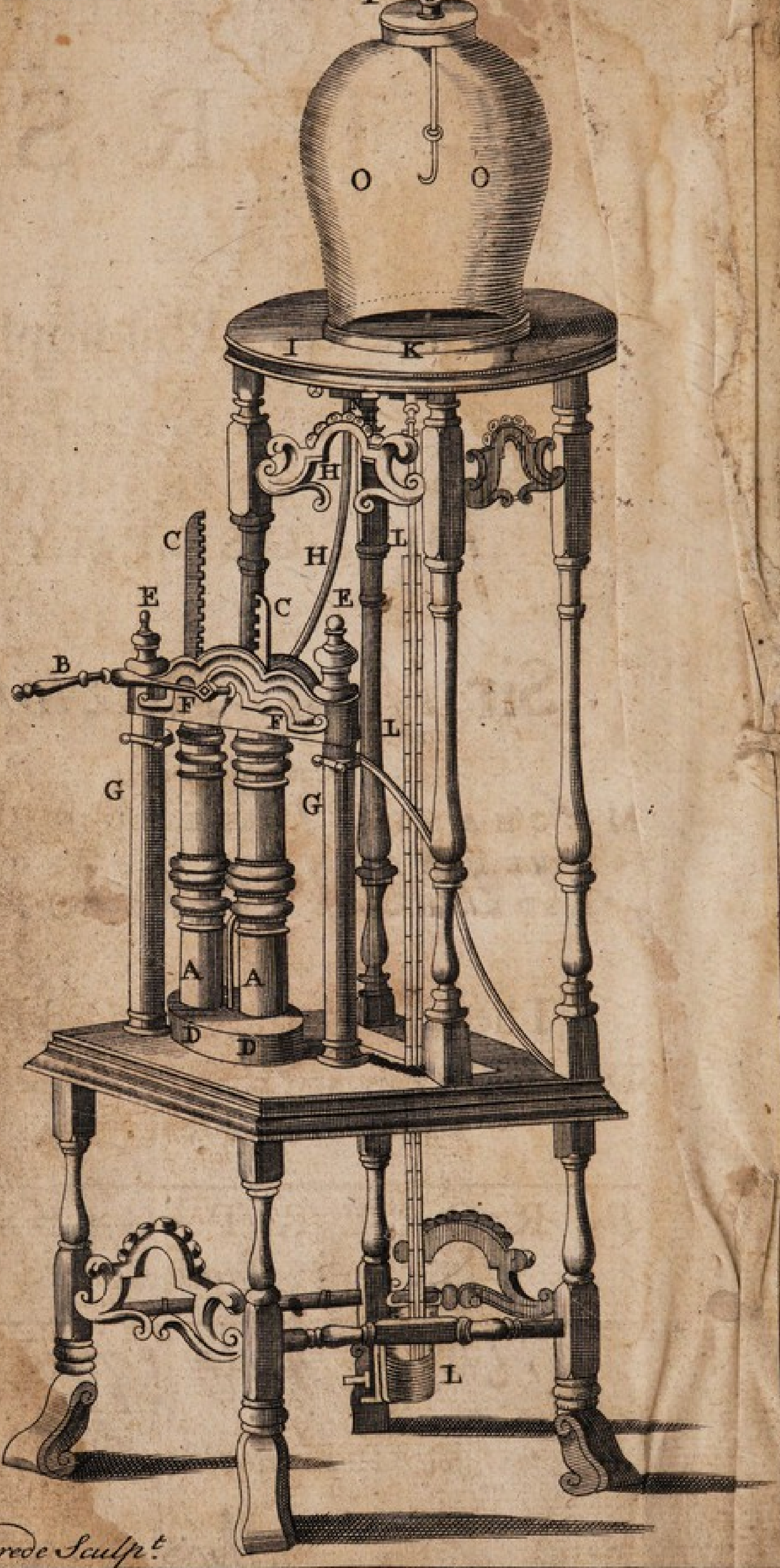
Common AIR-Pump



D. Pomarede Sculp^t.

A

COURSE

OF

Experimental Philoſophy;

BEING

An INTRODUCTION to the true PHILOSOPHY OF

Sir *Iſaac Newton*.

Containing,

MECHANICS, HYDROSTATICS, PNEUMATICS, OPTICS, and ASTRONOMY.

To which is added,

The Uſe of the GLOBES,

Done in an eaſy and familiar Manner for the Uſe of young Gentlemen.

By ROBERT GIBSON,

Teacher of Mathematics.

DUBLIN:

Printed for the Author, and OLI. NELSON, at *Milton*'s-Head in *Skinner-Row*, 1755.

Trinity College

PREFACE.

AS the Reader in perusing the following Sheets, will find the great Advantages which arise from the Subject, it will be unnecessary to say any Thing here in Recommendation of it: Therefore what I have to say concerning the Work, must be of the Design, and the Manner of it's Execution.

The Design then is, to explain in the most easy and concise Manner, so much of the Science, as may enable young Gentlemen, or Men of Business, to form a general Idea *of the Elements, or Rudiments of it: Experience in my Profession has convinced me that few desire more, or will give themselves the Trouble to form a critical Notion of every Part of it; because they must contend with voluminous Tracts, which contain many abstruse mathematical Reasonings, that require a previous Knowledge of the Elements of Euclid, Conic-Sections, Algebra, and Fluxions: And indeed a general and concise Description or Account of any Art or Science, is best adapted to answer the Views and Ends of the greatest Part of Readers.*

As to the Execution of the Work, the Subject is for the most Part illustrated by Experiments that carry with them Evidence, sufficient to satisfie the most curious Mind: There are some Geometrical Demonstrations,

ſtrations, which if the Reader would underſtand, will require the Aſſiſtance of Euclid; but as theſe are only a few, they may be paſſed by, by ſuch as are ignorant of Geometry, taking the Premiſſes of the Propoſition for granted. The other Reaſonings, where neither Experiment, nor Mathematics can be introduced, it is hoped, will be found to be ſufficiently Evident.

In drawing up this Courſe, I have not ſcrupled to take whatever I judged might beſt anſwer my Purpoſes, from the beſt Authors.

I will not pretend to ſay how far I have ſucceeded in my Intention, by rendering the Subject clear and evident; this, no doubt, will beſt appear to the Reader: But ſhould it prove ſo, and be a Means of exciting a Deſire in any to proſecute the Subject farther, my ultimate Wiſhes will be crowned with the deſired Succeſs.

Dublin May, 10th 1755.

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A
COURSE
OF
EXPERIMENTAL PHILOSOPHY.

CHAP. I.

Of the Properties *of* MATTER.

SINCE *Natural Philosophy* is not only the most pleasing, but the most useful Science for the Ease and Convenience of Life, it is no Wonder that Men in all Ages have embraced the Study of it. The numberless Improvements it has received from the *Philosophers* of the last Century, by betaking themselves to Experiments and Observations, far exceed what the Antients could ever arrive to, from the Measures they pursued by setting out upon Hypotheses or

Suppoſitions, ſo that what was in the utmoſt Obſcurity and Confuſion, is now rendred clear and evident; and this for the moſt Part is owing to the Diſcoveries of the Great Sir Isaac Newton. To illuſtrate ſome of theſe Truths, or to account for the Appearances of Nature from Experiments, in an eaſy and familiar Way, is the Deſign of this Courſe: In order to which it will be neceſſary, firſt to conſider the *Properties of Matter.*

Def By the Word *Matter*, we underſtand every Thing that has Extenſion or Bulk, and that reſiſts the Touch; or it is that which we call the Subſtance of Things, or that of which all Things do conſiſt under different Forms and Modes.

The Properties of *Matter*, or *Body*, are either *univerſal* and common to all Bodies, or *accidental* and peculiar to ſome only.

The Principal of the *univerſal Properties* of all Bodies or Matter, are theſe. 1. *Solidity.* 2. *Diviſibility*, 3. *Inactivity*, and 4. *Gravity.* And of theſe ſeverally.

I. *Solidity* is that Property of Body, which excludes all others out of the Place it poſſeſſeth; for no two Bodies can poſſibly be in one and the ſame Place at the ſame Time, for every Particle of Matter is impenetrable. Hence the Matter of the *ſofteſt Bodies* is equally *ſolid* with that of the *hardeſt*: Thus, a cubic Inch of Water will be no more compreſſed into leſs than a cubic Inch of Space, than will a cubic Inch of Iron or of Adamant.

II. *Divisibility* is a Property of Matter which follows from the last; for since no two Bodies, or Particles of Bodies can possibly be in one and the same Place at the same Time, they must exist in different Places; and so may be considered as distinct and seperate from each other, and therefore to be divided. The *actual Divisibility of Matter* will appear very surprizing from the following Experiments.

1. If an Ounce of Silver be gilt with 8 Grains of Gold, it may be afterwards drawn out into a Wire 13,000 Feet long, which shall be so closely covered with Gold, that the Silver cannot be seen with the best Microscope. Hence we may easily find, that one Grain of Gold may be actually divided into 1,950,000 visible Parts, each being the one hundredth Part of an Inch.

2. That great Philosopher, the Hon. *Robert Boyle*, Esq; who has furnished us with many Experiments on this Subject, tells us, that he dissolved one Grain of Copper in Spirit of Salt *Armoniac*, and that the Solution, when mixed with 28,534 Grains of Water, communicated a very deep and conspicuous blue Tincture to the Whole. Now, because a Grain of Water is found to be equal to .0037 of a cubic Inch, 28,534 Grains of Water will be equal in Magnitude to 105.5758 cubic Inches. If therefore a Line whose Length is the hundredth Part of an Inch, be easily discerned by the Eye, a Cube, whose Side is of that Length, will be much more discernable; but a cubic Inch contains one Million of such small Cubes, therefore 105.5758 cubic Inches will contain 105,575,800

 small

ſmall Cubes, the Side of each being the hundredth Part of an Inch; and thus, by this Solution, one Grain of Copper was divided into as many viſible Parts. But a cubic Inch of Copper contains almoſt 20,000 Grains, and therefore it may be actually reſolved into 2,111,516,000,000 viſible Parts: and if of this Copper there be taken a Particle of the Size of the leaſt Grain of Sand, or one whoſe Diameter is the hundredth Part of an Inch, ſuch a Particle of Copper, by the foregoing Solution, may be reſolved into 2,111,516 viſible Parts.

3. Mr. *Boyle* has alſo found by Experiment, that a certain Quantity of *Aſſa Fœtida*, which he expoſed to the open Air, loſt the eighth Part of a Grain of its Weight in ſix Days: But becauſe the Flux from odoriferous Bodies is continual, therefore it ought to be proportionable to the Time; and hence the Weight of the Effluvia which proceeded from the *Aſſa Fœtida* in one Minute, was the 69,120th Part of a Grain. Now the Magnitude of a Particle of Water, whoſe Weight is one Grain, is .00369 Parts of a cubic Inch; therefore a Particle of the ſame Water, whoſe Weight is the 69,120th Part of a Grain, will be equal in Magnitude to .0,000,000,533 Parts of a cubic Inch: but the Gravity of *Aſſa Fœtida* is to that of Water, as 8 to 7, and therefore the Magnitude of a Quantity of *Aſſa Fœtida*, whoſe Weight is the 69,120th Part of a Grain, will be equal to .0,000,000,466 Parts of a cubic Inch. Let us now ſuppoſe that we are capable to ſmell the Effluvia ariſing from

the

the *Assa Fœtida* to the Distance of five Feet only, on every Side, and that every Particle in the odorous Sphere be so large as the fourth Part of a cubic Inch, then the Sphere will consist of 57,836,916 of such Particles producing the Odour: Now all these Particles have been shewn to be equal to .0,000,000,466 Parts of a cubic Inch, therefore one of such Particles will be no more than .0,000,000,000,000,008 Parts of a cubic Inch, which is surely surprizingly small; notwithstanding, in this Computation we have supposed the odorous Sphere equally replete with the Effluvia, without allowing the Particles near the *Assa Fœtida* to be denser than those which are farther off.

4. Mr. *Lewenhoeck* tells us, that there are more Animals in the Milt of a single Cod-fish, than there are Men on the Earth; and from the Data of the Microscope he shews, that one of these Animalcula is at least 4,000,000 Times less than the smallest visible Grain of Sand. How inconceivably small then must the Globules of their Blood be? In short, upon reasonable Suppositions he shews, that they are so much less than a Grain of Sand, as a Grain of Sand is less than the Globe of the Earth; and tho' this Subtility of Nature is wonderful beyond measure, yet there are other Particles of Matter still more subtile than these; for the before-mentioned Globules are as vast Mountains when compared to the Particles of Light.

Having thus far considered the wonderful Subtility of Nature, and the minute Particles into which Matter is actually divided, it remains, that we now prove, the *infinite Divisibility of Matter*.

Fig. 1.

Fig. 1. A Line AB may be infinitely divided thus: Through the Points A and B, the Extremities of the Line AB, let the Parallels CD, EF be drawn; assume any Number of Points on one Side of the Line AB, as *a*, *b*, *c*, *d*, *e*, &c. from B towards F, and let any Point C be taken on the other Parallel AD, and on the other Side of the Line AB; then, if from the Point C to the Points *a*, *b*, *c*, *d*, &c. there be drawn the Lines C a, C b, C c, C d, *&c.* these will all cut or divide the Line AB, but none of the Points of Intersection can ever arrive to the Point A: For if the Point F were taken at an infinite Distance from B, there would still be an Angle FCD, equal to CFB (by 27.1 *Eucl.*) and therefore a Line A o, a Part of the Line AB will still remain undivided, and consequently A B is divisible in Theory, *ad infinitum.*

Fig. 2. Or a Line may be infinitely divided thus: Let a Circle be drawn, and its Diameter CD be infinitely continued on one Side, and to the Point C, one of the Extremities of the Diameter, let the Tangent AC be drawn, and the Secant AE: Now let AB be the Line to be infinitely divided; lay out upon the Radius ED, or upon the Continuation of the Diameter as many Points as you please, and with the Distance of each of these Points to the Point of Contact C, let ever so many Arches be described, they will respectively cut or divide the Line AB; and though a Point were taken upon the Diameter at an infinite Distance from the Point of Contact C, and with that Distance an Arch C *o* were described, the Point *o* of that Arch

Arch could never arrive to the Point A, inasmuch as a tangent Line can only touch a Circle in one Point, (by 13.3 *Eucl.*) and therefore a Line A *o*, a Part of the Line AB, will ſtill remain undivided, and conſequently AB may be infinitely divided.

III. *Inactivity* or *Paſſiveneſs* of *Matter*, is that Propenſity it has to continue in the State it is in, whether of Reſt or Motion, 'till it is made to alter the ſame by the Action of ſome external Force: And therefore if one Body contains two or three Times the Quantity of Matter that another does, it will alſo contain two or three Times the Inactivity; that is, it will require two or three Times the Force to put it into an equal Degree of Motion. And from this Principle are deduced the *Laws of Motion*, which will be explained in the following Chapter.

IV. *Gravity* is that univerſal Diſpoſition of Matter whereby a *leſſer Part* is carried towards the Center of any *greater Part*; thus all Parts of Matter or Bodies on the *Earth*'s Surface, have a Tendency to deſcend to its Center: and this is called their *Weight* and *Gravitation* in the leſſer Body, but *Attraction* in the greater.

Attraction is uſually diſtinguiſhed into that of *Coheſion* and *Gravitation*.

Attraction of Coheſion is that whereby very minute Bodies, or the Particles of the ſame Body are mutually drawn towards each other, and made to cohere and ſtick together. Thus,

1. If

1. If ſmall Glaſs Tubes, open at both Ends, be dipped in Water, Claret, Spirit of Wine, or any other convenient Fluid, the Fluid will riſe up the Tubes to a conſiderable Height above the Level; which muſt be owing to the Attraction of the Particles of Glaſs, becauſe the ſame Thing holds good in *Vacuo*, or in a Place void of Air, as under the Receiver of an Air-Pump, out of which the Air is exhauſted by Pumping.

2. The Heights to which a Fluid will riſe in Tubes of different Diameters, will be inverſely as the Diameters. *Fig.* 3. Thus, if the Diameter of the Tube A be double to that of B, the Fluid will riſe twice as high in B as in A.

3. If two poliſhed Plates of Glaſs be ſet parallel to each other at different ſmall Diſtances, and if their lower Edges be dipped in any Fluid, the Fluid will riſe between them in an inverſe Proportion to their Diſtance aſunder, as in the foregoing Tubes. If the Diſtance be about the hundredth Part of an Inch, the Fluid will riſe about an Inch high, and ſo in *Vacuo*.

4. Let the Edges of the poliſhed Glaſs Plates be cloſed at AB, and the oppoſite Edges at CD be kept a little diſtant by putting a Six-Pence, or any thin Body between them; if then the lower Edges be dipped in any Fluid, the Fluid will riſe between the Plates, and form an *hyperbolic Curve*, becauſe the Heights of the Fluid are inverſely proportional to the Diſtances of the ſeveral Parts of the Plates, and theſe as their Diſtances from their Point of Meeting at A, *Fig.* 4. For if AE, AG, AI, AD,

be

be taken as Abſciſſæ, then EF, GH, IK, DL,
will be the reſpective Ordinates, and conſequently
the Curve FHKL will be an *hyperbolic* one. 4th

5. Two little Spheres of Mercury brought near
each other, will mutually attract each other, and
become one Sphere.

6. A piece of Loaf Sugar will attract or draw 5
up a Fluid; in the ſame Manner Sap aſcends
in Trees, a Spunge ſucks in Water, and the Glands
of the Body draw in various Juices from the
Blood.

7. *Fig* 5. If two Pieces of Lead with convex 6
Surfaces be ſcraped clean and preſſed cloſely to-
gether, they will attract each other ſo ſtrongly
as to require 100, or 150 Pound Weight, to pull
them aſunder.

Hence it is eaſy to account for the Formation
of Bodies. For thoſe Particles that attract each
other ſtrongly, and touch each other in many
Points, form hard Bodies; thoſe whoſe Particles
touch each other in fewer Points, and perhaps do
not attract each other ſo ſtrongly, will conſtitute
ſofter Bodies, as Lead, Pewter, *&c.* thoſe whoſe
Particles are perfectly round, ſmooth, and void of
Attraction, if any ſuch there be, will conſtitute a
perfect Fluid; and thoſe whoſe Particles are not
round and void of Attraction, will form only an
Heap of Duſt or Sand.

This Kind of Atttaction extends but to ſmall 7
Diſtances; for if the two Spheres of Mercury be-
fore-mentioned be rolled in Duſt, they will not
run together, for the Duſt prevents Attraction.

Where the Sphere of Attraction ends, a repulſive Force begins; thus Water repels moſt Bodies, 'till they are wet. And it is upon this Principle that a dry Needle will ſwim upon Water, and that Flies walk upon it.

Attraction of Gravitation is that by which diſtant Bodies move to or tend towards one another; it is diffuſed throughout the ſolar Syſtem, and is probably extended to the other Syſtems of the Univerſe, yet at preſent we will conſider it only with reſpect to the Earth, the Parts whereof would fly aſunder by the diurnal Rotation, were they not kept together by the Influence of Gravity; whereby alſo we have dayly Inſtances of Bodies falling on the Earth, and of others on it to tend towards its Center.

This Power, at equal Diſtances from the Earth's Center, is always proportional to the Quantity of Matter in the Body on which it acts; for light and heavy Bodies, falling from the ſame Height, deſcend with equal Swiftneſs, provided they meet with no Reſiſtance from the Air. Thus, if a Piece of Gold and a Feather be let fall from the Top of an exhauſted Receiver at the ſame Inſtant of Time, they will both arrive at the Bottom in the ſame Time very nearly, and would in the very ſame Time, could the Receiver be perfectly exhauſted.

Hence the Forces of Gravity, whereby Bodies deſcend, muſt, at equal Diſtances from the Earth's Center, be as the Quantity of Matter in the deſcending Bodies; for if a certain Force of Gravity

carries

carries a Body of a certain Quantity of Matter, with a certain Swiftneſs, then a Body of double that Quantity of Matter, will require double that Force to give it the ſame Swiftneſs: So the Weights of Bodies at equal Diſtances from the Center of the Earth, are as the Quantities of Matter they contain, and therefore the Quantity of Matter in any Body may be meaſured by the Weight.

Sir ISAAC NEWTON has proved that the Gravity of any Body within the Earth's Surface, is as its Diſtance from the Center: Thus, if the Earth's Surface were 4000 Miles, from the center and a Body on its Surface weighs a Pound, then at 3000, 2000, or 1000 Miles from the Center, that Body will weigh $\frac{3}{4}$, $\frac{1}{2}$, or $\frac{1}{4}$ of a Pound, and ſo on to the Center, where it loſes all Gravity.

Gravity on and beyond the Earth's ~~Center~~ Surface, is inverſely as the Square of the Diſtance from the Center; or which is the ſame Thing, in a reciprocal Duplicate Ratio of the Diſtance from the Center, *viz.* at double the Diſtance it is four Times leſs, at triple the Diſtance nine Times leſs, *&c.* But where the Diſtances are ſmall, as $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, or a Mile, their Differences are ſo very ſmall, when compared to the Radius of the Earth, that they may be rejected, for they will not occaſion any ſenſible Error in Calculation.

The Velocity or Celerity of Bodies deſcending by the Force of Gravity, muſt be directly as the Times of their Deſcent: For ſince Gravity acts uniformly, equal Times muſt produce equal Effects,

As
if in a moment a Body falls a Mile
in twice the time it will fall

that is, a double or triple Time will produce a double or triple Velocity. Or if we imagine Gravity to exert itſelf by an infinite Number of Impulſes, then if one Impulſe in the firſt Moment of Time gives a Body a certain Degree of Velocity, in a ſecond Moment a ſecond Impulſe will give it another, a third another, and ſo on; ſo that this Force acting perpetually on the Body, muſt accelerate its Velocity proportionably to the Number of Impulſes; that is, proportionably to the Time of its Deſcent: The more ſwiftly any Body moves, and the longer it continues its Motion, the greater muſt the Space be which it runs over; ſo that the Space is had by multiplying the Time into the Velocity: But ſince the Velocity of deſcending Bodies are as the Times of their Deſcent, therefore the Space is had by multiplying the Time by the Time, or by ſquaring the Time. Thus, if a Body deſcends 2 Miles a Minute, for 2 Minutes the Space deſcribed muſt be 4 Miles; if 3 Miles a Minute, for 3 Minutes, the Space deſcribed muſt be 9 Miles, *&c.*

Hence 'tis evident, that the Space deſcribed

In 1 Minute will be 1 = the Square of 1.
In 2 Minutes will be 4 = the Square of 2.
In 3 Minutes will be 9 = the Square of 3.
In 4 Minutes will be 16 = the Square of 4, *&c.*

the Spaces being always as the Squares of the Times.

It has been found by repeated Experiments, that a heavy Body will fall 16 Feet and 1 Inch in a Second of Time, therefore in 2 Seconds it will deſcend defcend 4 Times as far, or 64 Feet 4 Inches; in 3 Seconds it will defcend 9 Times as far, or 144 Feet 9 Inches, &c.

Hence the Depth of a Well or Coal-Pit may be found, by obferving the Time a Body is falling to the Bottom.

In the fame Manner as heavy Bodies are accelerated in their Defcent, it is plain they muft be retarded in their Afcent. Therefore the fame Velocity which a Body acquires by falling, will be juft fufficient to carry it to the fame Height from whence it had fallen; for the Force of Gravity acting conftantly and equally againft the afcending Body will diminifh its rifing Motion 'till it is quite deftroyed.

The Center of Gravity of any Body is that Point wherein the whole Force of its Gravity is united and centred, fo that whatever fuftains that Point, bears the whole Weight of the Body; and if the Body be fupported at, or fufpended by, that Point, all the Parts of it will be in a perfect Equilibrium.

