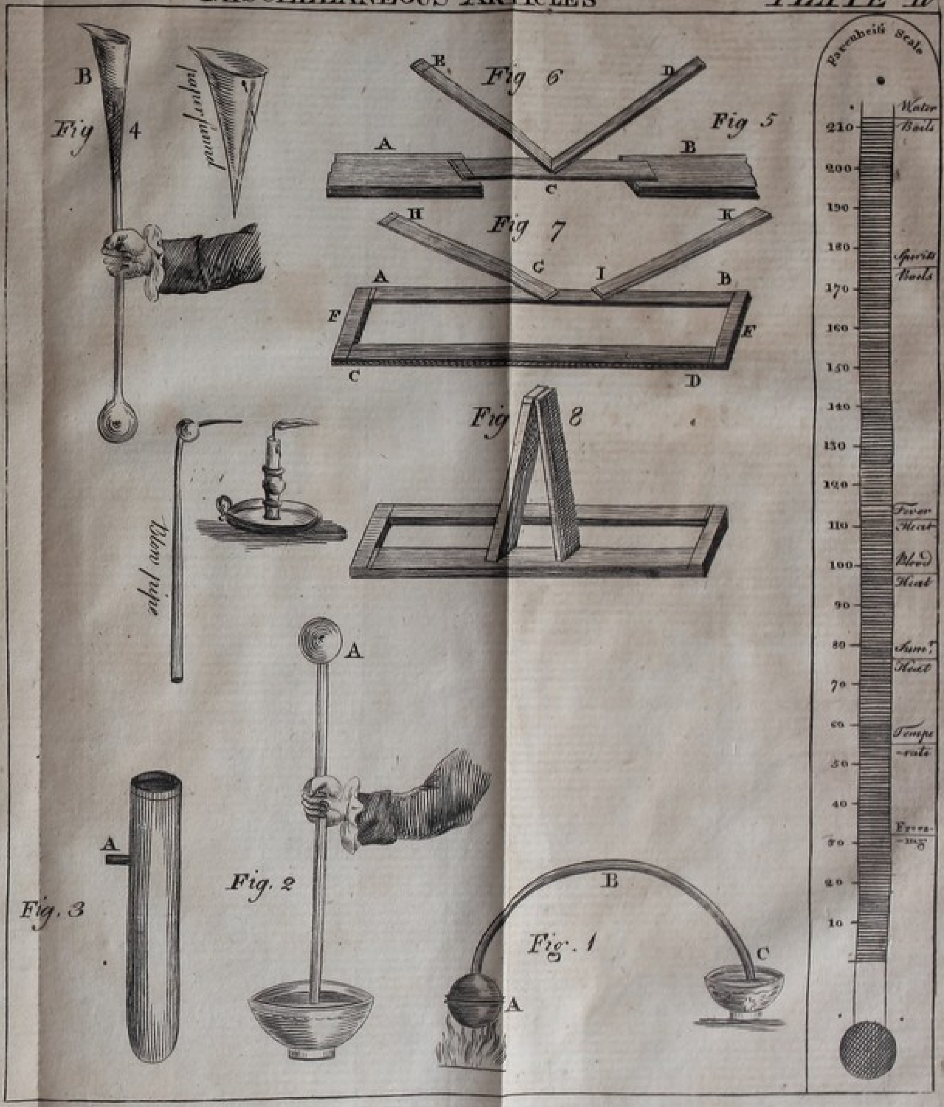

Fig 4
B
paper funnel
Fig 6
E
D
Fig 5
A
B
C
Fig 7
H
K
G
I
A
B
F
E
C
D
Fig 8
Blow pipe
A
Fig. 3
A
Fig. 2
B
Fig. 1
C
A
Water
Boils
210
200
190
180
Spirits
Boils
170
160
150
140
130
120
Fever
Heat
110
Blood
Heat
100
90
80
Sum^r
Heat
70
60
Tempe
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50
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Free-
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10

Mr. Mufchenbroek, it appears, that when iron is united with an acid, it will not become magnetical; but if the acid is feparated, and the phlogifton reftored, it will become as magnetical as ever.