If a perpendicular Line be drawn from the Center of Gravity of a Body, it will tend towards the Earth's Center, and fuch a Line is called the *Line of Direction*. Def

The Center of Gravity continually endeavours to move downwards towards the Center of the Earth; and therefore if a Body feems to move upwards by the Force of Gravity, it will notwithftanding be found that the Center of Gravity defcends. Def

Fig. 6.

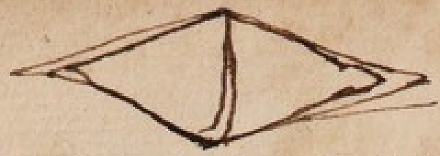


Fig. 6. Thus, if an Angle formed by two Rulers be placed on an horizontal Plane, and the Ends be raiſed above the Plane; and if a Body in the Form of a double Cone be laid near the angular Point of the Rulers, it will, when let go, move towards the raiſed Ends, and appear to aſcend, whereas it really deſcends: For the Center of Gravity conſtantly moves downwards, which will be eaſily obvious by performing the Experiment.

Fig. 7. Let a wooden Cylinder made hollow towards one Side, and filled with Lead, be placed on an inclined Plane, ſo that the Side which is neareſt the Center of Gravity may lean towards the upward Part of the Plane, it will then aſcend; but the Center of Gravity will at the ſame Time deſcend, provided the Inclination of the Plane be not too ſmall.

It is therefore contrary to the Nature of heavy Bodies, and of Courſe to the Center of Gravity, to aſcend of themſelves, or not to deſcend, when permitted ſo to do.

Fig. 8. Hence it is that Bodies ſtand when the Line of Direction falls within their Baſe: But if the Line of Direction, *Fig.* 9. falls without the Baſe, the Body will fall; for this Line does, as it were, tie it faſt to the Ground in the one Caſe, and pulls it over in the other.

Seeing therefore that the ſtanding of Bodies depend upon the Lines of Direction falling within their Baſes, it follows, that the larger the Baſe of any Body be, and the nearer its Line of Direction be to the Middle thereof, the more firmly muſt that

that Body ſtand; and that the leſs the Baſe of any Body be, and the nearer the Line of Direction be to its Side, the leſs firmly muſt that Body ſtand, and therefore it may be the more eaſily overthrown; becauſe the Line of Direction is ſooner and more eaſily removed out of the Baſe of the one, than of the other.

Hence it is that a Globe or Sphere rolls eaſily on a Plane, and that it is ſo difficult to make a pointed Body, as a Top, or a Needle to ſtand on its Point, or a thin Body on its Edge; and that a Body ſlides on an inclined Plane when its Line of Direction falls within its Baſe, when a Sphere or Cylinder being placed thereon will roll, and that any other Body whoſe Line of Direction falls without its Baſe, will tumble over.

Hence alſo it is that we are in the moſt firm Poſture when the Line of Direction falls juſt in the Middle between our Feet, that we are eaſily thrown down when it falls on or near either Foot, and that we fall, when it falls without either.

Hence alſo it is that we bend forward when we riſe from our Seat, or go up Stairs; that a Man leans forward or backward as he carries a Burden behind or before, or to the Right Hand or left, as he carries it on the oppoſite Side: and numberleſs other Inſtances of the like Nature might be added.

Having thus far explained the *Univerſal Properties* of Matter, it remains now to ſpeak of ſome of the *Accidental Properties* which are peculiar to ſome Bodies only; and more particularly thoſe of *Magnetiſm* and *Electricity*.

Magnetiſm

I. *Of Magnetiſm.*

Magnetiſm is a very ſurprizing Species of Attraction peculiar to that *Foſſil* called the *Magnet*, or *Loadſtone:* Theſe Stones are found in Iron Mines, and are much heavier and harder than Iron, but of that Hue; they are neither all of the ſame Size, Figure, nor indeed are they all exactly of the ſame Colour. The Properties peculiar to the Loadſtone are theſe.

1. It attracts Iron or Steel only.

2. If a Loadſtone put in a wooden Bowl-diſh, little Boat, or any light Thing that will ſuſtain it on Water, be let at Liberty, it will then turn one of its Sides towards the North and the other towards the South Parts of the Horizon; and theſe two Parts of the Loadſtone are called its *Poles*, and the Line which is ſuppoſed to paſs from one Pole to the other, is called its *Axis*.

3. Any Piece of Iron or Steel which has been touched by a Loadſtone will attract and lift up a leſſer Piece, and this laſt being touched by the former, will again attract a ſtill leſſer Piece, *&c.* and all theſe will have their Poles.

4. If a Knife be moved gently upon one of the Poles of the Loadſtone, from the Handle towards the Point, it will lift up more than if rubbed to any other Part; and if you then move the Knife on the ſame Pole gently from the Point towards the Handle, or the ſame Way on the other Pole, it will loſe all the Virtue it had before acquired,

and

and will not be able to lift up the ſmalleſt Needle.

5. That Point of a Needle of a Compaſs which has been touched upon one Pole of a Loadſtone, will Point to the oppoſite Part of the Heavens that Pole itſelf will turn to; thus, if the End of a Needle be touched on the South Pole of the Stone, it will, when ſet upon its Center-Pin, turn towards the North; and if it be touched on the North Pole of the Stone, it will turn towards the South; therefore the South Pole of a Loadſtone will attract the North End of a Needle or Sea-Compaſs, and repel the South End, and its North Pole will attract the South, and repel the North End of a Needle or Compaſs.

6. All Needles which are touched by the Loadſtone will point towards the North and South Parts of the Heavens nearly, and whatever Number of Degrees the Points of the Needle deviate from the true North and South Parts of the Heavens, juſt ſo much will be what is called the *Variation of the Needle*. The Needle varies in the ſame Place at different Times, and in different Places at the ſame Time. In the Year 1580 the Variation in *Dublin* was 11 Degrees eaſterly, and in the Year 1753 it was 19 Degrees weſterly; but how long it will continue ſo, Time and Obſervation muſt only determine. In ſome Places the Variation has been found to be 5, 10, or 15 Degrees, and at the ſame Time, at other Places, it has been found to be 20, 30, or 40 Degrees.

7. Bars of Iron which have ſtood a long Time in a perpendicular Situation will acquire the ſame

Virtue that a Loadſtone by touching will deliver to it in a Moment: Thus, the lower End of a *Window Bar*, or a Pair of *Tongs* with which we take up Coals, and which generally ſtands nearly perpendicular, will have the ſame Virtue as we find in the South Pole of a Loadſtone, and the upper End has the Virtue of the North Pole.

8. If a long ſlender Piece of Steel be heated red hot, and then dipped in Water perpendicularly; or if an Iron Rod be held perpendicularly, and the upper End of it be ſtruck by a Hammer; either of theſe will immediatly acquire the ſame Virtue of the above-mentioned Bar or the Tongs.

9. If two poliſhed Pieces of Steel be placed at the two Poles of a Loadſtone, they jointly will take up a much larger Piece of Iron, than the naked Stone itſelf will take up; for the Iron which is lifted up, touches the two Steel Poles, or the *Armour*, in more Points than the Stone itſelf can touch it in. But if the Armour be ruſty, ſo as to render the Contact leſs, or which is the ſame Thing, if we apply a ruſty Iron to it; or if betwixt the Armour and the Iron we put a Body that is very thin, as a Piece of Paper, it will then lift up no more than if it were unarmed, whereas the Interpoſition of ſuch ſort of Bodies does not at all alter the other Effects of the naked Loadſtone.

Hence it is that ſometimes a weak Loadſtone will carry off a Piece of Iron which is ſuſpended to one much ſtronger, and this muſt be when the weaker Loadſtone touches the Iron in more Points than the ſtronger does.

10. If a Braſs *Whirligig*, whoſe Axis is Iron or Steel, be ſpun round upon a Table, and then taken up by a Loadſtone, it will keep turning much longer than if it be left to move on the Table; becauſe the Friction is taken off, when it is ſuſpended by the Loadſtone, that it ſuffered when it was on the Table.

11. If a Loadſtone be let to take Ruſt, ſo as to get into its Pores, its Texture will thereby be deſtroyed, and the Stone will loſe much of its Virtue; and in like manner if it be put into a Fire, its Texture by that Means will be more deſtroyed, and therefore it will loſe much more, or perhaps all its Virtue.

12. The only Remedy to prevent a Loadſtone from Ruſt, or of being injured by too much Heat, is to ſurround it with a Coat of Iron; for the Iron will admit a much freer Paſſage to the magnetic Matter, than the Air does, for it bends itſelf and continues its Courſe in the Iron; and therefore the Pores cannot ſuffer ſo much as when the Stone is left naked in open Air.

13. If a Loadſtone be ſawed into ſeveral Pieces, each of theſe will have its particular Poles, which may be found by letting them ſwim in ſmall wooden Cups or Boats, as before.

14. It will be neceſſary here to obſerve, that the Needles of Surveying Inſtruments are frequently out of Order, and require often to be touched. The Reaſon of this, as I take it, is, that as ſoon as a Surveyor has finiſhed his Survey, he laps up his Needle in a Scrap of Paper, and throws it in any Manner into the Box by the Side of the Center-

D 2 Pin,

Pin, and in that Manner lets it lie 'till the next Time he has Occaſion to uſe it; if this proves a long Time, it is very probable his Needle will be out of Order: For the Needle, by the Virtue which is infuſed therein by the Touch of the Load-ſtone, as before, has a Tendency to point towards the North and South Points of the Heavens, and it will uſe all its Effort ſo to do, and will actually do ſo, if it be laid on its Center-Pin on an horizontal Plane in a Place where Iron is not near it to alter or change its natural Situation. Now, becauſe the Needle, when thrown by the Side of the Center-Pin, is debared of all its Power of pointing where it naturally would, tho' it exerts all its Power ſo to do, by the magnetic Virtue infuſed therein; it thereby ſuffers ſo great a Conflict, that it is deprived of its uſual Strength and Effort, by exerting it to no Effect, and thereby its magnetic Virtue is ſome way or other ſo withdrawn from it, that it becomes of little or no Uſe 'till it receives a new Touch; whereas, if the Needle be kept on its Center-Pin in an horizontal Poſition, as above, or if the Inſtrument be conſtantly uſed, the Needle will be many Years without requiring a new Touch. I am no Stranger to the Complaints of Surveyors concerning their Needles, and therefore I am the more confident in aſſerting that a Needle ſeldom, if ever, requires touching, which is conſtantly uſed, or kept on its Center-Pin; but the Cauſe of its not playing well, as it is termed, or not pointing duly as it ought to do, muſt either be owing to the Point of the Center-Pin being turned, ſo that the Friction of it againſt the Cap impedes the

the Motion of the Needle; or elſe that the Cap of the Needle is pricked, or a Hole is made therein by the Center-Pin being too ſharp, from a Jolt or Jump. So that in the general I am ſatisfied that Surveyors and Mariners would have fewer Complaints of their Needles and Compaſſes, were they kept always on their Center-Pins, except in carrying on Horſe-back or on a Carriage, where the Motion is very violent.

15. I have often heard it aſſerted, that Needles touched by different Loadſtones had different Tendencies towards the North and South Points of the Heavens, and therefore that different Needles had different Variations in the ſame Place; but from repeated Experiments, I have found the contrary. If indeed, Mathematical Inſtrument-Makers do not take ſufficient Care to put the Ring in the Box, ſo that the 360th and 180th Degrees thereof ſhall exactly correſpond with the Line on the Middle of the Index, and this again with the narrow Slits of the Sights, and with the Hairs in the Middle of the wide ones; the Difference ariſing in the Degree pointed to by two or more Needles, is to be attributed to the Inaccuracy of the Inſtrument-Maker, and not to any different Tendencies acquired by Needles being touched by different Loadſtones.

Laſtly, The attractive Quality of the Loadſtone acts in an inverſe or a reciprocal Ratio of the Diſtances the Iron or Steel is from the Stone; that is, at a ſingle Diſtance, the attractive Force is four Times greater than at a double Diſtance, and nine Times greater than at a triple Diſtance, *&c.*

II. *Of*

II. *Of Electricity.*

Electrics per se, are ſuch Bodies as will, when heated by Attrition, Rubbing, or Friction, attract and repel all light Bodies at the Diſtance of 10 or 15 Inches: Such are *Glaſs*, *Jet*, *Sealing-Wax*, *Agate*, and almoſt all Manner of *Precious Stones*, *Silk*, and *Amber*; from which laſt, on account of its general Character of taking up or attracting Straws, Pieces of Paper, and other light Bodies, it bears the Name of Electricity. *Non-electrics per se* are thoſe Bodies which cannot produce that Effect when rubbed, but they attract the electrical Effluvium or Matter from the *Electrics per se*, 'till they become replete, and then they produce the ſame Effects.

1. If a Glaſs Tube of about an Inch and an half Diameter, and two or three Feet long, be heated by Rubbing, it will alternately attract and repel all light Bodies. 2. It will not attract by being heated without rubbing. 3. Any light Body being once repelled by the Tube, will never ſuffer itſelf to be attracted again, 'till it has loſt its Effluvium by touching ſome *non-electric per se*. 4. If the Tube be rubbed with a moiſt Hand, or if it be touched by any Thing that is wet, it deſtroys the Electricity. 5. It attracts beſt when it is firſt rubbed with Bees-Wax, and after with a dry woollen Cloth. 6. When it is rubbed well, ſo as to be in good Order, if the Finger be moved by it, at the Diſtance of about half an Inch, the Vapour iſſuing therefrom, will ſnap and crackle againſt the Finger,

ger, and a Flaſh of Light will appear, if the Place be dark.

Fig. 10. If under a Glaſs Globe, or Glaſs Cylinder, fixed upon an Axis, be placed a Cuſhion covered with Buff Leather, and over it be hung a String of Wires from an Iron Bar which is ſuſtained by Silk Threads, proceeding from four wooden Pillars, and if the larger Wheel be turned briſk, and the Cuſhion be kept cloſe to the Cylinder, (which is affected by a Screw paſſing through the Spring to the Extremity of which the Cuſhion is fixed ;) then by the Attrition of the Cuſhion againſt the Glaſs, the Globe or Cylinder will emit a copious Electrical Effluvium, which being attracted by the Wires, will from thence be conveyed into the Iron Bar : From whence many Experiments may be performed, the principal of which are theſe.

1. If you put your Finger, or any other non-electric Body, near the electrified Bar, it will attract the Vapour viſibly, and a Flame will iſſue, crackle and ſnap in coming from the Bar, and in the Finger will be felt a ſlight prickling Pain.

2. If a Perſon ſtanding upon a Cake of Wax or Roſin, lays hold of the electrified Bar with his Hand, his Body will be filled with the electric Fluid which iſſues from the Bar through his Arm ; but this electric Matter will be loſt in the Floor, if the Cake, or whatever elſe he ſtands upon, be not an *electric per ſe*. And if any Perſon touches any Part of him who is ſo electrified, the electric Flame or Matter, will iſſue from the Part where he is touched,

touched, into the Finger that touched him, with a Snap, and will raiſe a ſudden prickling Pain in both.

3. If the electrified Bar be touched by any electric Body, as Glaſs or Wax, the Spark or Flame will be ſcarcely ſenſible, and therefore the Conſideration of it is avoided.

4. If two Perſons ſtanding on *Electrics per ſe*, be equally replete with the electrical Matter, touch each other, nothing will be ſeen to iſſue, ſo as to cauſe either Flame, Snap, or Senſation; becauſe in this Caſe, they may be looked upon as *Electrics per ſe*, and therefore will rather repel than attract each other: For if two Feathers be tied with ſmall flaxen Threads, and hung cloſe to each other over the Bar before it is electrified, upon electrifying the Bar, they become in a Moment electrified, and then they repel each other.

5. If two Perſons ſtand on Cakes of Wax, or on ſeperate electric Bodies, and if one of theſe only be electrified, then as often as either touches the other, ſo often will the Perſon who is not electrified attract the electrical Matter from him, that is, 'till they are equally replete with it: On their firſt Approach, the Snap and Senſation will be ſtrong, the ſecond Time it will be weaker, the third ſtill leſs, and ſo on; 'till the electrified Perſon communicates to the other Half of the electrical Matter he at firſt contained, except the little that is diſſipated at every Snap: For if another Non-electric touch each Perſon, the like Senſation will ariſe from both; and if the electrified Perſons

Perſons then touch each other, the Effect will not be ſenſible to either.

6. If there be three Bodies electrified which are of a given Magnitude, but different Denſity, one of Wood, another of Stone, and the third of Iron; then, if Bodies of the ſame Kind, which are not electrified, be held ſeperately towards each of them, the Senſation, Flame, and Snap will be greateſt from the denſeſt Bodies, weaker from the leſs denſe, and exceedingly weak from the Bodies that are leaſt denſe. Again, if the denſeſt touch the rareſt Body, the Effect will be ſtronger than when the rareſt Bodies touch each other, and weaker than when the denſeſt Bodies approach each other.

7. If a Wire be electrified in the Dark, and a Non-electric be held at ſeven or eight Inches Diſtance from the End thereof, there will be then ſeen to iſſue from the Wire, a continual Stream of luminous Matter, which will diverge to the Non-electric: The Divergency will gradually leſſen, 'till it becomes parallel, by approachiug nearer with the Non-electric. Again, if the Non-electric be held, not directly before the End of the Wire, but wide and diſtant about two Inches therefrom, the iſſuing Matter will deſcribe curvilinear Rays towards ſuch Non-electric.

8. If a Perſon holds a ſpoonful of warmed Spirits of Wine or Oil of Turpentine within an Inch or two of the Finger of a Perſon who is electrified, the Fluid and Spoon being Non-electrics, will attract the electrical Matter from his Body, ſo as to ſet the Spirits or Oil on Fire.

9. If a Perſon be bled in the Arm, and the Height to which the Blood riſes be well obſerved: If this Bleeding Perſon be immediately electrified, his Blood will be found to riſe to almoſt double the former Height, and the Globules towards the Top of the Stream, being now electrified, and therefore may be conſidered as *Electrics per ſe*, will repel one another: But as ſoon as he leaves the electric Body upon which he ſtands, or diſengages himſelf from the Bar, the Blood will immediately leſſen in its Height; and it will alternately riſe and fall as he touches and quits the Bar. The like may be done by electrifying a Copper Fountain when the Jet is ſet going.

10. If a light Wheel of Paper, made in much the ſame Manner with the Leaves of a Water-Mill, having a Needle for its Axis, be thence ſuſpended by a Loadſtone, and held oppoſite the End of an electrified Wire or Sword, it will be carried round with a ſurprizing Velocity.

11. If a Vial, cloſely covered with Lead, or any other Non-electric, be filled with Iron or Steel Filings, and ſecurely corked up, has a Wire inſerted through the Cork, and Filings contained in the Vial, the Cork being well covered with Wax, be electrified, the Vial by that Means will contain a great Quantity of Effluvium: If then a Perſon takes hold of another Wire or Chain iſſuing either from the Top of the inſerted Wire, or from the Bar, by one Hand, and he gives his other Hand to another, and that ſecond his other Hand to a third, and ſo on with ever ſo many Perſons; then, if the laſt Perſon of this Chain of Perſons touches the

Bar

Bar with his Finger, or a Wire, the electric accumulated Matter will instantly explode, and all the Persons composing the said Chain, will feel a very sensible Shock at the same Moment; which Shock may be encreased to a surprizing Degree, if two or three such Vials be electrified in the like Manner; which will be manifest from what has been already said.

The Cause of Gravity, as well as those of Magnetism and Electricity, having not hitherto been sufficiently accounted for by the most Ingenious, we therefore wave any Attempt of that Nature.

CHAP.

CHAP. II.

Sir ISAAC NEWTON'S Laws of Nature, *or* Laws of Motion *explained.*

Law I.

or

Every Body will continue in its State of Reſt, of moving uniformly in a right Line; except ſo far as it is compelled to change that State by Forces impreſſed.

THERE being in all Bodies a certain inactivity whereby they oppoſe every Change; therefore a Body at Reſt would remain ſo for ever, except it were compelled to change that State by a Force impreſſed. In the ſame Way, a Body in Motion would for ever continue to move forward in a Right Line, if ſome Force did not oppoſe its Progreſs; for there is not required a leſs Force to ſtop the Motion of any Body, than was before neceſſary to give that Body Motion. Since then the *Vis Incertiæ*, or Inactivity of Matter equally reſiſts equal Changes, it will not be leſs powerful to continue a Body in Motion, than to preſerve a Body in a State of Reſt.

Law II.

The Change of Motion is always proportionable to the moving Force impreſſed, and is always according to the right Line in which that Force is impreſſed..

For if any Force or Power gives a certain Motion to a Body, a double Force will give it a double, and a triple Force a triple Motion: And this Motion will be in the ſame Direction with the Force impreſſed, becauſe it ſolely ariſes from it; nor can any Body change from this Direction it acquires from the firſt impreſſed Force, except it be actuated on by ſome new Force which is in a different Direction: So that if this new Force be in the ſame Direction with the firſt acquired Motion of the Body, it will add to that Motion; and if it be oppoſed to the firſt Motion in an oppoſite Direction, it will retard it; but if it be impreſſed on the firſt Motion in an oblique Direction, it will be compounded of the two Forees as will be juſt now ſhewn.

Law III.

Re-action is always equal and contrary to Action; or the Action of two Bodies upon each other are always equal, and in contrary Directions. That is, by Action and Re-action equal Changes of Motion are acting upon each other, and theſe Changes are impreſſed towards contrary Parts.

Whatever preſſes or draws another Thing is equally preſſed or drawn by it, but in a contrary

Way.

Way. If a Horſe draws a Load, he is equally drawn back by it; for as much as he promotes the the Progreſs thereof, ſo much is he retarded in his Motion; that is, he, in Effect, is drawn back; for the ſame Force of Muſcles and Sinews which he exerts to draw the Load, would, if he were freed from it, carry him to a much greater Diſtance; and conſequently ſo far as his Progreſs falls ſhort of that Diſtance, he is in Effect juſt ſo far drawn back; and the ſame Motion he communicates to the Load, ſo much does he looſe of his own, the Load retracting upon him with the ſame Force he acts upon it: For which Reaſon if the Weight of the Load be increaſed ſo as to require the Horſe's whole Strength, no Motion will enſue.

When a Loadſtone attracts Iron, it is equally attracted by it. For let a Piece of Iron and a Loadſtone of equal Weight be ſuſpended by Cords of equal Lengths, and let them be within the Sphere of Attraction; then they will mutually move towards each other, and meet at the middle Point of their firſt Diſtance: And if either be fixed it will attract the other. And the like obtains in all Kinds of Attraction.

If there be two Boats of equal Dimenſions, or of the ſame Quantity of Matter placed by each other, if a Perſon in either puſhes the other Boat they will both equally recede from the Place they were in together. But if one Boat contains double or triple the Quantity of Matter of another Boat; and theſe Boats be placed by each other, if a Perſon in either puſhes the other Boat, the ſmaller Boat will recede twice or three Times as far as the larger;

ger ; that is, the Velocity of the ſmaller Boat will be two or three times greater than that of the larger, tho' the *Momentum*, or Quantity of Motion in each, that is, the Force impreſs'd upon each will be the ſame ; Action and Re-action being equal and contrary. In the ſame Way, if a Man in a Boat, which lies on one Side of a Man of War, whoſe Quantity of Matter is 1000 Times greater than that of the Boat, the Boat will then fly 1000 Times farther from the Man of War than the Man of War will from the Boat ; thus, if the Boat flies 10 Feet from the Man of War, the Man of War will have flown but the one hundreth Part of a Foot from the Boat ; yet the Moment, or Quantity of Motion in each will be the ſame. Hence, if one in a Boat puſhes againſt a Rock or Shore, the Boat will recede from either, while the Rock or Shore is immoveable : For the whole Earth, of which either is but a Part, is inconceiveably large with reſpect of the Boat ; and therefore the Velocity of the former may be eſteemed nothing in reſpect of what is found in the latter.

Or a Stone in the Air as much gravitates the Earth as the Earth does the Stone ; that is, a Stone as much draws the Earth towards it as the Earth does the Stone ; but becauſe the Quantity of Matter in the Stone is infinitely leſs than that in the Earth, the Velocity of the Stone will be infinitely greater than that of the Earth ; for, phyſically ſpeaking, that of the Earth will be nothing, which will eaſily appear upon a Calculation.

When a Boat is rowed with Oars, the Ends of the Oars drive the Water backwards, but the Wa-

ter

H ter acting upon the Oars forces them with the Boat to which they are fixed forwards: For if the Oars had nothing to act on, there could be no Re-action or Motion, since no Force could be impressed. Seeing therefore a Boat is carried forwards by the Re-action of the Water on the Oars, it follows that the broader the Blades or Ends of the Oars be, or the greater Number there are of them, or the swifter the Strokes are, the greater the Action must be against the Water, and of Course the greater the Re-action, and the Progress of the Boat must be.

Hence because swiming is nothing else than a Rowing with Hands and Feet; it is, that Persons are carried forwards in the Water. In like Manner Birds fly; for, by striking the Air downwards with their Wings, the Re action of the Air drives them upwards; and in striking the Air with their Wings backwards, the Re-action of the Air gives them a progressive Motion.

By these Laws it will be easy to prove, that,

If a Body be acted upon by two Forces in different, but not opposite Directions, they will describe the Diagonal of a Parallelogram in the same Time, that each Force acting seperately upon it will describe the Sides.

Fig. 11. Let A represent a Ship at Sea, and that it is drove by the Wind in the Direction of the Line AB, at the Rate of eight Miles an Hour from A to B, in a Current that sets in the Direction of the Line AD, at the Rate of four Miles an Hour: By these

these two Forces acting together on the Ship at A, it will at the End of the Hour be found at C, after having described the Diagonal of the Parallalogram AC.

For the Force AB will not hinder the Ship to approach the Line CD, which is parallel to it; neither will the Force AD hinder the Ship to approach the Parallel BC: therefore the Ship at the End of an Hour will be found in the Point C.

If both Forces act upon a Body so, as each will give it an uniform Motion, the Diagonal described will be a right Line as above. But if one of the Forces acts in such a Manner as to make the Body move faster and faster, while the other acts uniformly on it, then the Diagonal described by these Forces jointly will be a Curve: Thus, *Fig.* 12. Suppose one Force to drive a Body from A in the Direction AF, so as to make it move through the equal Spaces AB, BC, CD, *&c.* in equal Times; then suppose another Force to act upon a Body at A, in the Direction of the Line A*f*, in such a Manner as to make it describe the unequal Spaces A*b*, *cd*, *de*, &c. in equal Times; these two Forces will cause theBody to describe the CurveA,*g*,*h*,*i*,*k*,*l*. If the Spaces A*b*, *bc*, *cd*, &c. be the Spaces through which a Body falls by the Force of Gravity in equal Times, the Curve *A*,*g*,*h*,*i*,*k*,*l* will be such as is described by a Projectile, as a Ball from a Gun, and is called a *Parabola*. For, suppose in the same Time that the Force of Powder drives the Ball from A to B, that Gravity would cause it to fall from A to *b*, the Body in that Time would describe the Diagonal Ag, by the foregoing Rule: But, in double Time, Gravity will cauſe the Body to deſcend four times as far, or to *c*; and the force of Powder will carry it to twice its former Diſtance, or to C; ſo that at the End of the ſecond part of Time the Body will be found at *b*: And in like Manner, at the End of the third Part of Time the Body will be found at *i*; at the fourth, at *k*; at the fifth, at *l*, &c. and thus the Curve, (which by Writers of Projectiles, is demonſtrated to be that) of the Parabola, is generated.

It will be here neceſſary to ſay ſomething concerning *abſolute* and *relative Motion.*

Abſolute Motion, is the Motion of a Body when it moves from another which is at Reſt. And *relative Motion*, is the Motion of a Body when it moves from another which is alſo in Motion, at the ſame Time.

We cannot be ſure that any Thing we know of is at Reſt; for though we may imagine any Body to be at Reſt, yet there may be ſtill ſome very diſtant Body perfectly quieſcent, with reſpect to which it may change its Poſition, or really move.

Whenever the whole is moved, all the Parts will partake of that Motion, though theſe Parts are relatively at Reſt, or with reſpect to each other: Thus the ſeveral Parts of a Ship under Sail, as well as thoſe of the Loading, though they are relatively at Reſt, yet they are all really in Motion along with the Ship: And therefore every particular Part is diſpoſed to move with the ſame Celerity as the whole, though it ſhould

be

be ſeparated therefrom, or though the Reſt ſhou'd ſtop on a ſudden and their Motion ceaſe. Thus if a Ship be under Sail, and a Perſon lets a Stone or any heavy Body fall from the Maſt Head, it will fall exactly at the ſame Diſtance from the Foot of the Maſt, as if the Ship were at Anchor; and all Motions upon the Deck, and Bodies hanging perpendicularly, are the ſame as if the Ship were at Reſt, every Part having a Diſpoſition and a ſufficient Force to move with the ſame Degree of Celerity with the Ship; for, if the Ship were ſuddenly ſtopped by ſtriking againſt a Strand, or any large Body; the Perſons from the Diſpoſition of Motion in them, would fall forwards, and at firſt ſetting off, they will be apt to fall backwards, in as much as the Motion is not as yet communicated to them.

If a Stone be whirled about in a Sling, the Stone and that part of the Sling in which it lies, have the ſame Velocity becauſe they deſcribe the ſame Circles: But becauſe all Bodies affect to move in a right Line, the Stone would fly off in every Part of its Orbit, if it were not prevented by the String; for as ſoon as the String is let go, or breaks, the Stone will no longer continue its Circular, but will break out into a rectilinear Motion. This Endeavour of the Stone to break out of its circular Motion, into a Tangent, is called its *Centrifugal Force*, and is the Cauſe of ſtretching the String; for the ſwifter the Stone is whirled and the greater its Weight be, the greater will be the Tenſion of the String, or the more it will be ſtretched: And this Centrifugal Force can proceed from no other Cauſe but the Endeavour which all Bodies have to move in a right Line: And in like Manner if the Earths Motion were ſuddenly to ceaſe, all moving or looſe Bodies thereon would fly off with a violent Motion.

CHAP. III.

Of the ſimple mechanical Powers, namely, 1, The *Ballance.* 2, The *Lever.* 3, The *Pulley.* 4, The *Axis in Peritrochio,* or *Axis in the Wheel.* 5, The *Wedge,* and 6, The *Screw.* *With the Nature of Pendulums.*

IF two Bodies of different Quantities of Matter or Bulks be impelled with equal Forces, they are then ſaid to have a like Moment or Quantity of Motion, tho' the Velocity or Celerity of the Greater will be leſs than that of the Leſſer; as before, and therefore a Body however ſmall, may have a Moment equal to that of another Body how ever great. Thus if there be two Bodies whoſe Quantities of Matter are as 10 to 1, and their Moments equal, then the Celerities will be as 1 to 10, or the greater Bodies Celerity will be 10 Times leſs than that of the leſſer; that

that is when the Moments are equal, their Celerities will be reciprocally proportionable to thoſe Bodies; and the Product ariſing from the Quantity of Matter into the Celerity of one, will be equal to that which ariſes from the Quantity of Matter into the Celerity of the other: And on the contrary, when theſe Products are equal, their Moments or entire Forces are ſo too, and therefore the Moments of Bodies are uſually expreſſed by the Quantity of Matter into the Celerity. Upon this Principle depends the whole of Mechanics. For in all Engines whatſoever, the greatneſs of the Weight or Reſiſtance, muſt be compenſated by the Celerity of the Power to raiſe it; that is, the Celerity of the Power muſt be to that of the Weight as the Weight is to the Power.

I. *Of the Ballance.*

A Ballance is a Beam ſupported by an *Axis* upon which it turns, which *Axis* is the *Center of Motion*; the Parts of the Beam lying on each Side of it are called the *Brachia* or *Arms*: And thoſe Parts of the Arms to which the Weights are applied, are called the *Points of Suſpenſion*; And it Matters not, whether the impending Weight be ſuſtained by a ſhort or a long Cord, for Gravity acts equally at ſmall unequal Diſtances.

That a Ballance may be exact it is requiſite, 1ſt. that (*Fig.* 13.) the Center of Gravity of the Beam be a little below the Axis, or Center of Motion, for when there is an Equilibrium the

Beam

i.e. any thing less than a mile

1 Beam will not reſt but in an horizontal Poſition, and therefore the Weights which are compared together are equal. But if the Axis be below the Center of Gravity (*Fig.* 14.) and the Center of Gravity be moved out of the Perpen-
asons dicular Line, it will not return from its Tendancy to move downwards, for which Reaſon the
2 Weights will appear to be unequal, though in Reality they are not ſo. And the ſame Inconvenience will ariſe, if the Axis paſſes, through the Center of Gravity, (*Fig.* 15.) for notwithſtand-
3 ing the Equilibrium, the Beam will reſt in any Poſition.

2. The Arms ought to be of equal Weight and Length.

3. The Points of Suſpenſion ſhould be in a right Line with the Center of Gravity of the Beam.

4. The Friction of the Beam againſt the Axis ſhould be as little as poſſible. Then equal Weights ſhifted to either Scale will preſerve an Equilibrium. For if the Beam be conſidered as an inflexible Line whoſe Middle Point is the Center of Motion, and the Extremities, the Points of Suſpenſion; it is plain, if it be moved on its Center that thoſe Points will deſcribe equal Arches, and therefore that they have the ſame Celerity which being multiplied into equal appending Weights, the Products or Moments being equal, an Equilibrium will ariſe.

But if the Center of Motion be not in the Middle of the Line, the Points of Suſpenſion will not deſcribe equal Arches, for the Arches deſcribed defcribed by them though they are like, will not be equal to each other, but will be proportionable to their refpective Diftances from the Center of Motion; and therefore the Celerities of thefe Points will be proportionable to their Diftances from the Center of Motion: Wherefore in Order that an Equilibrium may be obtained, the Appending Weights muft be reciprocally Proportional to the Diftances of the Points of Sufpenfion from the Center of Motion; in Order that the Moments may be equal.

Fig. 16. Thus if the Diftance of the Axis from the Points of Sufpenfion be as 6 to 5, the appending Weights muft be as 5 to 6 to preferve an Equilibrium: For 6 multiplied into 5, will be equal to 5 multiplied into 6: And therefore the Moment is the fame on either Side. That is 5 Pounds at the Diftance of 6 Inches from the Axis, will maintain an Equilibrium with 6 Pounds at the Diftance of 5 Inches.

Hence a deceitful Ballance may be conftructed, for 6 Pounds will appear equal in weight to 5 Pounds, fo that a Perfon may be defrauded of a Pound at every Draft: But if one be fufpicious of any Defign of this Nature, let the Weights be fhifted into the contrary Scales and the Defraud will inftantly appear, for 6 into 6 is greater than 5 into 5, and then the Moments will be unequal.

Fig. 17. If feveral Weights be appended at feveral Diftances from the Axis, and if the Moment or Sum of the Products of each Weight into its Diftance on one Side, be equal to the Moment

or

or Sum of the Products of each Weight into its Diſ-tance on the other Side, an Equilibrium will ariſe.

Thus	10 into 5 = 50		
	6 into 4 = 24	7 into 10 = 70	
	3 into 8 = 24	4 into 7 = 28	
Sum	98	=	98 Sum

Hence it is eaſy to conceive how one and the ſame Weight may ballance different Weights: *Fig.* 18, Thus, one Pound at the Diſtance of 20 will either ballance 20 Pound at the Diſtance of one, 10 Pound at the Diſtance of 2, 5 Pound at the Diſtance of 4, 4 Pound at the Diſtance of 5, 2 Pound at the Diſtance of 10, or one Pound at the Diſtance of 20:

Hence alſo ,it appears that the Weights of different Bodies may be found by one Weight only, as in the *Statera Romana* or Steel Yard, *Fig.* 19. Thus, if a Beam AB be divided into 11 equal Parts, and if the laſt 10 of theſe or the Diſtance CB be again ſubdivided into 10 other Parts, the Diſtance CB will then conſiſt of 100 equal Parts: Now if the Axis or the Center of Motion be placed at C, at the Diſtance of one of the larger Parts from the Point of Suſpenſion A, from whence any Body W whoſe Weight is required, muſt be appended; and if on the contrary Arm, there be a moveable given weight P appended ; it is plain that by removing it to,or from theCenter of Motion C,'till anEqulibrium be maintained,that the Weight of the Body W may be diſcovered: For if the Weight P at the Diſtance of 8 Equiponderates that

that of W, at the Diſtance of one, from C; then the Weight W, is eight Times as heavy as the given Weight P.

II. *Of the Lever.*

A *Lever* is ſuppoſed to be an inflexible Line void of all Gravity; though ſuch as are commonly uſed, are both flexible and weighty.

In every Lever there is an immoveable Point, about which as a Center all the Parts of it turn; and whatſoever ſupports that Point is called the *Fulcrum* or *Prop*: And with regard to the different Situations of the moving Power and Prop, the Lever is divided into three Kinds.

1. Where the Fulcrum is placed between the moving Power and the Weight to be raiſed.

Thus, *Fig.* 20. if in raiſing a Weight W of 100 Pounds, there be applied a Lever WP whoſe Length is 36 Parts, and the Diſtance of the Weight W to be raiſed to the Fulcrum F, be 6 of thoſe Parts; then a Weight or Power of 20 Pounds being applied to the other End of the Lever at P, will be ſufficient to bring it to maintain an Equilibrium, as in the Ballance; becauſe the Moments 100 into 6, and 20 into 30 are equal; which Power P if it be ever ſo little encreaſed will be ſufficient to raiſe the Weight W.

Such Levers are commonly uſed for raiſing Stones, and in this Caſe the more weighty the Lever or Quarry-crow is, the more uſeful muſt it be; becauſe the Weight of that Part of the Crow which lies beyond the Fulcrum, far exceeds the other Part in Length, and acting in Conjunction with the Power, thereby facilitates the raising of Stones or other Weights.

To this kind of Lever may be reduced Pump-handles; and several other Instruments, such as Sciſſars, Pincers, Snuffers, &c. which are composed of two Levers whose Fulcrum is the Revit:

2. The second kind of Lever has the Fulcrum at one End and the Power at the other. *Fig.* 21.

This kind of Lever is therefore never used but in Cases of Neceſſity, or where the Weights to be raised cannot be managed in a more convenient Manner: because it is evident, the Power which is requisite to raise the Weight, must be greater than it, As in Case of a Ladder, which being fixed or kept down at one End, is raised by the Aſſistance of one or more Men, 'till they arrive to its Center of Gravity; and then it becomes a Lever of the third Kind.

To this second Kind of Lever may be reduced Oars, Wheel-barrows, Drays, Cars, Nut-crakers, Cutting-Knives the moving of Doors on Hinges, *&c.*

Since in this Lever the Distance from the Weight to the Fulcrum, is less than is the Power to it; it is evident that there cannot be a Ballance in any Case but where the Weight exceeds the Power.

If two Men carry a Burthen between them, as a Sedan-chair, a Weight on a Hand-barrow or on a Pole or Staff; it is plain they both sustain the Weight, and that when it is in the middle between them, that each sustains one half of

the

the Weight: But when the Weight is nearer to one than the other, he bears moſt that is neareſt to it, in that Proportion that the other is fartheſt from it: For the reſpective Powers are reciprocally as their Diſtances. Now the Poles, may be imagined as Levers of the ſecond Kind, and each Man's Shoulder as a Fulcrum with Reſpect to the other; ſo that the nearer the Weight is to the Fulcrum, and the farther the Power is from it, the greater is the Advantage.

This is alſo applicable to the Caſe of two Horſes of unequal Strength, to be yoaked ſo to a Draft that each may draw in Proportion to its Strength; which is done by dividing the Beam ſo, as that the Point of Traction be as much nearer to the ſtronger Horſe, as his Strength is greater than that of the other.

3. A Lever of the third Kind, is when the Power is between the Weight and Fulcrum. *Fig.* 22.

To this are generally referred the Bones of a Man's Arm or Leg; for when we lift a Weight in the Hand, the Muſcle that is exerted to raiſe that Weight is fixed to the Bone, about one tenth Part as far from the Elbow as the Hand is; and the Elbow being the Center about which the Arm turns, the Muſcle therefore muſt exert a Force ten Times greater than the Weight raiſed.

Hence we may eaſily calculate the Strength of the Muſcles in any Part of the Body, by trying how much they can lift at any Diſtance from the Center.

Hence alſo any Thing is with moſt Difficulty lifted at Arms Length, the Shoulder being the Fulcrum, and the Weight being at a greater Diſtance from it than if it were at the Wriſt or Elbow; and a Stick is more difficultly raiſed at full Length than at the Middle, becauſe the Center of Gravity of the Stick in the former Caſe, is farther from the Fulcrum than in the latter.

In a Compound Lever made of ſeveral ſingle Levers of the ſame Kind, the Power will be to the Weight in a Ratio compounded of the ſeveral Ratios, which thoſe Powers ſeverally have when applied to the Weight. Thus *Fig.* 23. If the Power of the Lever A be to the Weight to be raiſed as 1 to 5, that of the Lever B to the ſame Weight as 1 to 4, and that of the Lever C to the ſame Weight as 1 to 5; then the Power of one Pound being applied to the End of the Lever C, will ſupport the Weight of 100 Pounds at the End of the Lever A, ſince 5 into 4 and that into 5 are equal to 100, and 1 into 1 and that into 1 will ſtill make but 1: For at the right Hand End of the Lever A, the Weight will be one fifth leſs, or 20 Pounds; at the right Hand End of B, it is one fourth leſs than 20 Pounds, or 5 Pounds; and again at the right Hand End of C, it is 5 Times leſs than 5 Pound, or but one Pound.

III. *Of the Pulley.*

The *Pulley* is a ſmall Wheel that turns about its Axis, which has a drawing Rope paſſing over it, and is uſed in raiſing Weights; it is of two Kinds; fixed, and moveable.

The fixed Pulley is of no other Uſe but to raiſe the Weight in a different Direction, than in being over it to raiſe it perpendicularly, ſince it does not in the leaſt aſſiſt the Power; *(Fig.* 24) for whatever be the Space through which the Power P moves by drawing the Rope AP, the Weight W muſt in the ſame Time be drawn through an equal Space; and therefore the Weight will be ſupported by a Power which is equal to it. *N. B. In all the following Machines of Pulleys, W ſignifies the Weight to be raiſed, and P the Power.*

Fig. 25. When a Pulley to which there is a Weight fixed, is placed in the double of a Rope, whoſe End is faſtned to a Hook H; it is plain that to raiſe the Weight one Foot, each Side of the Rope muſt be ſhortened one Foot, counting from the Hook downwards; that is, the Power muſt be raiſed two Foot in Order to raiſe the Weight one, or the Celerity of the Power muſt be double to that of the Weight; and alſo becauſe the Power ſuſtains but half the Weight, the other half being ſuſtained by the Hook; the Power is to the Weight as 1 to 2, and therefore its Moment will be equal to the Moment of the Weight and will ſuſtain it: And this is juſt the reverſe of the fixed Pulley.

In a Machine conſiſting of ſome fixed and other moving Pulleys, and which have one common Rope to all; if one End of the Rope be fixed, the Power muſt be to the Weight as one is to twice

twice the Number of moveable Pulleys, for the Celerity of the Power is to that of the Weight in a like Proportion: Thus, (*Fig.* 26) if there be one fixed and one moveable Pulley, the Power muſt be half the Weight; and if two Pulleys are fixed, and two moveable, (*Fig.* 27, 28.) the Power muſt be one fourth of the Weight, and the Celerity of the Power will be four Times greater than that of the Weight, ſo that for every Foot the Weight is raiſed, the Power muſt deſcend four Feet. And in the General, if there be ever ſo many Pulleys ſome fixed and others moveable having one common Rope, the Power muſt be to the Weight, as one is to twice the Number of moveable Pulleys; and the Celerity of the Power to that of the Weight will be in a like Proportion; ſo that if there are 3, 4, or 5 moveable Pulleys, the Power muſt be one ſixth, one eighth, or one tenth of the Weight, and for every Foot the Weight riſes, the Power will deſcend 6, 8 or 10 Feet; or that Length of Rope or Cord will deſcend, for every Foot the Weight is raiſed.

Fig. 29. If the Rope inſtead of being ſixed at one End be faſtened to the Weight or to the Block which ſupports the moveable Pulleys, ſo as to riſe therewith, as in this Machine conſiſting of two moveable Pulleys; the Power will be to the Weight, as one, is to twice the Number of moveable Pulleys more by one; and the Celerity of the Power, will be to that of the Weight in a like Proportion. In this Caſe therefore the Power muſt be one fifth of the Weight, and for every Foot

Foot the Weight riſes, the Power will deſcend five Feet.

Fig. 30. If to any of the foregoing Machines be added a Runner, that is, a ſingle moveable Pulley which has its own Rope diſtinct, fixed at one End and the other faſtened to a Block; the Force of the former Machines will be doubled by this additional Pulley: For ſince the Point M moves with twice the Celerity of the Weight, as in the ſingle moveable Pulley, and the Power with five Times the Celerity of M, then the Power will have ten Times the Celerity of the Weight, and conſequently the Power will ſuſtain twice the Weight it did before.

Fig. 31. If a Machine be combined of one fixed and ſeveral moveable Pulleys, ſo that every moveable Pulley has a ſeperate Rope of its own; then, the Power will be to the Weight, as one, is to the laſt Term of a duple Progreſſion whoſe firſt Term is one, and the Number of Terms one more than the Number of moveable Pulleys. Thus, in this Caſe, if one be added to four, the Number of moveable Pulleys; the Number of Terms in the Progreſſion muſt be five: Then ſince one is the firſt Term, the laſt will be 16: For one doubled, will be equal to two, for the ſecond Term; two doubled, will be equal to four, for the third Term; four doubled, will be equal to eight, for the fourth Term; and eight doubled, will be equal to ſixteen for the fifth Term: So the Power will be to the Weight as one to ſixteen. For the Celerity of the Power is to that wherewith the Pulley G riſes, as two to one; ſo likewiſe is the Celerity of G to that of H, as two to one; alſo the Celerity of H to I, and I to that of K as two to one: Wherefore if the Celerity of the laſt Pulley K or the Weight be one, the Celerity of I will be two, of H four, of G eight, and of the Power P ſixteen.

Tho' this Engine be of greater Force than any wherein there is the ſame Number of moveable Pulleys, yet in as much as upon that very Account only it is that the Weights riſe but ſlowly, it is therefore but ſeldom uſed; for Men chuſe rather an Engine of two fixed, and two moveable Pulleys, with one common Rope; and if there be Occaſion to double the Force, this may be done by the Addition of a Runner.

IV. Of the *Axis in Peritrochio*, or the *Axis in the Wheel.*

Fig. 82 This Engine which is a very ſimple one, conſiſts of a Wheel fixed to an Axis that turns along with the Wheel; its Manner of raiſing Weights is thus: The Power P being applied to ſome Part of the Wheel's Circumference at A, turns the Wheel together with its Axis, and thereby raiſes one or more Weights W, W, on different Parts of the Axis; and becauſe the Wheel A, and its Axis revolve together; in whatever Time the Power P moves through a Space equal to the Circumference of the Wheel A, the Weight muſt in the ſame Time be raiſed through a Space equal to the Circumference of that Part of the Axis to which the Weight is appended

appended; therefore the Celerity of the Power will be to that of the Weight, as the Circumference of the Wheel is the Circumference of the Axis; and becaufe the Circumferences of Circles are to each other as their Diameters; the Celerity of the Power will be to that of the Weight, as the Diameter of the Wheel is to the Diameter of the Axis; if therefore the Power be to the Weight, as the Diameter of the Axis to the Diameter of the Wheel, the Power will then juft fuftain the Weight: Thus, if the Diameter of the Wheel be five Inches, and that of the Axis one Inch, a Power of one Ounce, or one Pound, being appended from any one Point of the Circumference of the Wheel, will fupport a Weight of five Ounces, or five Pounds which is appended from the Axis; and if the Diameter of the Wheel be ten Inches, and that of the Axis one Inch, then one Ounce at the Wheel, will fuftain ten Ounces at the Axis.