The dimenfions and fhape of a magnet will make a difference in its force, therefore the bars to be touched, fhould neither be too long nor too fhort, but in proportion to the thicknefs; if they are too long, the paffage of the magnetic matter coming out of one pole, and proceeding round the magnet to enter the other, will be impeded, and its velocity leffened. If they are too fhort, the fluid which comes out from one pole, will be repelled and thrown back by the other acting parts of the magnet, and thus be carried too far from the pole into which it ought to enter, and prevent the continued circulation of the magnetic matter. If they are too thin, then the number of pores are too few to receive a ftream fufficiently ftrong to refift the obftacles in the external fpace; while, if they are too thick, the ftrait and regular direction of the channel is injured by the difficulty which takes place in the arrangement of the interior channels, as the magnetic matter has not fufficient force to penetrate the fteel to any confiderable depth, and thus injures the circulation of the fluid.

All the pieces fhould be well polifhed; it is of the greateft importance that the ends fhould be flat and true, fo as to touch in as many points as is poffible, the ends of foft iron which keep up the circulation. Inequalities on the faces, but principally near the poles, are to be avoided, as thefe occafion irregularities in the circulation, and thus diminifh its velocity, which is one of the principal fources of magnetic power.

While the bars are touching, the ends of foft iron fhould be kept in conftant contact with the bars, for a momentary feparation is fufficient to deftroy the effect of the operation, as the fluid will be inftantly difperfed in the air.

The operator ought not to ftop longer on the firft bar than is neceffary to open the pores, and to arrange them magnetically, paffing immediately to the other, to form an opening for the fluid which iffues from the firft.

It is moft advantageous to turn the bar that is quitted, while the touching magnets are placed on the other; by this means the ftream that is to be excited will difpofe the channels of the firft, and thus render the operation more efficacious; befides, by only turning one bar at a time, the touching bars need never be totally removed during the whole operation, a circumftance which will contribute to the ftrength of the magnet.

The touching bars fhould never be feparated but at the equator of the magnet; and their motion over the others, fhould be flow and regular.

The magnetic powers of touching needles has been increafed by leaving them for fome time in linfeed oil.

It may contribute to the effects of the operation if the bars A and B, fig. 6, are placed in the direction of the magnetic meridian, and are inclined to the horizon in an angle equal to the dip of the needle.

The fixed power, thus communicated to a magnet, is impaired if it is laid amongft iron, or by ruft; it may be in-

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jured alſo by fire, as each of theſe circumſtances will change, or confuſe the direction of the magnetic ſtream.

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

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

If bars of iron are heated, and then cooled equally, in various directions, as parallel, perpendicular, or inclined to the dipping needle, the polarity will be fixed according to their poſition, ſtrongeſt when they are parallel to the dipping needle, and ſo leſs by degrees, till they are perpendicular to it, when they will have no fixed polarity; but if upon cooling a bar of iron in water, the under end is conſiderably hotter than the upper, and the upper end is cooled firſt, it will ſometimes become the north pole, but not always. If iron, or ſteel, undergo a violent attraction in any one particular part, they will acquire a polarity; if the iron is ſoft, the magnetiſm remains very little longer than while the heat continues. Lightening is the ſtrongeſt power yet known in producing a ſtream of magnetiſm; it will in an

inſtant, render hardened ſteel ſtrongly magnetical, and invert the poles of a magnetic needle.

To make a magnetical bar with ſeveral poles, place magnets at thoſe parts where the poles are intended to be, the poles to be of a contrary name to thoſe required, and if a ſouth pole is fixed on one part, the two next places muſt have north poles ſet againſt them; conſider each piece between the ſupporters as a ſeparate magnet, and touch it accordingly.

To produce Fire from two cold Liquors.