When the parts of the Axis differ in Thicknefs, as B and C do; if Weights be hung at thefe Parts, they may be fupported by one Power applied to the Wheel, provided the Product of the Power into the Diameter of the Wheel, be equal to the Sum of fhe Products of the feveral Weights, into the Diameters of the Parts of the Axis from whence they are appended: Thus, if the Diameter of the Wheel A be ten Inches, and the Power P be two Pounds, the Product will be 20; and if the Diameter of that part of the Axis B be four Inches, and the Weight W be three Pounds, the Product will be 12; and again, if the Diameter of that part of the Axis C be one Inch, and the Weight eight

Pounds, the Product will be 8; then the Power P will ſuſtain the Weights W.W, in as much as the firſt Product 20, the Moment of the Power, is equal to the Sum of the other two Products 12 and 8, the Moments of the Weights.

This may be applied to the Machine generally uſed in raiſing Water from Wells; for if an Handle projects five Inches from the Center of the Axis, and it be turned about, the Diameter of the Circle it deſcribes will be ten Inches. If then the Diameter of the Axis, about which the Rope from the Bucket revolves be one Inch, then a Power of 20 Pounds at Diameter ten, will ſuſtain a Weight of 200 Pounds at the Axis where the Diameter is one; for 20 into 10 or 200 the Moment of the Power, is equal to 200 into 1 the Moment of the Weight.

The like may be alſo applied to a perpendicular Axis, with croſs Bars running through it, for raiſing Weights from Ships, which Machine uſually bears the Name of a *Crane*, and is placed on Quays where Goods are landed; alſo to raiſe Stones for Buildings to any aſſigned Height, with the help of a fixed aud moveable Pulley; which Things are ſo frequently ſeen, that it is needleſs here to illuſtrate them by any Scheme or Figure; it may be alſo applied to *Calanders* uſed in ſmoothing Linen, to *Windlaſſes* and *Capſtrons* in Ships, to a *Spit* for roaſting Meat; becauſe the greater the Diameter of the Wheel the Chain is ſet into, be, the leſs Weight or Power to the Jack will be ſufficient to turn the Spit, and any Meat on it: And to many other Uſes of the like Nature.

V. Of

V. *Of the Wedge.*

Fig. 33. In cleaving Timber with a Wedge, the Force of the Strokes on its Baſe AD, is looked upon as the moving Power, and the Coheſion of the Parts of the Timber, as the Reſiſtance or Weight to be moved.

Then if the Power be to the Reſiſtance, as half the Breadth of the Wedge is to its Side, the Power will be equal to the Reſiſtance; and if the Power be increaſed it will overcome it.

From B the middle Point of the Baſe, let the Line BE be drawn perpendicular to the Side CD; and the Line BC the Height of the Wedge perpendicular to AD, biſecting the Angle ACD.

When the Wedge is driven into a Piece of Timber by Strokes of a Mallet from C to B, then CB will expreſs the Celerity of the Wedge; and the Reſiſtance of the Wood in cleaving, or the Celerity of the reſiſting Body on each Side of the Wedge, will be expreſſed by BE which is the Sine of the Angle BCE: Therefore that the Moment of the Mallet, may be equal to that of the Reſiſtance, they muſt be inverſely to each other as their Celerities; that is, the Power or Strokes on the Mallet, muſt be to that of the Reſiſtance, Coheſion, or Texture of the Wood to be rent or cleaved, as BE to BC, that is by ſimilar Triangles, as BD, half the Baſe of the Wedge is to DC the Side; or as AD is to AC and CD, or to 2 CD.

Hence it follows that ſimilar Wedges are of equal Forces; becauſe in theſe the Angle BCE remains the ſame, the Line BE which expreſſes the Reſiſtance, being the Sine of an Angle of the ſame Number of Degrees will be alſo the ſame: But in diſſimilar Wedges the Powers to be applied will be directly as the Sines of the Angle BCE; that is, as the Sines of the Angles BCE increaſe, the Forces or Powers requiſite to rend the Timber with Wedges will be in the like Proportion, which may be further confirmed by the following Experiment.

If two equal Cylinders rowling on their Axes along the Edges of two horizontal Rulers, be drawn together by a Weight of 2000 Grains, which is applied to a Cord, whoſe Ends are faſtened to the two Cylinders; then if there be three Wedges ſeverally applied between the Cylinders each of three Inches height, with the Weight of 300 Grains appended to the firſt, 600 to the ſecond, and 900 to the third, they will ſeverally be drawn down by their reſpective Weights. In this Experiment the Force which unites the Cylinders, together with the Friction of their Axes are conſidered as the Reſiſtance, and the Wedge with its appending Weight as the Power.

VI. *Of the Screw.*

The *Screw* conſiſts of two Parts the Male and the Female, the prominent Parts of the Thread of the Male, exactly fitting the Cavities of the Female. The chief Uſe of this Machine is, to

preſs

preſs the Parts of Bodies cloſely together, and ſometimes to break and divide them: When it is uſed, one Part is frequently fixed, while the other is turned round, and of Courſe the Power muſt move quite round the Cylinder, before the Weight or Reſiſtance aſcends from one Spiral winding to another: By as much therefore as the Circumference of the Cylinder is greater than the Diſtance or Interval between the Spiral Lines, by juſt ſo much may the Power be leſs than the Weight in order to Ballance it. It therefore manifeſtly follows, that the greater the Circumference of the Cylinder, and the ſmaller the Diſtances of the *Helixes* or Spirals are, the greater is the Force of the Screw.

This Inſtrument is attended with a very conſiderable Friction of the Parts againſt one another, and it is much greater in this than in any of the other Mechanical Powers: On which Account only, the Experiments uſed to ſhew the Force of the Screw, vary more than any of the reſt from the Theory.

Sometimes an Axis in Peritrochio is applied to this Inſtrument, upon Account of the Time loſt in ſhifting its Handle, as well as to increaſe the Power.

In an Engine compounded of ſeveral of the Mechanical Powers, it will be found a Matter of no great Difficulty to compute the Force of the Whole, from the Force of every Part; if what has already been ſaid be duly attended to; or by tracing through the Whole, the ſuperior Degree of Celerity with which the Power moves, when

compared

compared with the Weight or Reſiſtance that is to be raiſed or overcome.

But in computing the Power of any Engine it muſt be obſerved, that an Allowance muſt be made on the Account of Friction; becauſe no Engine can be made ſo perfectly ſmooth and exact, as to be free of it, and thereby ſome of its Force is loſt.

From what has been ſaid, it is plain, that the greater the Celerity of the Power be, the greater Weight it will raiſe, and therefore it is impoſſible that the ſame Power can raiſe a Weight of one Pound, and then a Weight of two Pounds, without increaſing its Celerity; *And that no Engine can poſſibly be contrived ſo, as to gain Power without looſing Time*: Thus it is eaſy by any of the foregoing Powers, to make one Perſon raiſe a Weight, equal to what 100 ſuch Perſons could jointly accompliſh, but that Perſon muſt be allowed 100 Times the Time to do it.

Of Pendulums.

A Pendulum is a Weight or heavy Body hanging at the End of a String, by whoſe *Vibrations* or Swings, Time is meaſured evenly.

The ſmall Vibrations or Arches, which are deſcribed by the ſame Pendulum, though they be unequal, are yet performed very nearly in the ſame Time: For if two Pendulums of equal Lengths, be put in Motion together at one Moment, having raiſed one higher than the other, before they are let go; it is plain the Arches

deſcribed

defcribed by one, will be greater than thofe defcribed by the other; and yet they will be found to be defcribed in the fame Time very nearly; for in one hundred Vibrations the Difference of Time will not be one Vibration.

Fig. 34, The Times wherein Pendulums of unequal Lengths perform their Vibrations, are to one another inverfely as the Square Roots of the Lengths. Thus, if the Pendulum A of 25 Inches long, and the Pendulum B of 36 Inches, be let to fwing together; then A will be found to perform 6, in the fame Time that B performs 5 Vibrations, thefe Numbers being the Square Roots of their Lengths 36 and 25. Or if the Pendulum B were 4 Times as long as the Pendulum A; A will perform 2 Vibrations in the fame Time that B will perform one, thefe Numbers being the Square Roots of 4 and 1.

It is agreed that in our Latitude, a Pendulum of 39.2 Inches long, will in a fecond of Time perform one Vibration; and therefore, that a Pendulum of 9.8 Inches long, will perform two Vibrations in a fecond; becaufe 39.2 is to 9.8 as 4 to 1, therefore 1 Vibration of the longer Pendulum will be performed in the fame Time that the fhorter performs 2.

The Length of a Pendulum is meafured from the *Center of Sufpenfion*, or Point upon which it Swings, to the Center of *Ofcillation*, or to the Center or Middle of the Ball or Bob, in which Center if all the Matter of the Pendulum were collected it would Vibrate in the fame Time.

The

The Time of the Vibration of a Pendulum is not altered by changing the Ball or Weight; for it has been already ſhewn in *Page* 10. that light and heavy Bodies deſcend with equal Swiftneſs, or in the ſame Time, provided they meet with no Reſiſtance from the Air, which in heavy Bodies is very inconſiderable; and therefore how heavy ſo ever the Weight be, the Time of a Vibration will be the ſame, while the Pendulum continues of the ſame Length: For if two unequal Weights, appended by Threads of equal Length, be let fall together from the ſame Height, they will continue to perform their Vibrations in the ſame Time.

From what has been ſaid it is plain, that becauſe one Vibration of a Pendulum of 39.2 Inches long, is performed in a Second of Time, it will be eaſy to diſcover, in what Time, any other Pendulum of a different Length will perform its Vibrations; or if the Time be given, the Length of the Pendulum may be obtained; but due Conſideration is to be had, that the longer Time a Pendulum takes to perform one Vibration, the fewer of ſuch Vibrations will be performed in any given Time, as in an Hour or a Minute, that is in either Caſe the Proportion will be Inverſe. Thus, if a Pendulum vibrates 30 Times in a Minute, and its Length be required; ſay as 900 the Square of 30, is to 3600 the Square of 60, or the Square of the Number of Vibrations performed in one Minute by a Pendulum, whoſe Length is 39.2; ſo is that Length 39.2 to 156.8 Inches the Length of the Pendulum required. And on the contrary, if it were required to find the Number

of

of Vibrations, a Pendulum of 156.8 Inches long will perform in a Minute; then 156.8 is to 39.2 as 3600 is to 900, the Square Root of which 30 will be the Number of Vibrations, a Pendulum of 156.8 Inches long will perform in a Minute. Or which is the ſame Thing, becauſe firſt 900 is to 3600 as 1 to 4, therefore 156.8 the Length of the Pendulum, which will Vibrate 30 Times in a Minute, muſt be 4 Times longer than 39.2, the Length of the Pendulum that Vibrates Seronds, or 60 Times in a Minute. And ſecondly, becauſe 156.8 is to 39.2, as 4 is 1, therefore the one fourth Part of 3600 or 900 muſt be the Square of the Number of Vibrations, which a Pendulum of 156.8 Inches long will perform in a Minute, and conſequently the Number of ſuch Vibrations will be 30.

Again, let it be required to find the Length of a Pendulum, that will Vibrate as often in a Minute, as it is Inches in Length.

The Square of 60 or 3600, the ſecond Term being multiplied into the third Term, 39.2 will give 141120 for the Product of the Means, and as that Number therefore muſt be alſo equal to the Product of the Extreams; it follows, that becauſe the Number of the Vibrations, of the required Pendulum in a Minute, are in this Caſe, equal to the Number of Inches in the Pendulum's Length, therefore, the Square of them Vibrations being multiplied into the Inches in Length, or which is the ſame Thing, the Cube of the Length, or of the Vibrations in a Minate, will be the Product of the Extreams, which as before, muſt be 141120, or the ſame as that of the Means; wherefore the Cube Root 141120, which is 52, muſt be the Inches contained in the Length of a Pendulum, that will Vibrate 52 Times in a Minute.

Since it is well known that all Metals expand with Heat, therefore the Pendulums of Clocks become longer in Summer than in Winter, and on this account Clocks go ſlower in Summer than in Winter, inaſmuch as the Vibrations of their Pendulums become ſlower, by their being lengthened by Heat: For this Reaſon, there is a Screw under the Bob, or Weight of every Clock Pendulum, by which Means, the Length of the Pendulum may be increaſed or diminiſhed, in order to make the Clock keep due Time; that is, that the Length of the Pendulum may always be 39.2 Inches for this Latitude.

We have here ſaid, that two Pendulums of the ſame Length, deſcribing unequal Arches, will make their Vibriations nearly equal in a given Time, but not exactly ſo; and therefore it muſt follow, that becauſe the Vibrations are not preciſely equal, that ſuch Pendulums cannot be admitted to be an accurate Diviſion of Time, inaſmuch as very ſmall Differences will in Time amount to a ſufficient large Difference, as Experience has taught us. Wherefore that the Vibrations of Pendulums may be rendered preciſely equal and exact, whether the ſame Pendulum deſcribes greater or leſs Arches, ſo as that Time may be meaſured with the utmoſt accuracy; Monſieur *Huygens*, diſcovered a Method, whereby a Pendulum by moving in the Curve of a *Cycloid*, will

will amply and unerringly fnpply whatever was before defective.

Fig. 35. If a Circle touching the right Line AB, in the Point A, be moved from A along that Line, in the Manner of a Wheel from A to B, fo as to perform one entire Revolution; then the Point C will defcribe a Curve Line ACB, which is called the Cycloid: And a Pendulum is made to move in this Curve thus, let the *Axis* of the Cycloid which bifects the Bafe perpendicularly, be produced the contrary Way towards E till DE be equal to DC; through the Points A and E, and B, let two Semi-Cycloids AE, EB be drawn each equal to half ACB, their *Vertices*, or Tops being at A and B; then if EA and EB be two Plates of fome Breadth, and a Pendulum of the Length of EC, appended from the Point E be made to Vibrate between thefe Plates; its upper Part which is ufually made flexible, will apply itfelf to that Plate, towards which the Body moves, by which Means it will move in the Cycloid ACB, and meafure Time equally; which has been fully proved, by the Author Monfieur *Huygens*, Dr. *Wallis*, Mr. *Cotes*, and many others.

CHAP. IV.

Of Hydroſtatics *or the Properties of* Fluids.

HYDROSTATICS when invented by *Archimedes*, conſiſted only in the Art of weighing Bodies in *Water* ; but it now comprehends the Nature and Properties of *Fluids* in general.

A *Fluid* in general is a Body, whoſe Parts yield to the leaſt Preſſure, and in yielding are eaſily moved one among another.

The conſtituent Particles of a Fluid muſt be very ſmall, hard, round and ſmooth ; we muſt grant that they are very ſmall, becauſe they are not to be diſtinguiſhed even with the Aſſiſtance of the beſt Microſcopes ; that they are hard, becauſe no Fluid is compreſſible, or can poſſibly be preſſed together into a leſs Space, than that which it naturally poſſeſeth ; (except Air or Steam, of which hereafter) and that they muſt be round and ſmooth, becauſe the Particles or Parts, eaſily yield to any impreſſed Force or preſſure.

It is moſt certain, that Fluids as well as Solids conſiſt of heavy Particles, whoſe Gravity is ever proportionable to the Quantity of Matter which they contain ; and therefore it follows, that the Surface of a Fluid will be ſmooth and level, if it be not actuated on by ſome extraneous Cauſe ; for ſhould

ſhould any Part be higher than the reſt, it muſt deſcend by the Force of Gravity, and ſo ſpread itſelf till it comes on a Level with the reſt; or Phyſically ſpeaking, till it partakes of the Earth's Rotundity.

Fig. 36. The Force of Gravity, likewiſe occaſions the lower Parts of Fluids, to be preſſed with a Force that is proportionable to their perpendicular Height from the Surface: For, ſuppoſe the Fluid in the Veſſel AE, to be divided into ſeveral equal Parts, by the Lines A,B,C,D,E; then its plain, that the loweſt Part, or that under the Line E, muſt ſuſtain a Preſſure of all thoſe Parts which are over it, and that the Parts D or C, will alſo be preſſed by thoſe Parts which are above them; and therefore any Part of the Fluid, or any Body which is immerſed in any Part of the Fluid, will ſuſtain a Preſſure which will be greater or leſs, as its Diſtance is from the Surface, or a Preſſure which will be proportionable to its perpendicular Height from the Surface. Thus an empty Bottle, being cloſe corked up, and ſunk to a great Depth in the Sea, will either be preſſed together by the Force of the incumbent Water, or will have its Cork thruſt into it. Which Experiment is well known to Sea-Men.

Since therefore the Parts of a Fluid which are at equal Depths below the Surface, are equally preſſed, they muſt conſequently be at reſt, and not in continual Motion, as ſome would have it: But when this equality of Preſſure is deſtroyed, then it is plain, a Motion will ariſe in the Parts

of

of the Fluid, which will continue till the Preſſure becomes again equal.

The Force wherewith the lower Parts of a Fluid are preſſed downward, exerts itſelf equally in all Manner of Directions ; *Fig*. 36, For if an Orifice be made at *s* in the Side of a Veſſel containing any Fluid, the Fluid will ruſh out with the very ſame Velocity, as if it run through a like Orifice made at *b* in the Bottóm, becauſe it will be Diſcharged through either in the ſame Time: And in like Manner, a Fluid will preſs upwards with an equal Force ; for if a Tube as *n* be turned upwards, the Fluid will ſpout from it almoſt as high as the Surface thereof in the Veſſel, and would quite as high if it were not for the Reſiſtance of the Air, and the Friction of the Water in the *Pipe* or Tube.

Fig. 37. The upward Preſſure of Fluids may be alſo demonſtrated thus: Take a ſmooth Weight as a Piece of Lead, and fitting it to the End of a Tube, with a wet Leather between them ; hold the Weight by a String, paſſing through its Center of Gravity, keeping the Tube cloſe thereto, and immerſe it to the Depth of 12 Times its own Thickneſs, or more, in Water ; (for Lead is above 11 Times heavier than Water); If then you let the String go, the Preſſure of the Water upwards againſt the Weight, will Support and keep it to the Tube, becauſe the downward Preſſure is taken off by the Tube.

Or thus ; If a Piece of Paper, be put over the Mouth of a Glaſs full of Water, and the Glaſs be carefully turned with the Mouth downward, the Water will remain ſuſpended in the Glaſs by the

Atmoſphere

Atmoſphere, or Air preſſing upwards, becauſe its downward Preſſure is taken off by the Glaſs.

The Preſſure which the Bottom of a Veſſel ſuſtains from a Fluid contained therein, is as the perpendicular Height of the Fluid only, and not as the Quantity of Fluid the Veſſel contains.

Thus, *Fig.* 38, If an unequal bended Tube ABC, having its open Ends A and C turned upward, has Water poured in at either the ſmaller End A, or at the wider End C, it will riſe to an equal Height in each Leg; and therefore the lateral or ſide Preſſure next the Bottom B, muſt be manifeſtly the ſame from each: But becauſe, the Preſſure of a Fluid on the Bottom of a Veſſel has been ſhewn to be equal to the lateral Preſſure, therefore the Bottom of the Veſſel is equally preſſed by the Fluid in the ſmaller Leg, and by that in the greater One, or as the perpendicular Height of the Fluid in each Leg, and not as the Quantity contained in each. more

Hence ariſes this *Hydroſtatical Parodox*, that a ſmall Quantity of a Fluid may be made to preſs as much, as any other Quantity how great ſoever; for if the Leg CB be increaſed to a Size however great, and the Leg AC be diminiſhed as ſmall as may be, or if the Quantity of Fluid contained in each, be according to any aſſigned Proportion whatſoever, the Preſſures at the Bottom will be equal, for the perpendicular Heights of the Fluid in each Leg will be the ſame.

Fig. 39. Let there be two Veſſels A and B filled with Water, whoſe Bottoms CD and EF are equal, but the Capacities of the Veſſels as different

as

as may be; if an equal Hole be bored in the Bottom of each, and the Veſſels be kept conſtantly filled to the ſame Height, the Water will be found to run with an equal Celerity from each; and therefore the Preſſure of the Fluid againſt the Bottom of each will be equal, ſo long as the perpendicular Height of the Water remains the ſame. It therefore evidently follows, that the Banks of the Sea are no more preſſed, than thoſe of a Pond or of a Ditch of equal Depth, abſtracted of the Force of the Waves, and of the Difference of Weight between Salt and Freſh Water.

From what has been now ſaid it is evident, that the Preſſures on equal Baſes are as the perpendicular Heights of the Fluids contain'd in them however different the Veſſels themſelves be: And univerſally that the Preſſure on any Baſe is meaſured, by multiplying the *Area* of the Baſe, into the perpendicular Height of the Fluid, without regarding the Quantity of the Fluid. Thus if two Veſſels of equal Baſes, have 5 Inches depth of Fluid in the one, and 4 in the other; the Preſſure on the Baſe of the firſt, will be to that of the ſecond, as 5 to 4: Again, if there be the Baſes of two Veſſels, whoſe Areas are as 4 to 1; and if the Depth of the Fluid in the firſt be 8 Inches, and that of the ſecond 32; then 4 multiplied by 8 or 32, will Meaſure the Preſſure on the whole Bottom of the firſt, and 1 multiplied by 32, or 32, will Meaſure the whole Preſſure on the ſecond; and ſeeing theſe Meaſures are equal, the whole Bottom of the firſt will be preſſed with a Weight, equal to

that

that which preſſes the whole Bottom of the ſecond. But when we ſay, Fluids preſs with a Force, which is proportionable their perpendicular Heights, we mean that they preſs in that Proportion, ſuppoſing their Baſes equal, or that they preſs in that Proportion upon any equal Parts of the Bottoms or Sides of Veſſels, when their Bottoms are unequal.

Since the Bottom of a Veſſel, bears a Preſſure proportionable to the Height of the Fluid, and that thoſe Parts of the Sides which are adjacent to the Bottom, bear a like Proportion, it therefore follows, that if a Hogſhead full of Liquor be ſet on an End, the Sides next the Bottom will bear the greateſt Streſs, and that the ſtreſs decreaſes, juſt as the Diſtance from the Bottom increaſes; for which Reaſon it is fit, that Veſſels of a conſiderable Height, ſhould be much ſtronger at the lower, than at the upper Parts, in order that they may be enabled to ſuſtain the Preſſure.

The Preſſure on the Baſe, being as the Height of a Fluid, it is eaſy to conceive, that if a full Hogſhead be ſet on an End, and a Pipe be inſerted through a Hole made in the upper End, and filled with a like Fluid, the Bottom will be as ſtrongly preſſed, and be in the ſame Danger of Burſting, as if the Hodgſhead was continued to the ſame Height as the Pipe, and filled with Liquor; and that if ſuch a Pipe were continued to a great Height and filled, no Hogſhead would be ſufficient to withſtand the Preſſure.

Of the Specific Gravities *of* Bodies.

The *Specific Gravities* of Bodies, are the Weights of Bodies of the ſame Size or Bulk when compared to each other; thus if a Cubic Inch of one Body be 2 or 3 Ounces, and a Cubic Inch of another Body weighs one Ounce, then the firſt Body is ſaid to contain two or three Times the Specific Gravity of the other, or to be two or three Times Specifically heavier than the other.

The *Relative Weight* or Gravity of a Body, is the Exceſs of it's Specific Gravity, above that of a Fluid, in which it is immerſed.

Fig. 40. A Body Specifically heavier than a Fluid when weighed therein, looſes ſo much of its Weight, as is equal to the Weight or Quantity of that Fluid as big as the Body: For, let the Body B be immerſed in the Veſſel A, filled with Water, it will throw out of A into the Veſſel CC, wherein it is immerſed, juſt ſo much Water as is equal to the Bulk of the ſaid Body B.

Hence if a Body be weighed in Water, and out of it, the Difference of Weights, will be the Weight of a Quantity of Water as big as the Body: And if the abſolute Weight of the Body, or it's Weight out of the Water, be divided by the ſaid Difference, the Quotient will ſhew how much heavier than Water that Body is.

After this Manner the Specific Gravities of Bodies may be found. Thus, If a Quantity of Mercury Weigh 84 Grains out of Water, and 78 Grains in Water, the Difference of theſe Weights,

6 Grains

6 Grains is the Weight of as much Water, as is equal in Bulk to the Mercury; if then 84 Grains, the abſolute Weight of the Mercury, be divided by the aforeſaid Difference 6, the Quotient 14 ſhews, that Mercury is ſpecifically heavier than Water.

By this Method, the Specific Gravities of ſeveral Bodies are found, that is how many Times they are heavier than Water, Bulk for Bulk; as in this Table.

A Table *ſhewing the* ſpecific Gravities *of certain* natural Bodies.

The fineſt Gold - -	19.640
Standard Gold of *England* -	18.888
Mercury - -	14.000
Lead - -	11.325
Fine Silver - -	11.091
Standard Silver - -	10.535
Copper - - - -	9.000
Caſt Braſs - -	8.500
Steel - -	7.852
Iron - - -	7.643
A Diamond - -	3.400
Clear Glaſs - - -	3.150
Green Glaſs - - -	2.620
Dry Ivory - - -	1.825
Ebony - - -	1.177
Human Blood - -	1.054
Cows Milk - - -	1.030
Sea Water - - -	1.030
Common Water - -	1.000

Dry Oak - - -	925
Spirit of Wine - : -	8 66
Cork - - - -	240

The ſpecific Gravities of ſolid as well as fluid Bodies, are different from one another in Summer and Winter. For in Summer all Things are rarified by the Sun's Heat, and in Winter they are condenſed by the Cold. Yet this Rarefaction or Condenſation is not alike in all Bodies, but very different, as will appear by the following Table, which ſhews the Weight of a Cubical Inch of *Paris*, there in Uſe.

	In Summer.			In Winter.		
	Oz.	Dr.	Gr.	Oz.	Dr.	Gr.
Mercury - -	7	1	66	7	2	14
Oil of Vitroil - -	0	7	59	0	7	71
Spirit of Vitrol - -	0	5	33	0	5	38
Spirit of Nitre - -	0	6	24	0	6	44
Spirit of Salt - -	0	5	49	0	5	55
Aqua-fortis - -	0	6	23	0	6	35
Vinegar - -	0	5	15	0	5	21
Vinegar diſtilled - -	0	5	11	0	5	15
Spirits of Wine - -	0	4	32	0	4	42
Cowes Milk - - -	0	5	20	0	5	25
River Water - -	0	5	10	0	5	13
Well Water - -	0	5	11	0	5	14
Water diſtilled - -	0	5	8	0	5	11

In the firſt Table, if the Point be taken from the Numbers, or which is the ſame Thing if each Number be multiplied by 1000, you will have the Ounces Avoirdupois which are contained in a Cubic Foot of each Body.

By this Table may be found the different Quantities of two Metals, which Metals are known to compoſe a Body however great or ſmall.

Find the Specific Gravity of the Mixture, or how many Times it is heavier than Water, as before: Then ſubſtract the Specific Gravity of the lighter Metal, found by the Table, from the Mixture, and that of the Mixture from the heavier; the firſt Remainder will ſhew the Bulk of the Heavier, and the latter the Bulk of the Lighter. If theſe Remainders be multiplied by their reſpective Specific Gravities, the Products will ſhew the Proportion of the Weights of each Metal of the Mixture. Thus;

Suppoſe there be a Body weighing 30 Grains, which I know to be a Compoſition of two Metals, as of the fineſt Gold and Copper, and that I find as before the Specific Gravity of the Mixture to be 13, or that it is 13 Times heavier than Water. Required how much of the fineſt Gold, and how much Copper there is in the Mixture.

From the Specific Gravity of the Body	13
Take the Specific Gravity of the Copper as in the Table - - -	9
There remains the Bulk of the fineſt Gold	4

From

From the Specific Gravity of fineſt Gold in the Table - - -	19. 64
Take the Specific Gravity of the Body	13.
There remains the Bulk of Copper	6. 64

Then fineſt Gold	19. 64	And Copper	9.
Mul. by	4.	Mul. by	6. 64
The Prop . of Gold	78. 56	Prop. of Cop.	59. 78

So that for every 78.56 Pounds, Ounces, or Grains of the fineſt Gold, there will be 59.76 Pounds, Ounces, or Grains of Copper in ſuch a Mixture.

Let theſe Numbers be added together

Gr.	
78.56	
59.76	
138.32	whole Mixture

	Gr. Mix.		Gr. Gold		Gr. Mix.		Gr. Gold
Then ſay, as	138.32	:	78.56	::	30	:	17
			Gr. Cop.				Gr. Cop.
	138.32	:	59.76	::	30	:	13

So that the Body contains 17 Grains of fineſt Gold, and 13 Grains of Copper.

N. B. This Proceſs is only inſerted for the Uſe of Beginners.

Fig. 41. A Body ſpecifically lighter than a Fluid will ſwim thereon, in ſuch a Manner, that a Quantity of that Fluid equal in Bulk with the immerſed Part of the Body, will be as heavy as the whole Body.

Let the Body B be put into a Veſſel A filled with Water; it will throw out of the Veſſel A into the Veſſel CC in which it is placed, juſt ſo much Water as will be equal in Bulk to the Part immerſed, and the Water ſo thrown out of the Veſſel A, will be exactly equal in Weight to the whole Body.

Hence the lighter a Fluid is, the deeper a Body will ſink in it, upon which depends

The Uſe of the Hydrometer or Water-poiſe.

The *Hydrometer* is an hollow Glaſs or Ivory Ball with a ſmall hollow Stem of about 5 or 6 Inches long, oppoſite to which on the other Side of the Ball adheres a ſmaller Ball which is partly filled with Mercury, in Order to keep the Stem perpendicular to the Fluid in which the Balls and Part of the Stem are immerſed.

Fig. 42. The Uſe of this Machine is to diſcover the Specific Gravities of Fluids, and this is done by firſt ſetting it to float in one Fluid, and obſerving the Degree cut by the Fluid on the graduated Stem which is Marked and Numbered; and then by putting it in any other Fluid and obſerving the Number on the Stem cut by the Fluid, and this laſt Number will be to the for-

mer

mer, as the Specific Gravity of the firſt is to that of the laſt Fluid: Thus,

The Hydrometer being put into Water ſinks to the Number 87, and being put into Spirit of Wine ſinks to 100: Whence the Specific Gravity of Water is to that of Spirit of Wine, as 100 is to 87.

Hydrometers made of Ivory are better than thoſe of Glaſs, for if the Stem be Glaſs the Fluid will riſe about it from its attractive Force, and give a greater Number than it ſhould.

The Flux of Water from Reſervoirs *through* Orifices *and* Pipes.

If Water flows through an Orifice in the Bottom of a Veſſel which is kept conſtantly full, or to the ſame Height; the Velocity with which it flows out, is as the Square Root of its Height above the Orifice.

Fig. 43. Let there be two Veſſels alike in all Things, except that one is four Times as tall as the other, or let the Height of A be 20, and that of B 5, each having a Circular Orifice of $\frac{1}{5}$ Part of an Inch in the Bottom. If theſe Veſſels be filled with Water and ſet running, the Water being conſtantly ſupplied above as faſt as it runs out below; the taller Veſſel will diſcharge 21 Ounces in a Quarter of a Minuet, and the latter 11 Ounces: Therefore the Velocity with which the Water flows out of the taller Veſſel, is to the Velocity wherewith it flows out of the ſhorter, as 21 is to 11, that is as 2 to 1 nearly; which Numbers

Numbers are the Square Roots of 4 and 1, which exprefs the Proportion of the Heights of the Water above the Orifices.

Hence if an Orifice in the Side of a Veffel, be placed as much above an horizontal Plane, as the Surface of the Water is above it; the Water will Spout to twice the Diftance, that the Orifice is above the Plane.

Fig. 44. Let two Veffels A and B be full, and let A be fet upon a Plane equal to its Height, and the Orifice made in its Side next the Bottom; and let the Orifice in B be in the Middle of the Side: Then the firft will be found to Spout to the Length of the Veffel and Stand, and the other to the Length of the Veffel.

The Diftance to which Water fpouts from an Orifice in any Part of the Side of a Veffel, will be twice the Sine made from the Orifice, to a Circle defcribed from the Top of the Water to the Bottom of the Veffel. Thus, *Fig* 45.

Let a Veffel filled to 16 Inches, and fupplied to that Height be perforated in the Middle at A, and towards either End at B and C, five Inches above and below the Middle. From the Top of the Water to the Bottom, let the Semi-Circle be defcribed, and from the Orifices C,A,B, let the Perpendiculars, or Sines BF, AE, CD be drawn: Then the Water will Spout from the feveral Orifices, to twice the Diftance of thefe Sines, that from A will be found to Spout more than 15 Inches, and the Spouts from B or C will be 11 Inches.

The Velocity wherewith Water flows out of a Cylindrical Pipe inserted horizontally in the Side of a Vessel, is as the Square Root of the Height of the Water, above the Place of the Pipe's Insertion directly, and the Square Root of the Lehgth of the Pipe inversely. For the Place of the Orifice may be looked on as if it were in the Bottom of the Vessel, since no Water under it can flow out; and the same Velocity wherewith the Water flows out of the Cylindrical Pipe, with the very same Velocity it flows in it, at the other End, that is, it will be as the Square Root of the Height of the Water above the Orifice: But the Water in the Pipe becomes a Clog, and impedes the Velocity rushing in at the Pipe, and the longer this Pipe is, the greater the Impediment will grow, and of Course the less will be the Velocity of the Water in the Pipe; and this is found to be Inversely as the Square Root of the Pipe's Length: For if a Pipe that is 16 Feet long, and half an Inch Diameter, be inserted horizontally in the Side of a Vessel, and the Water in the Vessel be kept constantly 3 Feet above the Orifice, this Pipe will Discharge 161½ Ounces in half a Minute: Let the Pipe be then shortened, so as to be only 4 Feet in Length, and set a running, it will then Discharge 321 Ounces in half a Minute, which is near twice as much as it did before; so that the Quantities discharged will be to one another Inversely, as the Square Roots of the Pipe, which in this Case is as 4 to 2, or as 2 to 1.

Having

Having thus far given ſome of the general Properties of Fluids, it will not here be amiſs, if we inquire into the Nature and Uſe

Of Water.

1. Water affords Drink to all Animals, for it is impoſſible to prepare any Drink, that is neceſſary for Life and Health, of which the greateſt Part is not Water.

2. It diſſolves Meat in our Mouths, and occaſions all Taſtes to be perceived by Animals..

3. It is the Vehicle of all Animal Nutriment, to the reſpective Parts of the whole Body.

4. It is the Cauſe of Life, ſince by diluting the Blood, it affords it an eaſy and free Paſſage through the Veſſels.

5. It is the Cauſe of Vegitation, and of the Growth of Vegitables.

6. If Water were not by ſome Means conducted into the Bowels of the Earth, Foſſils could not grow. For it produces a petrifying Juice when mixed with the Earth, which applying to other Earths is converted into Stones and Flints.

7. It is the Vehicle of Fiſhes.

8. It is the Vehicle of Ships, by which Merchandize is extended to the moſt remote Nations.

9. It forms Rain, which by its Deſcent purifies the Air, and Waſhes away all Kind of Filthineſs and Impurity.

10. It is the ſole Cauſe of Springs and Rivers; it is of Uſe in moving Mills, and for innumerable other Uſes.

Water is Fluid, Liquid, Humid, Infipid, without Smell, Limpid, Lucid, without Colour, Volatile by a fmall Heat, it will not burn in Fire, but on the contrary extinguifhes it; and therefore it is eafily diftinguifhed from all other Fluids.

The Species of Waters are reduced to Six. 1. That which falls in Rain, Hail, or Snow. 2. Spring-Water. 3. River-Water. 4. Well-Water. 5. Lake-Water. 6. Sea-Water. And of thefe feverally.

Rain, Hail, and Snow, were originally Water which was exhaled from the Surface of the Earth, in the form of Vapour, and compofed Clouds, from whence it fell upon the Earth; which fhall be hereafter more fully explained.

Thefe airy Exhalations or Vapours being received by the Earth, penetrate therein according to its various Circumftances. Some of thefe Waters fink to the deepeft Places, and if they can burft forth they conftitute Springs, which throw out Waters higher or lower, according to the different Altitudes of the Sources which collect them.

Rains and Springs flowing along the Earth's Surface to low and hollow Places, conftitute Rivers.

If we dig into the Earth to any confiderable Depth, we find a Bed of Sand, that affords plentiful Veins of Water, which ouze through the Interftices of the Sand into the Bottom of the Hole or Well, and by this Means we are fupplied with what is called Well-Water.

Lake-Water is compofed of Rain, Springs, and fometimes with Rivers.

And

And Sea-Water is Salt and Bitter, and conſtitutes the Ocean.

Natural Water is ſeldom pure, being corrupted by the ſubtile Particles of the Earth. For Rain in its Paſſage through the Earth waſhes it, and carries with it the Seeds of the moſt tender Plants, Animalcula which ſwim in Air, Volatile aeriel Salts, ſubtile Earths, and many other Things which float in the Air. And according as Water runs through different Earths, Salts, Vitriols, Metals, Sulphers, Soaps, &c. they are known by different Names, as Sulpherous, Chalybeate, Aluminous. In Spaw-Waters are found Chalk, Ocre, Braſs, Sulphur, Vitriol, Nitre, Lead, Cerus. In the *Bath-Waters* of *England*, were found in the Quantity of one Barrel, 5 Ounces and 3 Drachms of Stone, 2 Ounces and a Drachm and a half of blue ſulpherous Earth, and 3 Ounces of Salt, as well Sea-Salt as of Nitre. In the *Pyrmont*-Waters there is much bitter Salt, Iron, and gravelly Earth.

Hence according to its various Ingredients it produces different Effects. There are Waters near St. *Baldomar*, in the Province of *Lionnois* in *France*, and near *Valentiola* in the Kingdom of *Toledo* in *Spain*, which abound with an intoxicating Spirit, as ſtrong as Wine. Others are of a poiſonous Quality, as a Fountain called *Styx*, near *Nonacris* in *Arcadia*, which deceives and kills Strangers, as no Suſpicion can ariſe either from its Appearance or Smell. There are many Kinds of noxious Waters, which cauſe ſcrophilous Diſorders, and others which looſen Men's Teeth. But the Ingredients

gredients through which ſuch Waters paſs, are the Cauſe of theſe bad Effects, and not the Water only.

Well-Water that flows through ſmall Flints, or a Bed of fine Sand is very pure; but otherwiſe it is infected with the ſame Terreſtrial Parts as Spring-Water. Lake and River-Waters are impure, as they contain Mud, Filth, Plants, Fiſhes, and whatever elſe the Wind, the Air, Men, or Animals caſt into them. Sea-Water contains not only Salt, but Bitumens, and all Kinds of Filthineſs, becauſe Rivers diſcharge themſelves into it. Sea-water therefore is not only ſalt but has a particular Bitterneſs which ariſes from the Bitumen that flows out of Submarine-ſprings, as alſo from the Oils of Plants, Animals, and the nitrous Salts. The Salt that is in Sea-water at the Depth of ſix Inches from the Surface, is of a different Temper than that which is taken at greater Depths. For if the firſt Salt be laid upon blue Paper, it makes it red like Nitre, which does not happen from the deeper Salt.

Some learned Men have thought, that the bitter Sea-ſalt is volatile, and is by that Means diſperſed through the Atmoſphere, and that it is the Mother of natural Vitriol, Alum, Nitre, Ammoniac. This Bitumen ſeems to be the Cauſe why Sea-water ſhines in the dark, when daſhed againſt hard Bodies.

Sea-water is purified by paſſing through very fine Sand gathered in deep Veſſels and heaped upon one another, for thereby it looſes its bitterneſs and unſavory Taſte, and becomes mere Water.

And hence it is that Wells dug upon a ſandy Sea-ſhore afford ſweet Water.

This may be alſo performed by certain porous Stones, yet thereby the Sea-water will not be quite freed of its bitterneſs.

Dr. *Liſter* informs us that Sea-water may be purified by Means of the Alga or Sea-weed, that ſuddenly perſpires the Water.

Deſlandes made Funnels of Virgin's-wax, which being filled with Sea-water, it became ſweet. And *Luetman* let Sea-water paſs through ſoaking Paper, which he afterwards ſuffered to Putrify, and whatever Salts are in it, become volitile and fly off, and the terreſtrial Parts remain behind: Again he paſſes the Water he received through the ſoaking Paper, through other Paper of the like Kind, and this he affirms is purer than diſtilled Water, becauſe the Salts and Earths are now taken away. This Method is recommended by *John Gadeſten* AN. 1516, as Dr. *Hales* relates.

Sea-water is beſt purged from its Impurities when it is reſolved into Vapours, either by the Sun, or by culinary Heat. Therefore Rain thus becomes pure, though it be formed of Water out of the Ocean, of Lakes, of Rivers, and of many different Exhalations from ſeveral Bodies on the Earth's Surface. For pure Water is eaſily raiſed into Vapours by a ſlender Heat of the Sun, whereas the Salts and other groſſer Parts are raiſed with much more difficulty. The *Egyptians* being ſenſible of this, drew their Water by Night out of the *Nile*, before the Sun had exhaled the more ſubtile Parts. If Sailors by Night draw Fleeces of Wool over the Deck and Sides of a Ship when they are in the midſt of the Ocean, they in the Morning may ſqueeze freſh Water thereout fit to drink: But the pureſt Water of all is made by repeated Diſtillation, which leaves the unwholeſome Dregs remaining in the Veſſel; and it will be more perfect and pure if the Diſtillation be made from Rain Water, or from Snow gathered in a clean and deep Place, and but little defiled by the Air: Yet notwithſtanding all that has been ſaid, any of thoſe Waters however well purged, will have both a Taſte and Smell, which is not as grateful as common freſh Water.

Mankind have taken uncommon Pains to render Salt-water freſh for the Uſe of diſtreſſed Mariners; and for this End have ſuffered it to putrify. Now when it is in a State of Putrefaction, if it be diſtilled to half, it will ſtink moſt offenſively, but the next Day the Reſidue or what remains is ſweet and clear, as all the Dirt and Filth is left behind. If the Sea-water be completely Putrified, the Water of itſelf becomes ſweet and limpid; and then Part of it may be diſtilled, but not all, becauſe the Spirit of the Sea-ſalt remains at the Bottom, which would aſcend were the whole diſtilled; and that diſtilled Water will ſtill have an urinous Smell, though it be freſh and pretty pure, and will be of a brown Colour, and have a Sediment like ſome Well-waters; but this Smell goes off in Time, and it ſerves very well for boiling Peaſe, making Burgoe, Broth, and for many other Uſes on board of Ships.

The

The Putrefaction of Sea-Water is increafed by adding Ifing-Glafs to it. The greater the Putrefaction be, the more wholefome the Diftillation, produced from it will be, which have occafioned fome to add the *Lixivium* of the Salt of *Tartar*, and then to have it Diftilled again; others have added Salt of Tartar, Lime, Bones, and calcined Shells of Oyfters, and then have Diftilled it again, though with lefs Succefs than the former.

Some by impregnating a glutinous Mixture, as Whites of Eggs, Milk, Ifing-Glafs, and other like Things, have made Water purer by the Gluten imbibing the Impurities; but even by this Method, Sea-Water will ftill have a difagreeable Tafte, which common Frefh-Water has not.

Others have mixed Crude-Tartar in Salt-Water in order to abforb the Sea-Salt; again Oil of Tartar has been poured into Sea-Water to precipitate the Sea-Salts with it, and then they diftill the Water and ftrain it. *Glauber* imagined that Lapis Specularis would anfwer this Purpofe when reduced to Powder. And others have added acid Spirits yet with the help of all thefe Things, they could never frefhen Sea-water fo as to make it fit for Man's Ufe, for fome Salt and fome Bitternefs ftill remained. Dr. *Hales* has gone far beyond others in Trials of this Kind.

The pureft Water is thus known. 1. If it be clear and tranfparent without any Colour, Tafte or Smell. 2. If when a Solution of Silver in Spirit of Nitre is put to it, the Water continues limpid as before, otherwise it will be turbid and bluiſh. 3. If it will not look like Milk though Oil of Tartar be pounded in it. 4. if it does not become thick by the Infuſion of a Solution of Sugar of Lead. Laſtly if *Venetian* Soap be equally diſſolved by the Water without leaving any Fragments behind.

Mr. *Richard Cunningham* Chemiſt, exhibited two Proceſſes in the Elaboratory of the College of *Dublin*, on the 6th Day of Auguſt 1754 for rendering Sea-water freſh and potable, ſo as to be uſeful at Sea. The Salt-water was taken up in *Dublin Bay* between *Dunlary* and the *Head* of *Howth*. The firſt Proceſs was according to Mr. *Appleton*'s Method which was lately diſcovered, and the other according to Mr. *Cunningham*'s own Invention; and after trying ſeveral Experiments on the Purity and Freſhneſs of the ſaid Waters it was found, that the Water purified by Mr. *Cunningham*'s Method was preferable to that done by Mr. *Appleton*'s. For Dr. *Rutty* tells us that Mr. *Cunningham*'s Water continued exquiſitely clear, without forming the leaſt Cloud or Opacity with the Solution of Silver, or with the Solution of Sugar of Lead, and that Mr. *Appleton*'s did not.

Mr. *Cunningham* informed Dr. *Edward Barry*, Dr. *Ferral*, Mr. *Croker* Chemiſt to the College, *William Maple*, and *John Putland* Eſqrs; before whom he performed ſeveral Proceſſes, that the Ingredients he uſed, are cheaper and leſs troubleſome than thoſe made Uſe of by Mr. *Appleton*.

Rain, Well, or River Water being filled in Casks to carry to Sea, will be changed in the Colour, Taste and Smell, so that it becomes nauseous and stinking, and not easily drinkable for Seamen. This Change is made by little Insects which floating in the Water soon become a Multitude; if this stinking Water boils upon a Fire, the Animalcula die immediately, and with the other Filth subside or sink to the Bottom.

Many have endeavoured to preserve Water from Insects and Putrefaction by mixing with the Water such Bodies as kill the Insects; yet this Mixture, though it answers that End, is destructive and injurous to the Health of Man. The diligent Dr. *Hales* found by repeated Experience, that an Ounce of Oil of Sulpher, or Eight Scruples of the Oil of Vitriol, are sufficient for every Butt of Water. If Butts are smoked with the Fumes of burning Brimstone, before they are filled with Water, it will be a great Means of preventing the Increase of the Animalcula, or of preventing the Water of being so horribly nauseous as it otherwise would be.