MIX together 2 drachms of oil of cloves, and 2½ drachms of the ſpirit of nitre, made with oil of vitriol. Let the mixture be made by pouring the acid at once upon the eſſential oil, and they inſtantly take fire.

This is an experiment very ſurpriſing; and very often ſpoken of; but ſometimes attempted without ſucceſs. He who buys his ingredients at the next Chemiſt's may eaſily be diſappointed; for one of them may be adulterated; and the other made by a wrong proceſs. Though the ſpirit of nitre made with the oil of vitriol, will take this effect; neither oil of vitriol itſelf, nor ſpirit of nitre made in the old way will do it; nay, the very ſpirit made with the vitriolic acid, is, for certain reaſons, ſometimes diſtilled from ſuch proportions that it will not anſwer. The proceſs is eaſy; and he who would perform the experiment to his ſatisfaction, would do well to draw the acid off himſelf,

in a particular proportion: if it be made according to the following directions it will never fail.

Lay a quantity of purified nitre ſome time in a warm place, that it may be perfectly dried; pound it to a groſs powder; and put it in the ſame place again to be dried more perfectly; then put into a glaſs retort a pound and one ounce of this ſalt; and a pound and two ounces of good oil of vitriol; lute on a receiver and ſet the retort in a ſand furnace; make but a gentle fire and raiſe it only gradually; never let it be higher than is juſt ſufficient for driving over the ſpirit. The diſtillation being finiſhed, keep this ſpirit carefully ſtopped.

This will never fail of firing the oil of cloves; nor is that expenſive oil neceſſary for the experiment; for it will, when thus made, fire almoſt any of the vegetable or animal oils.

To make Alum Phoſphorus.

REDUCE to a fine powder half a pound of common alum; mix it with two ounces of dry wheat flour; grind theſe together, and put the powder into an iron diſh, or ladle; ſet it over the fire, and it will melt. Keep ſtirring it about till it concrete into a dry maſs again. Then reduce it a ſecond time to powder; put this into the ladle, and burn it again till it be of a dark brown colour, nearly black. Remove this from the fire, and put the powder into a tall phial; ſet this upon a little ſand in a crucible, and pour ſand about it; then ſet it on a naked fire, and make the bottom of the crucible red hot: keep the fire at this degree

degree for twenty minutes. After this ſtop the phial with a cork, and then remove the crucible from the fire. Let all cool: then take the phial out of the ſand, and put it up in a dark place. This is the alum phoſphorus; or, as ſome call it, the black phoſphorus. At any time, if a little of this powder be poured out of the bottle, it takes fire of itſelf, and burns away to a coal, or cinder. The beſt method of ſhewing its effect, is by pouring it out upon a piece of coarſe paper, which has been hung up in a damp place.

The Phoſphorus of Urine.

THIS is the moſt conſiderable of all the bodies that have been called *Phoſphori*, and it is the moſt troubleſome to be made. Many proceſſes have been given for it; but many who have tried them after the *authors*, have failed of ſucceſs. Whether this has been owing to their fault, or that of thoſe who have lain down the inſtructions, is not eaſy to ſay; however the following is leſs difficult than many. It is very nearly that by which *Boerhaave* made it; and is very exactly the proceſs by which I have aſſiſted in making it.

Boil about twelve or fourteen gallons of freſh urine in a very large veſſel, and with great care that it do not boil over, till it be reduced to a ſmall quantity, and have the conſiſtence of honey; take this out of the veſſel, in which it was boiled, and ſet it in a glaſs in a warm room: let it ſtand a long time, for it is neceſſary it ſhould putrefy; and this does not come on ſuddenly. When it has been thoroughly putrefied put it into an iron pot, ſuch as is uſed for diſtilling ſpirit of hartſhorn in large quantities, and lute on

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an alembic head of earthen ware, ſuch as are made for thoſe pots. Lute on the head very firmly; and fit to the noſe a long pipe; admit this into a large receiver. When all is thus ready make a fire under the pot, and raiſe it by degrees to a great height: an alkaline ſalt is ſublimed, and afterwards a yellow oil comes over; the fire is then to be increaſed, ſo as to keep the bottom of the pot red hot for ſome time; a thicker oil and a ſecond ſalt will come over: theſe, if there be uſe for them may be preſerved: the remainder is now prepared for making the phoſphorus.