Pure-water being closed up in a Vessel of Gold, Silver, Lead, or Pewter, whether infected by Air or purged from it at a cold Season, being pressed by a Screw or struck with a Hammer cannot be condensed into a less Space than is the Capacity of the Vessel which contains it, as many Philosophers have proved by Experiments. The Water will transude or glide through the Pores of the Metal which compose the Vessel, and on its Surface will lie like Dew all around; so that by as much as the Cavity becomes greater by the external Preſſure or Force, by ſo much exactly will the Water perſpire through the Metalic Pores; as may be ſeen by ſtricking a Hammer againſt a Globe or Ball filled with Water, for at every Stroke the Water will ouze out.

The Particles of Water are hence very hard as was ſaid before; and therefore they do not eaſily change their Figure, nor do they fill their own Pores or Interſtices between them.

Hence alſo, a flat Board may be as eaſily broke by ſtriking the flat Side againſt Water, as if it had ſtruck againſt a hard Body. And Leaden Balls fired from a Gun obliquely againſt Water become as flat, as if they had ſtruck againſt Stones; nay they ſometimes break to Pieces. Therefore if a Glaſs Veſſel be completely filled with Water, and its Mouth be cloſely ſhut with a Cork; if the Cork which we here ſuppoſe to touch the Water be forced in farther, the Veſſel will break.

Hence we may learn, that it is convenient that Bungs of Caſks or Corks of Veſſels ſhould not touch the Fluids they contain: For if they do, it is odds that the Veſſels be not broken if tranſported to a greater Degree of Heat; provided the Bungs or Corks ſtand; and if the Veſſels be not broke, the Bungs or Corks will fly out.

CHAP. V.

Of Pneumatics *or the* Properties *of* Air.

AIR is a very thin elaſtic Fluid which ſurrounds the Globe of the Earth. It is a difficult Matter to aſcertain the Nature and Origin of Air, as it is an imperceptable Fluid to all our Senſes, except that of Feeling. From the Impreſſion and Reſiſtance it makes, we know there is ſuch a Body, which every where ſurrounds us, and is of the utmoſt Importance to Mankind.

Mr. *Boyle* gives us the beſt Account we have of its Origin. He ſuppoſes it to conſiſt of three different Kinds of Corpuſcules, viz. 1. Of Numberleſs minute Particles, which in the Form of Vapours or Exhalations aſcend from the Earth, Water, Vegitables, Animals, &c. in ſhort of almoſt all Subſtances on the Earth's Surface or very near it. 2. Of ſtill a more ſubtile Matter, conſiſting of infinitely ſmall Atoms, occaſioned by the Magnetical Effluvia of the Earth, and other moſt minute Particles, ſent with the Light which iſſues from the Celeſtial Luminaries, occaſioning thereby the Idea of Light in us. 3. Of an elaſtic Subſtance which is the Baſis of the other Parts, and conſtitutes the Eſſence of Air, concerning the Structure of which various Hypotheſes have been framed.

Some

Some have compared the elaſtic Particles to the Springs of Watches coild up, and endeavouring to reſtore or expand themſelves; others to compreſſed Wool which expands it ſelf when the Preſſure is taken off; and others, to ſlender Wires of different ſpringy Conſiſtances, and Subſtances, which will admit of Compreſſion and Expanſion, yet in the whole all amount to one and the ſame Thing.

Before we proceed to explain the Properties of the Air, it will be neceſſary to deſcribe the *Air-pump*.

The Air-pump is a Machine by which the Air contained in a proper Veſſel, may be exhauſted or drawn out.

Otto de Guerick a Burgo-maſter of *Magdeburg* was the firſt Inventor of this curious Inſtrument; which was afterwards very greatly improved by Mr. *Boyle*, Mr. *Papin*, and Mr. *Hawkſbee*.

The common Air-pump is repreſented in the *Figure fronting the Title Page*, where AA, are the two Braſs Barrels, in which the Piſtons CC move up and down. The Braſs Tube or Pipe marked HH is called the Swans-neck, through which the Air paſſes under the Receiver OO, by a ſmall Hole K, in the Middle of the Braſs-plate I I on the Top of the Pump, to a Braſs-piece in the Box DD; which being perforated lengthways to the Middle Point under the Barrel, tranſmits the Air to a Bladder-valve to be pumped out. The Mercurial Gauge which communicates with the Receiver or Glaſs Veſſel on the Top is marked

LLL.

LLL. The Stop-cock N, ſerves to readmit the Air when there is Occaſion. B is the Handle or Winch for working the Pump. GG, are two Pillars ſupporting the Frame of the Pump-wheel, which is ſcrewed upon them by the two Nuts EE. As to the Uſes of the other Parts, they will eaſily be comprehended by inſpecting the Figure.

The Opperation of this Machine depends on the Elaſticity or ſpringing Force of the Air: For by working the Pump, the Air in the Receiver will expand it ſelf; by which Means Part of it will be forced into the Barrel of the Pump, to be carried off. By thus continuing to work the Pump, the Air in the Receiver will be gradually exhauſted, but can never be wholly drawn out ſo as to leave a perfect Vacuum under the Veſſel.

We now proceed to explain the Properties of Air, and

I. *That Air is heavy.*

This will evidently appear to be true from the following Experiments.

Let a Glaſs Bottle, to which there is a Braſs-neck with a Cock therein that opens and ſhuts, be ſcrewed into the Plate of an Air-pump and the Cock left open, have the Air exhauſted from it by Pumping, and the Cock then cloſed to prevent any Air from ruſhing into the Bottle; if then the Bottle be unſcrewed from the Pump, and appended at one End of a Ballance, with a Weight juſt ſufficient to ſuſtain it at the other

End

End, has its Cock then opened, the Air will ruſh into the Bottle, and the Bottle will deſcend. If it be one that contains about 40 Cubic Inches, it will require 10 Grains to reſtore an Equilibrium; ſo that 40 Cubic Inches of Air, are equal in Weight to 10 Grains; and thus the Weight of a Cubic Foot of Air has been found, and diſcovered to be 850 Times leſs than a Cubic Foot of Water.

Let a Braſs or Copper Rim be covered over one End with a Wet Bladder well ſtreched and cloſely bound round the Rim by a Thread or String, have the open End of the Rim laid on the Pump; upon exhauſting the Air from within Side of the Rim, the Bladder will be found to be preſſed downwards by the incumbent Weight of the Atmoſphere more and more as the Pump is kept working, till at length the Bladder is broken, and a loud Report is produced by the Air's ruſhing in to fill the Vacuity.

Let a thin ſquare Glaſs Vial being cloſe corked up, having a very ſmall Orifice made quite through the Cork, be placed on an Air-pump under a Receiver: Upon exhauſting the Air from under the Receiver, the Air will alſo be exhauſted from the Vial through the Orifice: If the ſtop Cock be then opened and the Air readmitted, it will ruſh with ſuch Violence on the Vial, as to break it to Pieces; becauſe a ſufficient Quantity of Air cannot ruſh through the Orifice made in the Cork of the Vial, in a Moment, to enable it to withſtand the outward Preſſure.

Let

Let a Glafs Veffel, part filled with Mercury or any other Fluid, be placed on the Pump under a Receiver; and let a Tube clofed at one End and open at the other be inferted through an Orifice in a Collar on the Top of the Receiver with wet Leather about it, fo as that the open End may not reach the Mercury in the Glafs Veffel: The Receiver being then exhaufted of Air, the Tube will be alfo exhaufted: Let the Tube be then pufhed down gently into the Mercury in the Glafs Veffel, and the Air readmitted into the Receiver, it will then be found to prefs fo heavily on the Mercury in the Glafs Veffel as to drive it up the exhaufted Tube, untill the Weight of the elevated Mercury preffes as forceably againft that Part which is immediately under the Tube, as the Weight of the Air does on every other equal Part which is without the Tube.

Fig. 46. By the Weight and Preffure of the Air, Water is raifed in Pumps, and Fire Engines, thus. Let AB reprefent a Pump, or Tube open at both Ends, C a fixed Plug with a Hole through its Middle, covered with a Leather *Valve* like a Trap Door, that will eafily open to let the Water pafs upwards, and fhut to prevent the Water paffing downwards: D a moveable Plug, *Pifton*, or *Sucker* made in all Refpects as the former, but joined to the Rod E, and that Rod to the Handle that works it. The Sides of the Pifton are cafed with Leather to fit the Cavity of the Pump fo tight that neither Air or Water can pafs between. At fome Diftance above the

 Pifton

Piſton is an Orifice at O in the Side of the Pump through which the Water is diſcharged in the following Manner. The Piſton D being drawn up, driving the Air before it, thereby cauſes a *Vacuum* between C and D; and the Air preſſing on the Water in the Well, drives it through the Plug C whoſe Valve opens to let it through, to fill up the Vacuity; then upon depreſſing the Piſton D, the Valve of C ſhuts and prevents the Water to return downwards, and immediately it riſes through the Piſton D whoſe Valve opens, and lodges itſelf thereon; and then by a Stroke of the Handle, the Piſton D, is raiſed and the Water lying on it is diſcharged through the Orifice O.

The Fire Engine, or little Dutch Pump, which is often uſed to Water Streets or Gardens, is thus conſtructed.

Fig. 47. Let a Plug be fixed at C with a Valve, as in the foregoing Pump, to ſuffer Water to paſs through it upwards, but not to return. D is a ſolid Piſton without either Bore or Valve which is fixed to a Rod, and that to a Handle T by which it is worked. A little above the Plug C there is an Orifice O in the Side, wherein a Tube OE is inſerted, in which Tube there is a fixed Plug V with a Valve that opens outwardly and ſuffers no Water to return. Now when the Piſton D is raiſed it is plain that it cauſes a Vacuity between D and C, and the Air preſſing on the Water in which the Machine ſtands, drives the Water through C on the Valve of which it lodges; the ſolid Piſton D then being

thruſt

thruſt down will drive the Water through the Orifice O, and up through the Tube or Pipe OE; but on drawing up the Piſton, the Valve at V in the Tube OE immediately ſhuts by the Deſcent of the Water from E to V, and prevents it coming backwards on the Valve in the Plug C: And thus by the help of Leathern Pipes, Water may be conveyed to the Tops of the higheſt Houſes.

That the Atmoſphere is heavier at one Time than at another, we are confirmed of by the *Barometer* or Weather Glaſs, invented by *Torricellius*, and is thence known amongſt Naturaliſts by the Name of the *Torricellian-tube*. It is made by filling a Glaſs Tube of about three Feet long with Mercury, which Tube is hermetically cloſed or ſealed at one End, and by putting your Finger to the other End invert it in a Veſſel as A or B, (*Fig.* 48) which is partly filled with Mercury without letting in any Air: Upon taking the Finger away, the Mercury in the Tube will remain ſuſpended between 28 and 31 Inches above the Surface thereof in the Veſſel.

This Mercury is kept up the Tube by the Weight or Preſſure of the Atmoſphere on the Mercury in the Veſſel; for if the Tube and Veſſel be put under a Receiver on an Air-pump, and if the Air be exhauſted from the Receiver, the Mercury in the Tube will all fall down into the Veſſel; and if the Air be again reſtored, the Mercury in the Veſſel will be drove up the Tube to its former Height.

The Mercury in the Tube is never found to riſe higher than 31 Inches, even when the Atmofphere is moft condenfed or moft weighty; nor does it ever fall lower than 28 Inches though the Atmofphere were moft rarified, or in its lighteft State: And hence it is that Barometers are graduated on either Side from 28 to 31 Inches, as the Barometers B and C are; and oppofite to thefe Divifions you have Words which exprefs the State of the Atmofphere, or what Kind of Weather will foon enfue. When the Air is moft rarified, or when it is in its ligheft State, it is then unable to fuftain the Clouds and therefore great Rains fall; and yet we are apt to fay that fuch Weather is very heavy: And on the contrary when the Air is moft condenfed, and therefore moft weighty, it is moft able to fuftain the Clouds, and the Weather is then fineft, and we are apt to fay it is light Weather: For the Air when it is moft rarified, is very thin, and a great Part of it glides through the Lungs, and therefore the Refpiration is weak, which greatly difturbs and weakens the human Frame and renders our Spirits low and heavy, as well as thofe of other Animals; and again, when the Air is moft denfe it will not be able to ouze out of, or glide through the Lungs, and therefore it is then fitteft and beft for Refpiration, which adds Life and Spirits to the Body, and thereby occafions us to fay it is fine light Weather.

Fig. 48. The Barometer AD is a Diagonal one, whofe Height from A to D is 28 Inches; let DE be 3 Inches, and thereby AE 31; if to E be drawn a perpendicular EF, and if from any Point therein as F, there be drawn the Diagonal

FD:

FD: If a Tube be turned in that Direction it will more apparently ſhew the riſe or fall of the Mercury, than either of the Barometers B or C can, and ſuch are graduated from D to F.

The Barometer C is turned at one End, and a little above the Turn is a Ciſtern or Baſon to receive the deſcending Mercury: In the Top of this Ciſtern there is an Orifice to let in the Air, in order that it may preſs upon the Mercury in the Ciſtern; and thereby as its Gravity increaſes or decreaſes that the Mercury may the more readily riſe and fall; and theſe Kind of Barometers are moſt frequent.

Beſides theſe Barometers here mentioned, there are the *Wheel* and *Conical* Barometers: But as they are all actuated by the foregoing Principles, it is needleſs to be particular about them.

In any Barometer, the Mercury in the Tube will have a convex Surface if it be riſing, but if it be falling the Surface will be concave.

If the like Experiment were tried with a long Tube and Water, the Water would never be found to riſe higher than 36 Feet 2 Inches, or to fall lower than 32 Feet 8 Inches; for Water, by the foregoing Table of the Specific Gravities of Bodies, is found to be 14 Times heavier than Mercury: That is to ſay, if the Surface of the Earth were covered 28 Inches deep with Mercury, or with 32 Feet 8 Inches depth of Water; they would preſs equally on it, and each Preſſure would be equal to the Preſſure of the Atmoſphere when in its lighteſt State.

Hence

Hence it is that the Surface of Water in a Well muſt be leſs than 33 Feet from the End of a Pump's Piſton; and yet Water may be raiſed by a Pump to any Height, provided the Rod of the Piſton be made long enough.

The ſurpriſing Force with which the Atmoſphere preſſes in all Directions may be further evinced, thus;

Let two Braſs hollow Hemiſpheres each of 3 Inches Diameter, the one with a Ring on its Vertex, and the other with a Screw and Cock on its Vertex, be laid one upon the other with wet Leather between the Edges, the Screw Hemiſphere being firſt inſerted in the Plate of an Air-pump and its Cock opened; exhauſt the Air that is between the Hemiſpheres through the ſcrewed Neck and cloſe the Cock: Then if the whole be unſcrewed from the Plate, the two Hemiſpheres will be found to be ſo cloſely preſſed together by the Atmoſphere as to require 150 Pounds to pull them aſunder when the Air is in its lighteſt State, and at other Times, 160, 180 or 200 Pounds will ſcarcely be ſufficient to ſeperate them: For theſe Weights will be in Proportion of the Preſſure of the Atmoſphere at different Times, and when it is in different States.

Hence it is that Air is found to preſs above $16\frac{1}{2}$ Pounds upon every Square Inch, or with a Weight of 31144 Pounds upon a midling Man, whoſe Surface is about 15 Square Feet; which would infallibly cruſh him to Pieces if the Air within him did not counterballance the external Preſſure.

If

If a Perſon lays his Hand over a ſmall open Receiver, and thence exhauſts the Air, he will find ſo great a Weight or Preſſure on the Back of his Hand as not only to give him Pain, but to endanger the breaking of his Hand; which is immediately eaſed by reſtoring the Air.

If the Braſs Hemiſpheres which before were exhauſted, and which required a great Weight to ſeperate them, be put under a Receiver on an Air Pump, upon exhauſting the Air out of the Receiver, the Hemiſpheres will ſeperate and fall aſunder from each other, which manifeſtly ſhews that their ſtrong Coheſion is owing to nothing elſe but to the Preſſure of the Atmoſphere upon them.

Fig. 49. The *Siphon* or *Crane* is a bended Tube ABC, which being filled with Water, and putting the ſhorteſt Leg A into the Water, the Veſſel will be emptied by paſſing through the Siphon, and will be diſcharged at the other End C, provided that End be any Thing lower than the Surface of Water in the Veſſel: For the Atmoſphere preſſes upon both Ends of the Tube and ſo keeps it full, but the Water in each Leg preſſes downwards in Proportion to their perpendicular Heights AB, AC; now ſeeing BC is greater than AB, the Water will yield to the greateſt Preſſure and therefore will be dicharged at C, ſo long as C is lower than the Water in the Veſſel.

This is the true Cauſe of the Siphon's running, becauſe if a little Hole be made about the Top of the Tube while the Water is running; or if the Siphon be put under a Receiver and thence the Air be exhauſted

exhausted, the Fluid in the Siphon will divide at the Top and fall down through each Leg.

Hence Water may be made to run through Pipes over any Hill, House, or Wall that is not above 33 Feet high; provided the Place you would bring it to, be lower than the Spring Head, or the Surface of the Water you would bring it from: Because 33 Feet of Water is equal to the Pressure of the Atmosphere when the Air is in its lightest State, as we have already but just shewn.

Other Fluids will rise in a Siphon to a greater or to a less Height, according to their Specific Gravities.

Fig. 50. If a Siphon *a*,*b*,*c*, be placed within a Vessel having one Leg passing through its Bottom: If Water be poured into this Vessel, it will not begin to run out of the Siphon till the Surface of the Water be above the Top of the Siphon: But then the Water will run down the Leg *ac*, which being once filled will continue to discharge the Water at *c* as long as there is any in the Vessel, which must be sufficiently evident from what has been already said.

In this Manner we may account for the ebbing and flowing of Springs: For if Water be imagined to run gradually into the foregoing Vessel till the Surface covers the Top of the Siphon, if then the Water runs out of the Siphon faster than the Vessel is supplied therewith, it will empty and continue to stop till the Siphon be again covered.

These intermitting Springs will be rendered more obvious, if we let ABC to represent a Hill wherein

wherein there is a Cavity C; if in this Cavity there is a Paſſage or Vein running in the Direction WED, then if the Rains which fall on the Hill by paſſing through the Pores of the Earth fill the Cavity C higher than the Top of the Vein to E, the Water or Spring at W will continue running till it has withdrawn the Water in the Cavity ſo low as D; and then it will ſtop 'till the Cavity be repleniſhed again, and it riſes above E and then it will flow again, and ſo on.

2. *Of the Elaſticity of Air.*

By the Elaſticity or ſpringing Force of the Air, we underſtand it to be that Force wherewith the Particles of Air expand themſelves and recede from each other, as before: And this happens when the Preſſure which keeps them together is taken off.

That Air is Elaſtic will be evident from the following Experiments.

If Air be cloſely corked up in a thin Square Vial, and the Bottle be put under a Receiver on an Air Pump: Upon exhauſting the Receiver the confined Air in the Vial will by its Elaſticity burſt the Bottle to Pieces.

Tie up a little Air in a Bladder, and put it under a Receiver; when the Air is exhauſted from the Receiver, the Bladder will ſwell as if it were blown up.

Take a Glaſs of warm Ale or any other glutinous Fluid, and putting it under a Receiver, exhauſt the Air, and the Liquor will riſe in large frothy Bubbles and run over the Glaſs.

For the Liquor being glutinous contains a great Number of Particles of Air, which upon removing the outward Air expand themſelves; and as they cannot diſengage themſelves of the clammy Liquor about them, they raiſe it up and carry it over the Glaſs in the Form of Froth.

Put an empty Glaſs Bottle with its open Mouth down into a Glaſs Veſſel of Water, cover both with a Receiver, and thence exhauſt the Air; the Air in the Bottle will be then obſerved to ſwell and bubble through the Water.

Inſert a ſmall Glaſs Tube open at each End into a Bottle Part full of Water, ſo that the lower End of the Tube may be below the Surface of the Water; and let the Inſertion be made by Means of a Screw and Collar of Leathers, in ſuch a Manner, that no Air can paſs into or out of the Neck of the Bottle: Let the Whole be then covered with a tall Receiver, and the Air being thence exhauſted; the Water will riſe up through the Tube in Form of a Jet, which will be higher or lower as the Receiver is more or leſs exhauſted: for the Air in the Bottle, by its Endeavour to expand itſelf, preſſes on the Surface of the Water, and ſo drives it up the Tube.

The Elaſticity of the Air is equal to the Preſſure of the Atmoſphere, becauſe it ſuſtains that Preſſure: For the Air in the Bottle, or in any other Veſſel, will expand with a Force, that is equal to that with which it is preſſed; Action and Re-action being equal and contrary: And

hence

hence the Elaſticity of a ſmall Quantity of Air, is equal to that of a great Quantity.

The Denſity of the Air is always as the Force that preſſes it, and therefore the Air towards the upper Part of the Atmoſphere, being leſs preſſed than that near the Earth, it will thereby become thinner; ſo that the farther we go up Mountains we find the Air becomes the rarer, and the Rarity is found to be ſuch, that if Altitudes in the Air, be taken in Arithmetical Proportion the Rarities of the Air at theſe Altitudes will be in Geometrical Proportion. Thus,

At the Altitude of				
	7	Miles from the Surface of the Earth	4	Times thinner or rarer than at the Surface
	14		16	
	21		64	
	28		256	
	35		1024	
	70		1048576	

Hence we may eaſily by Calculation find, that a Cubic Foot of common Air at the Height of 500 Miles would be ſo much rarified or expanded as to fill a Sphere of equal Diameter with that of the Orbit of Saturn; and therefore the Planets may eaſily move through the Heavens without ſuffering any ſenſible Reſiſtance.

Though by this Rule for finding the Rarity of the Air, there will ſtill be Air at infinite Diſtances, yet at the Height of 40 or 50 Miles, it is ſo rare, that what is above that Diſtance is inconſiderable. And therefore, the Height of the Atmoſphere is generally reckoned to be about 45 Miles.

Since the Denſity of the Air is proportionable to the Compreſſing Force, and this is equal to the Elaſtic Force; it therefore follows that in aſmuch as the Denſity is increaſed, the Elaſticity will be increaſed in the ſame Proportion.

Upon this Principle are founded artificial Fountains, which play by Means of condenſed Air: They are of two Kinds, Single and Double.

Fig. 52. The ſingle Fountain is made of Braſs. and is every where ſhut except, that through the Middle of the Baſon BB there paſſes down a Pipe PP, whoſe lower End reaches nearly to the Bottom of the Fountain, and to the upper End, there is fixed a Stop-cock, by Means of which, the Pipe may be ſhut or opened as Occaſion requires.

Some Part of the Fountain ADC being filled with Water poured in through the Pipe, a Condenſer or forcing Engine is ſcrewed to the Top of the Pipe above the Cock, by Means whereof a great Quantity of Air is driven through the Pipe and remains condenſed above the Surface of the Water in the Fountain. When therefore the Condenſer is taken off, and the Cock opened, the condenſed Air above the Water, preſſing ſtrongly on it, drives the Water up through the Pipe, and thereby forms a Jet.

The Force wherewith Water is thrown up, is as the Denſity of the included Air, above the external Air.

Fig. 53. The double Fountain conſiſts of two ſingle ones, as AA, and BB, faſtened to a hollow Cylinder CC which plays upon the Pins DD as

upon

upon an Axis: Each Fountain has a Pipe P whofe lower End reaches nearly to the Bottom of its Fountain. From the Bafon of the Fountain AA there iffues another Pipe TE which opens at E, in the Fountain BB, which Pipe neither communicates with the Fountain AA, nor with the hollow Cylinder CC. In like Manner there iffues another Pipe in the Bafon BB which paffes through that Fountain and Cylinder, and opens in the Fountain AA.

The Whole Machine is then placed in an upright Pofture by Means of a Carriage which fupports it; and the Pipes of the lower Fountain being ftopped, water is conveyed in it through the Pipe T, which iffues from the Bafon of the upper Fountain; by the running of which Water into the lower Fountain, the Air contained therein, becomes condenfed; if then, both the Pipes of the upper Fountain be ftopped, and the lower Fountain be turned upon its Pins, the Water which it contains will fall to its Bottom and the lower End of the Pipe P will be immerfed therein, in the Manner reprefented in the upper Fountain; fo that upon opening that Pipe, the Water will be driven through it, by the Elafticity of the condenfed Air, and as it falls upon the Bafon, it will be conveyed thence through the Pipe T, into the lower Fountain; and when the upper is exhaufted, and ceafes to play; if its Pipes be ftopped, and turned downwards as before, the other may be fet a going in the fame Manner; and fo on as long as you pleafe.

3. *That Heat will rarifie Air.*

Air being heated will rarifie or be made to ſwell and expand itſelf; and this Property may be fully evinced by tying up a ſmall Quantity of Air in a Bladder, and laying it before a Fire; the Air in the Bladder will be ſo much rarified by the Heat, as ſometimes to cauſe the Bladder to ſwell as if it were blown up tight.

Wind is a neceſſary Conſequence of this Property of Air; for when the Air is heated by the Sun, or by any culinary Fire, it will ſwell and drive the adjacent Air away; and thus, by various Degrees of Heat, in different Places, there will ariſe various Winds.

Hence if Air be very 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 Wind, a Stream or Current of Air from all Parts, towards the Place where the Heat is; which is the Reaſon, why Air ruſhes with great Violence, into the Door of a Glaſs-houſe, or through the Key-hole of a Door, or through any ſmall Chink of a Room wherein is a Fire, as well as that Smoak is carried up a Chimney: Take it in general, that the Air will preſs towards that Part of the World which is moſt heated.

Upon this Account it is, that the Trade-winds at or about the Equator, conſtantly blow from the Eaſt towards the Weſt; for when the Sun ſhines perpendicularly on any Part of the Earth, it will heat the Air which is over that Part greatly, and occaſion it to rarifie and riſe upwards; and this will occaſion the adjacent Air to ruſh in, to fill up the Vacuity, which will conſequently cauſe a Wind, Stream, or Current of Air from all Parts, towards the Sun: And ſince the Sun, with reſpect to the Earth, moves from Eaſt to Weſt, the common Courſe of the Air will be alſo that Way continually preſſing after the Sun; and therefore, at the Equator where the Sun ſhines ſtrongly, there will be a continual Eaſterly Wind; but on the North Side it will incline a little to the North, and on the South Side a little to the South.

This general Courſe of Trade-winds, about the Equator, is changed in ſeveral Places, and upon ſeveral Accounts.

1. By the Attraction of the Moon, which on the Meridian may as reaſonably be ſuppoſed to raiſe or ſwell the Air, as it does the Water in the Tides.

2. By certain Exhalations that riſe out of the Earth, at certain Times, and from certain Places, by Earthquakes eſpecially, and by Vulcanos.

3. By the fall of great Quantities of Rain, Hail, or Snow which cauſe a ſudden Condenſation or Contraction in the Air.

4. By the ſudden melting of Snow on the Mountains, which cauſes the Condenſation near them ſuddenly to ceaſe.

5. By burning Sands that retain the ſolar Heat, to a Degree incredible to thoſe who have not felt it,

cauſing

caufing a more than ordinary Degree of Rarefaction in the Air, which Is over them.

6. By the Oppofition of high Mountains that reflect the Wind, and alter the Line of Direction.

7. By the Suns declining towards the North, or South, and thereby heating and rarefying the Air in this or that Part of the Earth All which particular Caufes may chance either to confpire with, and ftrengthen the general one before cited, or may oppofe in Part or leffen its Efforts, according to the Diverfity of Time, Place, and Circumftance that may happen in the Courfe of Things.

To thefe Particulars, or fuch like, are owing.

1. The great irregularity, and uncertainty of Winds, in Places which are far from the Equator, as in moft Parts of *Europe*.

2. Thofe periodical Winds, which blow half a Year one Way, and the other half another Way, as in the *Indian Sea*.

3. Thofe Winds, which on the Coafts of *Guinea*, and on the Weftern Coafts of *America* blow always from the Weft to the Eaft.

4. Sea Breezes, which in hot Countries blow generally from Sea to Land in the Day Time; and the Land Breeze, which blows in the Night: And in fhort all thofe Storms, Hurricanes, Whirlwinds, and Irregularities which happen in different Times and Places, muft proceed from fome fuch Caufes as thofe before mentioned.

Particular Defcriptions of the Motions of the Air in various Parts of the World might be eafily given, but as this would be a tedious Tafk, we

fhall

shall proceed to explain the Nature of *Sounds.*

That Sounds depend on the tremulous Motions of the Air, will be manifest by placing a Bell under a Receiver, in such a Manner as that it may be rung at Pleasure; upon drawing the Air out of the Receiver, the Sound of the Bell will be less and less audible the more the Air is exhausted, so as at last almost to die away and scarcely to be heard; and again upon readmitting the Air, the Sound will revive and will increase the more as the Air is let in.

When the Parts of a Bell, Drum, Musical String, or any other Elastic Body, are set in Motion by a Stroke, they vibrate, or move forward and backward alternately through very small Spaces; in going forward they compress the Air, and in returning backward the compressed Air expands itself; so that the Parts of the Air, which are contiguous to the sonorous or trembling Body, go and return in the same Manner, with the Parts of the Body, and these again agitate those Parts of the Air which are beyond them, and so on 'till at last the Motion ceases: So that Sounds are propagated every Way, as it were from the Center to the Superficies of a Sphere.

The Propagation of Sounds may very well be compared with Circles made in the Water, by throwing a Stone into it. And as those which are made in a running Stream, extend themselves further towards the lower than towards the upper Part of the River, because the whole Water in which they are formed carries them that way: So likewiſe we may conceive, that if the Wind carries the Air towards one certain Place, the trembling Motion in which Sound conſiſts, will ſooner go in this way than the contrary. Thus we find by Experience, that the Sound of a Canon, and in general all other Sounds are heard ſooner with the Wind than againſt it. And it may happen, that Air may be moved ſo quick, that its Parts may fly from us as faſt as the Sound goes, and ſo it may not be heard at all.

Becauſe the trembling Motion of the Air, in which Sounds conſiſt, is communicated gradually, ſo as to affect thoſe Parts which are near the ſounding Body, ſooner than thoſe that are further off, the Sound muſt neceſſarily take up ſome Time in going along, and thus we find by Experience, that if a Canon be diſcharged at two or three Miles Diſtance, that we ſee the Flaſh ſome Time before we hear the Noiſe.

Hence the Velocity of Sound is found to be 1142 Feet in one ſecond of Time; and thus the Diſtance of any Ship that fires a Gun at Sea, may be known by means of a Watch that meaſures Seconds, by obſerving the Time between the Flaſh and the Report.

The further the ſounding Body is off, the leſs will be the Noiſe, becauſe the tremulous Motion of the Air ſpreads wider ſucceſſively, and thereby becomes weaker 'till at length it dies away.

The Sounds of Muſical Strings, conſiſt in the Agitation they are put in, by the Bow being made rough with Roſin; for if the Bow be rubbed with

with Tallow or Oil, the Strings will have no Sound, becaufe they flip under, and are not fhaken by it.

The Sounds of drinking Glaffes, as made by rubbing the Finger about the Rims, are of the fame Nature with the Strings of a Violin; for the Finger here fupplies the Place of a Bow.

The Sound of a Bell is occafioned by the Stroke of the Clapper againft it, which alters its Figure a little from a Circle to an Oval: And becaufe it is made of a Metal ftiff, but elaftic or fpringy, that Part which is moft diftant from the Center, returns towards it fomething nearer than at firft; fo that the Places which were the Extremities of the longeft, will become thofe of the fhorteft Diameter; and thus the Figure of the Bell is changed all the Time it is ringing. This will be more manifeft to any Perfon who lays his Hand upon a large Bell, juft when the Clapper ftrikes, for he will be affected with a furprizing Numnefs; and the Hand being laid upon a fmall Bell will either damp, or quite ftop its Sound.

The Sound raifed by ftriking a piece of Wood, or in general any hard founding Body, confifts in its tremulous Motion, which is owing to its Elafticity or fpringing Force.

Hence all Bodies that are void of Elafticity, have a low or imperfect Sound.

Since Sound is propagated every Way, from the Center to the Surface of a Sphere, it is plain that two Perfons who are not in the fame concentric Circle or Sphere cannot hear the Sound at the fame Inftant of Time. And if the Motion of Air, which might be communicated to a great Diſtance, meets ſome hard Body which it cannot ſhake, it may cauſe the Motion to reflect or return backward, and this redoubled Sound is called an *Echo*.

If Sound meets ſeveral Bodies at different Diſtances, which are capable of reflecting it back again, and if that which returns from the moſt diſtant Place, ſtrikes upon the Ear, after the Impreſſion of the former is quite gone off, it muſt in its turn produce a new Senſation of Sound. Hence it is evident we may meet with *Echos* which will repeat the ſame Word ſeveral Times.

The more a Muſical String is *ſtrained*, the *ſharper* is the Sound, for its Vibrations will become the quicker; and the *looſer* the Strings are, the Vibrations will be *ſlower*; and therefore the Sound will be more *flat*: And this is the Reaſon of *Flats* and *Sharps* in Muſic.

When two ſounding Bodies ſtrike the Air at the ſame Time, they impreſs ſuch a Motion upon it, as is compounded of the two Motions, if they acted upon it ſeperately; and conſequently the Air puts the *Organ* of hearing, into ſuch a tremulous Sort of Motion, as gives a Senſation of diſtinguiſhing the two Sounds ſeperately.

If two Strings, or any other ſounding Bodies, do ſo exactly agree in their *Vibrations* of *Pulſes*, as to ſtrike the Air at one and the ſame Time, or if they ſtrike together every ſecond or third Stroke; or if one performs 5 whilſt the other performs 6 Vibrations; then the Ear will be uniformly ſtruck upon, and in ſuch a Meaſure,

that

that it will perceive the Diſtance, and be pleaſed with the Cadence; and this is the Reaſon why Muſicians call theſe Pulſes *Concords*; as an *Uniſon* and *Octave*, a *Fifth* and a *Third* are.

On the contrary, if Vibrations ſo far diſagree as not to ſtrike together, or meet each other, we muſt perceive an inequality, and ſomething diſagreeable and harſh in the Sounds; and theſe Muſicians call *Diſcords.*

Some may perhaps think that the longeſt and ſhorteſt Vibrations of a Muſical String, are not performed in the ſame Time; but upon due examination they will find them to be exactly equal.

If two Strings of the ſame or of different *Lutes* be *Uniſons*, that is, if the Number of Vibrations of the one be equal to thoſe of the other, in the ſame Time, we cannot move one but the other will ſound alſo, or at leaſt it will tremble; whereas it will not tremble at all, if we move any other String near it which is a *Diſcord.* For the Strings which are *Concords* being capable of the ſame Vibrations, very conveniently communicate them to each other, and there can be no Agreement in them, if the Strings are not *Uniſons*, becauſe the Air which is put in Motion by the one, does not find the other diſpoſed to receive its Motion; ſince every Stroke except the firſt being out of Time they conſpire to deſtroy each other's Motion.

This Diſpoſition that a Body has to move, when the Air is ſhaken by another Body, is to be found in other Things as well as in the

Strings

Strings of a Lute, or other Mufical Inftrument: This has been experienced by Gentlemen in the Army, when they have obferved the Glafs Windows to tremble very fenfibly upon beating of a certain Drum, and at the fame Time would not tremble at all upon beating of others which are much louder.

So likewife if two Glaffes, by putting in a proper Quantity of Water, be made *Unifons*; the preffing of our Finger hard upon the Edge of either of them, and moving it round, will make the Water in the other curl, and dance about.

Mr. *Boyle* tells us that upon difcharging of Canons, a fick Man who had his left Hand cut off, thought himfelf almoft fhattered and torn to Pieces; of another that upon fcraping a piece of Iron with a Knife, he could not hold his Water; and of a third, that upon tearing thick Paper his Gums would bleed.

To thefe fort of Motions may be afcribed the Caufe of certain *Shiverings*, which we fometimes feel all over our Body, and which reaches even to the Heart, upon hearing the found of a Trumpet, a Concert of Mufic, *&c.* For it may be that the Blood is difpofed to yield eafily to the trembling of the Air.

And becaufe the Membrane or *Drum* of the Ear, which is fomething like Parchment, being agitated by the external Air, caufes different Motions on the Capilliments of the Nerves of the Ear; therefore it will be more or lefs fhaken according as it is more or lefs ftretched; fo that

Attention

Attention confifts in nothing elfe but in a due ftretching or loofening of this Membrane, and by keeping it in that Pofition where it will beft receive the Impreffion and Motion which Sound gives to the external Air.

Of the Diving Bell.

The Diving Bell is a large Veffel of Wood or Copper, with Weights about the Bottom in Order to make it fink, when full of Air, with the Mouth of the Bell downwards: The Diver fitting under his Bell is let down with the included Air, to the Depth defired.

The Management of this Machine depends upon the Knowledge of the following Principles.

1. That a Body being immerfed in a homogeneal or a like Fluid, is always preffed with a Force proportional to its Diftance from the Surface.

2. That the Denfity of Air is always as the Force that preffes it, that is with a double Preffure, it will be preffed into half, or with a triple Preffure into one third of the Space it before poffeffed.

3. That Air is vitiated by paffing through the Lungs of Animals.

Doctor Halley's *Defpription of his Diving Bell.*

" The Bell I made ufe of was of Wood, containing about fixty Cubic Feet in its Concavity, and was in the Form of a *Truncate Cone*, whofe Diameter

Diameter at the Top was three Feet, and at bottom five. This I coated with Lead ſo heavy that it would ſink empty, and I diſtributed the Weight ſo about its Bottom, that it would go down in a perpendicular Situation and no other. In the Top I fixed a ſtrong, but clear Glaſs, as a Window to let in the Light from above; and likewiſe a Cock to let out the hot Air that had been breathed; and below, about a Yard under the Bell, I placed a *Stage* which hung by three Ropes, each of which was charged with about one Hundred Weight, to keep it ſteddy. This Machine I ſuſpended from the Maſt of a Ship by a *Sprit*, which was ſufficiently ſecured by *Stays* to the Maſt Head, and was directed by *Braces* to carry it over Board, clear of the the Ship's Side, and to bring it again within Board, as Occaſion required.

To ſupply Air to this Bell when under Water I cauſed a couple of Barrels of about thirty-ſix Gallons each, to be caſed with Lead, ſo as to ſink empty; each having a Bung Hole in its loweſt Part to let in the Water, as the Air in them condenſed on their Deſcent; and to let it out again when they were drawn up full from below: And to a Hole in the uppermoſt Part of theſe Barrels, I fixed a leathern Trunk or *Hoſe*, well liquored with Bees-wax and Oil, and long enough to fall below the Bung-hole, being kept down by a Weight appended, ſo that the Air in the upper Part of the Barrel, could not eſcape unleſs the lower Ends of the *Hoſe* were firſt lifted up.

The

The Air Barrels being thus prepared, I fitted them with Tackle proper to make them riſe and fall alternately, after the Manner of two Buckets in a Well. Which was done with ſo much Eaſe, that two Men with leſs than half their Strength could perform all the Labour required; and in their Deſcent they were directed by Lines faſtened to the under Edge of the Bell, the which paſſed through Rings placed on both Sides of the Leathern *Hoſe* in each Barrel; ſo that ſliding down by thoſe Lines, they came readily to the Hand of a Man who ſtood on the Stage, on purpoſe to receive them, and to take up the Ends of the *Hoſe* into the Bell. Through theſe *Hoſe*, as ſoon as their Ends came above the Surface of the Water in the Barrels, all the Air that was included in the upper Parts of them, was blown with great Force into the Bell, while the Water entered at the Bung-holes below and filled them; and as ſoon as the Air of the one Barrel, had been thus received, upon a Signal given, that was drawn up, and at the ſame Time the other deſcended; and by an alternate Succeſſion, furniſhed Air ſo quick and in ſo great plenty, that I myſelf have been one of five, who have been together at the Bottom, in nine or ten Fathoms Water, for above an Hour and a half at a Time, without any ſort of ill Conſequence; and I might have continued there as long as I pleaſed, for any Thing that appeared to the contrary. Beſides, the whole Cavity of the Bell was kept entirely free from Water, ſo that I ſat on the Bench, which was diametrically placed near the Bottom, wholly dreſſed with all my Cloaths on; I only obſerved that it is neceſſary to be let down gradually at firſt, at about twelve Feet at a Time, and then ſtop and drive out the Water that entered, by receiving three or four Barrels of freſh Air, before I deſcended farther. But being arrived at the Depth deſigned, I then let out as much of the hot Air that had been breathed, as each Barrel would repleniſh with cool, by means of the Cock at the Top of the Bell; through whoſe Aperture, though very ſmall, the Air would ruſh with ſo much Violence, as to make the Surface of the Sea boil; and cover it with a white Foam, notwithſtanding the great Weight of Water over us.

Thus I found I could do any Thing that was required to be done juſt under us; and that by taking off the Stage, I could for a Space as wide as the Circuit of the Bell, lay the Bottom of the Sea ſo far dry, as not to be over Shoes thereon. And by the Glaſs-window, ſo much Light was tranſmitted, that when the Sea was clear, and eſpecially when the Sun ſhone, I could ſee perfectly well to write or read, much more to faſten and lay hold of any Thing under us that was to be taken up. And by the return of the Air Barrels, I often ſent up Orders, written with an Iron Pen on ſmall Plates of Lead, directing how to move us from Place to Place as Occaſion required. At other Times when the Water was troubled and thick, it would be as dark as Night below; but in ſuch a Caſe I have been able to keep a Candle burning in the Bell as long as I pleafed, notwithftanding the great Expence of Air requifite to maintain Flame.

This I take to be an Invention applicable to various Ufes; fuch as *Fifhing* for *Pearl*, *Diving* for *Coral*, *Spunges* and the like, in far greater Depths than has hitherto been thought poffible: Alfo for fitting and plaining of the Foundation of Moles, Bridges, *&c.* upon rocky Bottoms and for the cleaning and fcrubbing of Ships Bottoms when foul, in calm Weather at Sea. But as I have no Experience of thefe Matters, I leave them to thofe that pleafe to try. I fhall only intimate, that by an additional * Contrivance, I have found it not impracticable for a Diver to go out of our Engine to a good Diftance from it, the Air being conveyed to him with a continued Stream, by fmall flexible Pipes; which Pipes may ferve as a Clew to direct him back again when he would return to the Bell."

CHAP.

* The Contrivance here mentioned, was a Veffel made in the Shape of a Bell, fo big as to cover a Man's Head and Shoulders; this was put over a Divers Head and with it he walk'd out of the Bell upon the Bottom of the Sea up and down, and had the Air conveyed to him by flexible Tubes.

CHAP. VI.

Of Optics, *or the* Properties *of Light.*

LIGHT is a moſt ſubtile Fluid whoſe particles are exteamly ſmall; and are thrown off from Luminous Bodies by the vibrating Motions of their Parts with a ſurprizing great Velocity; for it is found by means of the *Eclipſes* of the *Satellites* of JUPITER that they paſs from the Sun to the Earth in about ſeven Minutes; for theſe Eclipſes when the Earth is between the Sun and JUPITER, are found to happen about ſeven Minutes ſooner than they ought to do by Aſtronomical Tables; and when the Earth is beyond the Sun with reſpect to JUPITER, they happen about ſeven Minutes later than they ought to do; ſo that in the latter Situation of the Earth, they are found to happen about fourteen Minutes later than in the former; that is light will paſs through the Diameter of the Earths Orbit in fourteen Minutes, or from the Sun to the Earth, which is Eighty-one Millions of Miles in ſeven Minutes.

Droptics *or the Nature of the Refraction of Light.*

That the Motion of Light is rectilineal is evident from the Shadows which opaque Bodies caſt when placed in the Light of the Sun, or of

any

any other luminous Body; and yet the Beams or Rays of Light, in paſſing out of one tranſparent Body or *Medium*, as Air, Water, Glaſs, Diamond, a Vacuum, *&c.* into another of a different Denſity, are bent or turned out of their Way, or they are made to change the Direction of their Motion; and this bending or change of Direction is called *Refraction*; and it is found, that Rays which paſs from a rarer into a denſer *Medium*, bend towards a perpendicular Line, let fallen from the Point of Incidence on the refracting Surface; and on the contrary, when they paſs out of a Denſer into the rarer *Medium*, they decline or bend from that Perpendicular.

Fig. 54. Thus let the Veſſel ABCD which we are firſt to ſuppoſe to be empty, be placed where the Sun ſhines obliquely, and let the Point B where the ſhadow of the Brim D falls on the Bottom of the Veſſel, be obſerved; then let the Veſſel be filled to any Height as E F with Water, and let the Point of Incidence L where the Shadow of the Brim D, or the Ray I L, will fall on the Surface of the Water, be alſo obſerved; and ſuppoſe the Perpendicular GLH to be drawn through the Point of Incidence L; then it will be found that the Shadow of the Brim will no longer be ſeen in the Point B at the Bottom of the Veſſel, but at ſome other Point, as at K which is nearer to the ſaid Perpendicular; for by Degrees, as the Water is poured in, the Shadow at B will be found to creep nearer and nearer to the Perpendicular, the more you fill the Veſſel, that is, it will be the more refracted towards the

Perpen-

Perpendicular, the more the Veſſel is filled. And on the contrary, if we ſuppoſe K L M to be a Ray of Light paſſing from Water into Air, inſtead of its Motion being found in M L the Direction of the Line L K, it will be found to recede more from the Perpendicular, or to L D I.

If a Stick be laid over a Veſſel when the Sun is in the Zenith or directly over Head, the Shadow will fall upon the ſame Part of the Bottom of the Veſſel whether it be full or empty; ſo that Perpendicular Rays ſuffer no Refraction.

The bending of Rays or Refraction to or from the Perpendicular, ſeems owing to the Superiority of Attraction, that the denſer has to the rarer Medium; which is alſo more or leſs, as the Rays fall more or leſs obliquely on the refracting Surface, which divides the Mediums.

Put the End of a ſtrait Stick obliquely into a Veſſel of Water, and look upon it obliquely, it will appear to be bended at the Surface of the Water, in the ſame Manner as the Rays of Light are bent, but in a contrary Direction.

If you put a Shilling at the Bottom of a Baſon or Cup, and withdraw yourſelf from it by Degrees, ſo as to looſe the Sight of the Shilling, then if the Veſſel be but partly filled with Water, you will ſee the Shilling very plainly.

Hence it is that we always ſee the Sun before it riſes, and after it ſets, becauſe the Atmoſphere about the Earths Surface is more denſe at the

riſing

riſing or ſetting of the Sun, than at any other Time of the Day.

What has been ſaid of Water may be applied to any other tranſparent Body, only the Refraction of ſome is greater than in others.

The Angle I L G (ſee the foregoing Figure) contained between the Ray I L and the Perpendicular L G is called the *Angle of Incidence*, and the Angle K L H contained between the ſame Perpendicular, and the ſame Ray after Refraction, is called the *Angle of Refraction.*

The Sine of the Angle of Incidence, is to the Sine of the Angle of Refraction, always in a given Ratio. Thus, When a Ray of Light paſſes out of Air into Glaſs, the Ratio is as 3 to 2, out of Air into Water as 4 to 3, out of Air into Diamond as 5 to 2.

Hence we may eaſily ſee, how Rays will paſs through all ſorts of Glaſſes.

Of Glaſſes.

Glaſs may be ground into theſe ſix different Shapes.

1. *A plane Glaſs*, or one that is ground quite plane or flat on each Side, and whoſe Parts are every where equally thick.

2. *A Plano-convex*, or one that is plane or flat on one Side, and Convex or round on the other.

3. *A Double-convex*, or one that is Convex on each Side.

4. *A Plano-concave*, or one that is concave or hollow on the one Side, but plain on the other.