Let the pot cool, and take out the reſiduum; throw it into a mortar a little heated, and beat it to a coarſe powder; have ready ſome powdered charcoal; mix with this powdered maſs twice its weight of the powdered charcoal; grind them a little together, and then put the mixture divided into three or four portions, into ſo many little glaſs retorts; cover theſe with a coat of *Windſor* loam, carefully laid on, to the thickneſs of one ſixth of an inch. Place theſe in a reverberatory furnace, and fit on large receivers filled with water, to ſuch a height, that the necks of the retorts may be buried an inch and half under the water. Make the fire gradually, but raiſe it at the laſt to the moſt extreme degree. Continue it in this unremitted violence; and after twelve or fourteen hours a bluiſh looking matter will fall from the necks of the retorts in ſmall quantities, and ſink to the bottom of the receivers. This is the phoſphorus. The fire is to be continued as long as any of it can be forced over; and then the veſſels are to be removed and unluted.

The phoſphorus now remains in the bottom of the receivers in looſe fragments, and it is to be collected together without taking it out of the water. To this purpoſe a ſmall veſſel is to be put into each receiver, and the quantity of phoſphorus it contains is to be got together, and taken out covered with water in this ſmaller veſſel. This veſſel is to be ſet in a ſand heat, and by degrees the phoſphorus will melt, as the water continues boiling. When it is thus reduced to a maſs, it is to be put into a proper veſſel, and kept always under water, except when it is taken out to be uſed. The method here laid down, though tedious, is not difficult.

Phoſphorus of Lime.

REDUCE to powder ſix ounces of crude ſal ammoniac, and mix it with thirteen ounces of lime, that has been ſlack'd by the air, or has lain in the air till it has fallen to powder. Mix theſe very well together, and put them into a crucible big enough to hold twice the quantity. Melt them together in a ſtrong fire, and as the matter ſwells and riſes up, ſtir it about with a ſpatula: when it runs perfectly in every part, remove it from the fire, and pour it out into the bottom of a mortar; let it cool, and preſerve it in a wide mouthed glaſs well ſtopped.

At any time when a piece of this is ſtruck upon with a hammer, it takes fire, and burns as it breaks under the blow.

Of

Of Objects for Microscopes.

THE works of nature are the only ſources of true knowledge, and the ſtudy of them the moſt noble employment of the mind of man. Every part of the creation demands his attention, and proclaims the power and wiſdom of its Almighty Author. The ſmalleſt ſeed, the minuteſt inſect ſhews the ſkill of providence in the aptneſs of its contrivance for the purpoſes it is to ſerve, and diſplays an elegance of beauty beyond the utmoſt ſtretch of art.

The wiſe in all ages have been ſenſible of this truth; and, as far as they were able, have ſtudied and enquired into the receſſes of nature; but for want of proper helps have frequently been miſtaken. As certain principles muſt firſt be learned e'er we can become maſters of any ſcience, ſo in the ſchool of nature, we muſt begin with the *minutiæ*, the ſmalleſt and moſt uncompounded parts, e'er we can underſtand the larger and more conſiderable.

The ancients, having only their naked eyes to truſt to, were uncapable of any great diſcoveries of this ſort: but we are ſo happy, that by the help of glaſſes, we can diſtinguiſh and examine objects many thouſands of times leſs than what the ſharpeſt eye unaſſiſted can diſcern: In ſhort, microſcopes furniſh us as it were with a new ſenſe, unfold the amazing operations of nature, and preſent us with wonders unthought of in former ages.

Who, a thousand years ago, would have imagined it possible to distinguish myriads of living creatures in a single drop of water? Or, that the purple tide of life, and even the globules of the blood, should be seen distinctly rolling through veins, and arteries smaller than the finest hair? That thousands of animalcules should be discovered in the *semen masculinum* of all creatures? That not only the exterior form, but even the internal structure of the bowels, and the motion of the fluids in a *gnat* or *louse*, should be rendered objects of sight? Or that numberless species of creatures should be made visible, though so minute, that some thousands of them are less than a grain of sand?

These are noble discoveries that enlarge the capacity of the human soul, and furnish a more just and sublime idea than mankind had before, of the grandeur and magnificence of nature; and the infinite power, wisdom and goodness of the Divine Being.

He must certainly be delighted with the works of nature who makes them his study; since every animal, flower, fruit, or insect, nay, almost every particle of matter affords him entertainment. Such a man can never feel his time hang heavy on his hands, or be weary of himself, for want of knowing how to employ his thoughts: each garden or field are to him a cabinet of curiosities, every one of which he longs to examine fully; and he considers the whole universe as a magazine of wonders, which infinite ages are scarce sufficient to contemplate and admire enough. Indeed, when we compare the structure of a mite with that of an elephant, the largeness and strength of one may strike us with wonder and terror; but we shall find ourselves

quite

quite loſt in amazement, if we attentively examine the ſeveral minute parts of the other. For the mite has more limbs than the elephant, each of which is furniſhed with veins and arteries, nerves, muſcles, tendons and bones: it has eyes, a mouth, and a proboſcis too (as well as the elephant) to take in its food; it has a ſtomach to digeſt it, and inteſtines to carry off what is not retained for nouriſhment: it has an heart to propel the circulation of its blood, a train to ſupply nerves every where, and parts of generation, as perfect as the largeſt animal. Let us now ſtop, look back, and conſider, as far as our abilities can reach, the exceſſive minuteneſs of all theſe parts; and if we find them ſo ſurpriſing and beyond our ideas, what ſhall we ſay of thoſe many ſpecies of animalcules, to whom a mite itſelf is in ſize as it were an elephant.

All theſe and numberleſs wonders more the microſcope can exhibit to us. I have deſcribed this noble invention in the *Introduction to uſeful Knowledge*, and ſhall now point out ſome objects for the curious to examine by it.

1ſt. The ſilver tree, in the preparing of which obſerve the following directions: diſſolve a little ſilver in a ſmall quantity of aqua-fortis; when this is done, add twice the quantity of common water to it, and the preparation will be made. When you apply it to the microſcope, drop a little upon a plain glaſs, and put therein a ſhort piece of ſmall braſs wire, and immediately trees will appear growing, which may be obſerved till it has ſpread as far as the liquid extended.

2d. The cryſtallization of ſalts are curious objects, and are prepared in the following manner. Diſſolve a little

ſal-ammoniac

ſal-ammoniac in common water, place it upon the glaſs as above directed; and while you are viewing it, hold a hot iron near the glaſs in order to make it more expeditious in evaporating; which, as ſoon as it takes place, imitates the branches of trees, and diſplays ſuch beauty, as will fill every beholder with wonder and admiration. N. B. Every different kind of ſalt forms a different figure.

3d. A variety of other curious collections will be found highly entertaining, viz. 1. The fly. 2. Louſe. 3. Mites in cheeſe. 4. Scales of fiſhes. 5. Eels, ſerpents, or little worm-like animalcules found in vinegar and paſte. 6. Animalcules in ſeveral infuſions. 7. Feathers. 8. Hair. 9. Wings of flies. 10. Flies which infeſt fruit and other trees. 11. Sting of a bee. 12. The human ſkin. 13. Tranſverſe cuttings of wood. 14. The beard of a wild oat. 15. Mouldineſs. 16. Small ſeeds, &c.

This ſmall claſs of objects is but trifling in compariſon of the inexhauſted ſtore which abounds in every part of the creation, and there is not a particle of matter but what affords amuſement for the microſcope.

F I N I S.