5. *A Double-concave*, or one that is concave on each Side.

6. *A Miniſcus*, or one that is ground concave on one Side, and convex on the other. And of theſe in Order.

1. *Fig.* 55. If a Ray of Light, paſſes through a plane Glaſs, it will go in and paſs out in the ſame Direction, though not preciſely in the ſame Right-line: Thus, if a Ray of Light RD fall obliquely on the Surface of the Glaſs AD, it will be refracted in the Direction CD, from what has been juſt ſaid; but when it comes out of the Glaſs at C into the Air, it will be refracted in a contrary Way; ſo that EC will be parrallel to RD.

2. *Fig.* 56. If parallel Rays of Light paſs through a Convex Glaſs, they will be collected and converge in a Point behind it: Thus, the Ray RD which falls perpendicularly in the Middle of the Glaſs, will go through it without ſuffering any Refraction as hath been already ſhewn; but the Ray ST which paſſes through the Side of the Glaſs, falls obliquely upon the Surface, and will therefore be refracted, and in coming through the Glaſs will meet each other at F and compoſe a *Pencil of Rays*; and the nearer the Verge of the Glaſs the Rays fall, the more oblique they will be, and therefore will be more refracted; and hence it is that the Point F which is called the principal *Focus* will be nearer to, or further from the Glaſs, as the

the Glaſs is more or leſs convex, or as the Rays are more or leſs refracted.

Hence it alſo is, that a convex Glaſs will ſet fire to Things, by the Suns Rays paſſing through it.

This *Focal Diſtance*, or Diſtance of the Glaſs from the Focus, is equal to twice the Radius of the convex Surface, in *Plano-convex* Glaſſes; and in a Glaſs which is equally convex on each Side it is once the Radius of either Surface; but if a Glaſs be more convex on one Side than on the other, divide twice the Product of the Radii by their Sum, and the Quotient will be the Focal Diſtance Sought.

Fig. 57. If a Ray of Light paſſes obliquely through a convex Glaſs, it will go forward in the ſame Manner as if it had paſſed through a plane Glaſs; that is, it will come out of the Glaſs in the ſame Direction in which it entered: For the Ray R D will be refracted at the points D and E in the ſame Manner, as if it had paſſed through the plane Surfaces *ab*, *cd*, which are parallel to each other, as is eaſy to conceive; but if Rays as RB, RP paſs through the Side of the Glaſs, they will be refracted, and ſo will converge and meet each other in F; and on the contrary, the Rays FB, FP, which flow from the Point F, will be alſo refracted and will meet each other in the Point R.

The Rays that flow through a double convex Glaſs, or a double *Convex-Lens* from any Object, will paint an inverted Picture of that Object, upon any white Body, which is placed at the *Focus* of the *Lens*.

R *Fig.*

Fig. 58. Let LS be the double *Convex-lens*, and let AH be the Object to be painted in an inverted Poſition be placed before it, the Rays which flow from the Point A will be refracted by the *Lens* and unite in the Point a; in like Manner thoſe Rays which flow from the ſeveral Points B, C, D, E, F, G, H of the Object AH will unite in the Points b, c, d, e, f, g, h, ; therefore if the *Lens* be inſerted into a round Hole cut in a Window Shutter, and if the Room be darkened, and the Object be placed before the *Lens*, and if a Sheet of white Paper, or any other white Body, be placed at a proper Diſtance behind the Glaſs, there will be found a true and perfect Picture of the Object in all its Colours; but in an inverted Poſition.

In the like Manner, Houſes, Perſons, or Carriages paſſing by may be ſeen in an inverted Poſition; and in Order to ſee them the more diſtinctly it is neceſſary that the Sun ſhould ſhine on them at the Time of making the Experiment.

The Diſtance of the Picture from the Glaſs may be found if the Diſtance of the principal Focus be found as before, and the Diſtance of the Object from the *Lens* be known: thus, multiply the Diſtance of the principal Focus by the Diſtance of the Object, and divide the Product by their Difference, and the Quotient will be the Diſtance of the Picture from the Glaſs.

If the Object be brought nearer to the *Lens* the Picture will be removed to a greater Diſtance, for the Rays which flow from any ſingle Point, will diverge or ſpread more as they fall upon the Glaſs,

Glaſs, and therefore they cannot ſo ſoon converge or meet together behind it. If the Diſtance of the Object from the Glaſs be equal to the Diſtance of the principal Focus of that Glaſs, the Rays which flow from any one ſingle Point of the Object will be ſo refracted by paſſing through the Glaſs, that they will go out of it parallel to each other, and therefore there can be no Picture behind the Glaſs.

The Picture that is made by a *Convex-lens* or Glaſs, will be as much bigger or leſs than the Objects, as its Diſtance from the Glaſs is more or leſs, than the Diſtance of that of the Object from the Glaſs; thus as DI is to Id, ſo is AH to ah. (*See the foregoing Figure.*)

The Appearances of a *Camera-obſcura* owe their Formation to a double *Convex-lens* being fixed to the Extremity of a Tube, which iſſues Horizontally from one Side of a ſmall ſquare Box, wherein is a looking Glaſs, a Speculum or a plane Mirror, put ſlantways from Corner to Corner, ſo as to make half a right Angle with the Bottom of the Box; the Top of the Box is covered with a flat Glaſs ground only on one Side, which receives the Pictures of Objects, thus,

Fig. 59. Let AB be an Object, placed before the *Lens* CD which is fixed to the End of the Tube to the Box; GH the looking Glaſs which makes with the Bottom of the Box HF half a right Angle; GM the rough Glaſs Plate that receives the Picture of the Object. The Rays which flow from the uppermoſt Part of the Object A, after paſſing the *Lens* would converge in F, were they not intercepted by the looking Glaſs GH which reflects them upwards, where they will meet in ſome Point K, which is as far above the *Speculum* as the Point F is behind it. In like Manner the Rays which flow from the loweſt Part of the Object B would converge in E, were they not reflected by the *Speculum* to meet in the Point I which is as much above it, as the Point E is behind it; and ſince the Rays from the extream Points A and B, of the Object AB, convene at K and I, ſo all the intermediate Points of the Object AB, will convene between K and I, and the Object AB will be painted on the Horizontal rough Glaſs Plate GM, between the Points K and I.

The *Magic Lantern* is a Lantern out of which iſſues an Horizontal Tube capable of being made longer or ſhorter as may be found neceſſary, by means of one Part moving or ſliding within the other; to the Extremity of this Tube is fitted a double *Convex-Lens*, and in the other End next the Lantern is inſerted a *plano Convex-glaſs* with the flat Side next the Lantern; within the Lantern oppoſite to this Glaſs is fixed a Light, which paſſes through that Glaſs, and thereby is thrown very ſtrongly upon little frightful Images painted in dilute Colours on Pieces of thin Glaſs, five or ſix of which being fixed in a Slider, are moved to and fro acroſs a ſquare Arm, which is placed between the two Glaſſes: Theſe Figures are thruſt through this Arm in an inverted Poſition, and by Means of the *Lens* at the Extremity of the Tube, are painted in an erect Poſition, on a

white

white Cloath placed at a proper Diſtance; which Diſtance may readily be found by drawing out or putting in the moveable Tube, or by moving the Lantern or the Cloath to a greater or to a leſs Diſtance from each other till the Images become diſtinct.

Having fully ſhewn that convex Glaſſes cauſe the Rays to converge and to meet in one Point, it remains now to ſhew that Rays which paſs through a concave *Lens* will diverge more after they have paſſed through ſuch Glaſſes, than they did before; thus, *Fig.* 60 two Rays AB and AC which diverge from the Point A through the *Lens* BC, will not continue to proceed in the Direction of thoſe Lines towards D and E, but will diverge more or open wider towards F and G. Again, if FB and GC be two Rays converging towards H, after they have paſſed the Glaſs, they will converge much ſlower or much further towards A. For if a Candle be placed before a *Convex lens*, and its Image be received on white Paper as before; then if a *Concave-lens* be interpoſed between the convex one and the Image, the Image will thereby be projected to a greater Diſtance and become more inlarged than before, but it will be leſs diſtinct.

Of Viſion.

Having ſhewn how the Rays of Light paſs through *Convex* and *Concave-lens*'s, we are now to ſhew how they will be affected by paſſing through the Humours of the Eye.

If

If a ſmall Portion be cut off a Globe, and if in Lieu thereof, a Portion of a ſmaller Globe, but of the ſame Baſe with the Segment, be ſubſtituted, they conjunctly will exhibit the true Form of the Eye, ſince the Eye is more convex before than in any other Part.

Fig. 61. The Eye conſiſts of ſeveral Membranes or Coats which lie within each other, of which the outermoſt is called the *Tunica Adnata*, or *Conjunctiva*; it has its riſe from that Membrane which inveſts the Skull, and it covers the whole Ball of the Eye, except the foremoſt tranſparent Part, which projects without the Eye-Lids, and what is commonly called the *White of the Eye*, but by Anatomiſts the *Cornea.*

Beſides this Membrane which is not reckoned with the Coats of the Eye, there are three which are properly called Coats; the firſt or that under the *Conjunctiva* is called the *Sclerotica* as SS, which is very tough, and is derived from the *Dura Mater*, which encompaſſes the Eye with the *Optic Nerve*, the fore Part of it becomes tranſparent like poliſhed Horn, and is thence called the *Cornea* as ABC.

The ſecond Membrane is called the *Tunica Coroides*, as CC, it is derived from the *Pia Mater*, and is alſo tranſmitted from the Brain through the *Optic Nerve*, but it is much thinner than the former; the fore Part of this Coat is called the *Uvea* or the *Iris*, and is that Circle that encompaſſes the *Pupil*, or what is commonly called the Sight of the Eye. The Iris conſiſts of ſeveral concentric muſcular Fibres, which are joined acroſs at right Angles by other ſtrait Fibres like

Radii

Radii, ſo that by the Contraction of the former, the *Pupil* is leſſened, but it is enlarged by the Contraction of the latter.

The third Coat is called the Retina, as RR; and it is the *Optic Nerve* that ſpreads itſelf over the Bottom of the Eye, oppoſite to the *Pupil.* Theſe Coats contain a *Capſula* or Bag, wherein are the three Humors of the Eye.

The firſt we ſhall notice is the *chriſtaline Humor* which is convex on both Sides, but ſomething flatter before than behind as CH; it is ſupported by ſmall muſcular Fibres, as Af and Cf, called *Ciliary Ligaments*, which are inſerted into this Humor as well as into the *Choroides*, and being cloſely united form a Membrane which ſeperates two other Humors of the Eye; the foremoſt of which is called the *Aqueous Humor*, or what is contained between ABCff, becauſe it is of the Conſiſtance of Water and like thereto, being very limpid and tranſparent; and in the hindmoſt is lodged the *Vitreous Humor* VV, which has that Name, becauſe it reſembles melted Glaſs. And behind all theſe is the *Optic Nerve* O.

From what has been ſaid of *Convex-lens*'s, and of the Eye, it will plainly follow, that as any Object may be collected on the other Side of a *Convex-lens*; ſo the Humors of the Eye in general, but more particularly the *Cryſtalline Humor*, being the ſame as a *Convex-lens*, the Rays which flow from the Object will meet upon the Bottom of the Eye, and there make an inverted Picture on the *Retina*; juſt as if the ſame Object were pictured upon a white Cloath behind a *Convex-lens*.

For

For if you take a fresh Bullock's Eye, and cut away from the back Part, the Coats or Skin which cover the *Vitreous* Humor: then by placing a white Paper upon that Part, and by holding the Eye towards a lighted Candle, or any bright Object, so that the Rays which flow from it, may pass through the *Pupil*, you will then find the inverted Object upon the Paper, *Fig*. 62. for the Rays which flow from the Point A unite on the *Retina* at a, and those which flow from the Point B unite in b, and all the intermediate Points in the Object AB, are united on the intermediate Points on the *Retina*, and so produce an inverted Image of the Object thereon. But this union of Rays depend upon distinct Vision; for should they be united before they reach the *Retina*, or beyond it, the Rays issuing from one Point in either Case, will not unite but spread and take up some Space on the *Retina*, and therefore those which flow from contiguous Points of the Object will be so mixed and blended, that the Representation of the Object will be very confused.

Hence it is necessary that the Eye must be contracted or dilated in Order to see Objects at different Distances distinctly; in Order that the *Cornea* may become more or less Convex, so as to increase or lessen the refractive Force; which is done by Means of six Muscles which are inserted in the *Sclerotica*; and this most Men are able to do.

But there are some defective in this Point, who are unable to see any Thing distinctly, but when placed very near; and this is the Case of their Eyes who are called *Myopes*, purblind and short

sighted;

ſighted; in ſuch the *Cornea* is too convex, and therefore the Rays converge before they reach the *Retina*: Such Perſons Eyes are moſt laſting; becauſe as the Eyes of all Perſons flatten by Age, for want of a due Supply of Humors, the Rays will converge more and more towards the *Retina*, and perhaps at length meet it when they become old, and thereby they will enjoy diſtinct Viſion.

Concave Glaſſes are found very uſeful to purblind People, for they cauſe the Rays to diverge ſo much, notwithſtanding the great convexity of the *Cornea*, that they will not meet till they arrive at the *Retina*, and thus they render the Object diſtinct.

Such Perſons as have ſeen diſtinctly, and whoſe Sight begins to fail them, find that Things near them cannot be ſo well ſeen as others, that are more remote; for in old Men the *Cornea* becomes flat for want of a due ſupply of Humors, and therefore the Rays will converge beyond the *Retina*, and conſequently on it, they will diverge and ſcatter, and thereby render near Objects indiſtinct.

The proper Remedy for this Defect is a *Convex-lens* which will leſſen the Divergency and cauſe the Rays to meet on the *Retina*.

If there be two old Perſons ſuch, that one of them can ſee at ſmaller Diſtances than the other; in Order to make them both ſee at any leſſer given Diſtance; the Eye which can ſee at a ſmaller Diſtance muſt be furniſhed with a Glaſs of a greater *Radius* than the other. And herein conſiſts the Secret of younger and older Spectacles, thoſe being deemed youngeſt that are ground to the greateſt

S *Radius*,

Radius. Or thus, the flatter and older the Eye is, the more Convex muſt be the Glaſſes to ſee through.

Catoptrics *or the Nature of the Reflection of* Light *and of* Colours.

If a Ray of Light falls upon an opaque dark Body, Part of it will be reflected, and Part will enter the Body and be loſt in its Pores; but if a Ray falls upon a tranſparent Body, Part of it will be reflected, and Part will enter the Body and be refracted, as before ſet forth; and this was the general Opinion of all Writers upon *Optics*, before Sir ISAAC NEWTON who has ſhewn in the 8th *Propoſition* of the 2d *Book of his Optics*, that the Particles of Light are turned backwards before they touch the reflecting Body, by ſome Power which is equally diffuſed all over its Surface; but whether the Particles of Light be reflected by ſtriking on the Body, or whether they be repelled or reflected before they touch the Body, this Law will obtain; that the Angle of Incidence or that contained between the incidentRay and a Line drawn perpendicular to the reflecting Surface at the Point of Incidence, is equal to the Angle of Reflection, or to that which is contained between the ſame perpendicular and the reflected Ray.

Fig. 63. Thus, if AB be a reflecting Surface, and if CD be a Ray of Light fallen thereon, it will be reflected in the Line DE, ſo that the Angle of Incidence CDF will be equal to the Angle of Reflection EDF; wherefore if it falls perpendicu-

larly

larly, it will be reflected back into the perpendicular DF.

By Reflection from a plane *Speculum* or *Mirror* of very smooth Metal, or even from a well ground looking Glass, an Object seems to appear as far behind it as it is before it: *Fig.* 64. For the Rays which flow from the Point A of the Object AB will fall upon the *Mirror* MR in P, and will thence be reflected to the Eye at E by the foregoing Law, and therefore will enter the Eye as if they flowed from *a*: In like Manner the Rays which flow from B, will meet the *Mirror* at F and will be thence reflected to the Eye at E, and of Course appear to the Eye as if they had issued from *b*; therefore the Object AB will appear to be at *ab*.

In like Manner it may be easy to conceive from *Figures*, 65, 66. why the Object appears bigger in the *Concave Mirror* represented in the first Figure; and why in the second Figure it appears to be less than it really is, in a *Convex Mirror*.

Fig. 67. If parallel Rays, as ab,ab,ab, *&c.* fall upon a concave Mirror MR they will be reflected into a Point F, called the *principal Focus.*

This is the Reason why the Suns Rays reflected from a *concave Mirror*, burn with incredible Force in that Point.

If an Object be placed before a *concave Mirror*, at a Distance that is greater than the principal Focus, the Rays which flow from it being reflected by the *Mirror*, will make an inverted Picture of the Object, upon any white Body placed to receive them; provided it be ſet beyond that Point where the refracted Rays will croſs one another.

Fig. 68. Let MR be a *concave Mirror*, and AB the Object; the Rays iſſuing from A which fall on the *Mirror* at P, will be reflected along the Line PD making the Angle of Reflection equal to the Angle of Incidence; and the Rays iſſuing from the Point B which fall on the *Mirror* at C, will be reflected along the Line CE; if then a Sheet of white Paper as ST be placed perpendicularly any where beyond the Point G, where the reflected Rays concur or croſs each other; you will have on it the Picture b a of the Object AB in an inverted Poſition.

If the Eye be placed beyond the Sheet as at E in the Continuation of the reflected Rays Cb, Pa, it will receive them as if they flowed from a real Object at ba; and hence we ſee the Reaſon of the odd Phœnomenon exhibited by a *concave Mirror*, of a Body ſeeming to be ſuſpended in the Air between the Eye and the Mirror.

The nearer the Object is to the principal Focus, it is eaſy to ſee from the foregoing Figure and what has been ſaid, that the greater Diſtance the Picture muſt be from the *Mirror* in order to make it of an equal Size, and the contrary; for the Rays will diverge more as they fall upon the *Mirror*. What has been ſaid of Pictures made by *Convex Glaſſes* will hold good of thoſe which are made of *Concave Mirrors*.

To find the Diſtance of the Picture from the *Mirror*, multiply the Diſtance of the Object from the *Mirror* into the Radius of its Concavity,

and

and divide that Product by the Difference between twice the Diſtance of the Object from the *Mirror*, and the ſaid Radius, the Quotient will be the Diſtance required.

It has been already ſhewn how the Rays of Light are refracted, by paſſing through different Mediums; we come now to ſhew how ſome Rays of Light are more refracted than others,; and that accordingly as they are differently refracted, they excite in our Minds, Ideas of different *Colours*.

Fig. 69. Let the Sun ſhine into a dark Chamber through a ſmall Hole at H, cut in a Window Shutter, ſo long and broad as to fit a Triangular *Glaſs Priſm* as A: Place then the Priſm ſo before the Hole, that the Rays of Light HA which paſs through the Hole, may fall obliquely on one of its Sides, and they will ſuffer different Refractions by paſſing through Parts of the Priſm that are of different Denſities; ſo that inſtead of their going out in one Direction they will paſs in different Directions, repreſented by the Lines AB, AC, AD, *&c.* and in falling either on the oppoſite Side of the Room or upon a white Paper, will paint thereon a Series of moſt beautiful and lively Colours, in this Order: Thoſe that are leaſt refracted by the Priſm, and therefore go in the Direction of the Line AB, will be of a very bright and intenſe *Red*, the next going in the Direction AC will be of an *Orange* Colour, then will follow *Yellow*, *Green*, *Blue*, *Purple* and *Violet*.

There are different Degrees in all theſe Colours: Thus, the Red degenerates by Degrees into an Orange,

Orange, the Orange into a Yellow, the Yellow into a Green, *&c.*

There is not an equal Quantity of Rays belonging to each of theſe Colours; for if the oblong Column or Series of Colours BK be divided into 360 equal Parts; Sir ISAAC NEWTON has ſhewn, that the Red took up 45 of them, the Orange 27, the Yellow 48, the Green 60, the Blue 60, the Purple 40, and the Violet 80.

If all theſe Colours be blended together, they will make a white; thus,

Fig. 70. Having divided the Rays of the Sun by a Priſm as before mentioned, receive them upon a *convex Lens* as LS, which will refract them in ſuch a Manner, that they will croſs each other at F, and if a white Paper as DE be placed there to receive them, we ſhall find they will excite the Idea of a ſtrong White; but if the Paper be placed further from the Glaſs as at FG, the different Colours will appear again in a contrary Order: And if any one of the Colours be interrupted by an opaque Plane as BC before it meets at F, the white will be inclining to a Violet or a Red, according as the Red or Violet Rays are ſtopped.

When a Ray of Light is once ſeperated from the reſt, it cannot be divided into any other Colours, though it be never ſo often reflected or refracted.

As White is a Compoſition of all Colours, ſo is black a Privation of them all, and is therefore properly called no Colour.

Any

Any one of theſe Colours except Red, may be made by mixing together the two adjoining priſmatic Colours: Thus, Orange and Green being mixed, will make a Yellow, a Mixture of Yellow and Blue will make a Green, Pnrple and Green will make a Blue, *&c.*

All Bodies appear of that Colour, whoſe Rays they reflect moſt; as a Body appears Red when it reflects moſt of the Red-making Rays, and abſorbs the reſt; a Blue or Green Body reflects the Blue or Green-making Rays; and ſo of the reſt.

Of Microſcopes and Teleſcopes.

A Microſcope is an optical Inſtrument uſed to render Inſects and other ſmall Bodies or Objects the more conſpicuous,

Fig. 71. The ſingle Microſcope, is only a ſmall convex Glaſs as LS, under which the Object a b is placed in its Focus, and the Eye at or near the ſame Diſtance on the other Side; then from what has been already ſaid, and the Figure, it is plain, that the Rays which flow from the Extremities of the Object a b, will enter the Eye in the Lines LE, SE, and conſequently will be ſeen under a greater Angle, and ſo appear larger than if there had been no Glaſs.

If you would know how much this Glaſs magnifies; divide the leaſt Diſtance at which an Object can be diſtinctly ſeen with the naked Eye, by the focal Diſtance of the Glaſs, and the Quotient

tient will nearly ſhew, how much the Glaſs Magnifies.

Fig. 72. The *Compound Microſcope* is generally made of three Glaſſes which are thus diſpoſed; the Object Glaſs or *Lens* LS is of about half an Inch or an Inch *Focus*, CD and FG are two Eye Glaſſes placed ſometimes cloſe together, and ſometimes at an Inch or two diſtant from each other; ba is a ſmall Object placed at a greater Diſtance from the *Lens* LS than is its principal Focus; ſo that the Rays flowing from the Object ba through the *Lens* LS, make an inverted Picture at AB, which will be as much larger than the Object, as its Diſtance from the *Lens* is greater.

The Eye Glaſſes CD, FG anſwer the End of a ſingle Microſcope: For the Rays which flow from the Ends of the enlarged inverted Object AB will enter the Eye under the Angle CED, which is much greater than the Angle under which they would be ſeen by the naked Eye; and the Rays which flow from any Point of the Object, will enter the Eye parallel to each other, and therefore will be ſeen diſtinctly, by what has been already ſaid.

The *Solar Microſcope* is thus made.

Fig. 73. Having made a Room very dark, let a Hole be made in the Window Shutter, of about three Inches in Diameter, ſo that the Sun may caſt a Cylinder of Rays into the Room: In this Hole, place the End of a Tube containing two Glaſſes and an Object, *viz.* 1. A convex Glaſs aa, of about two Inches in Diameter, and of three

Inches

Inches Focal Diſtance, is to be placed at that End of the Tube which is to be put into the Hole. 2. The Object ob being put between two Pieces of Glaſs is placed about two Inches and an half from the Glaſs aa. 3. At a little more than an Inch from this Object is placed a ſmall Glaſs de, of about half an Inch in Diameter and of one Inch Focal Diſtance.

Things being thus prepared, the Rays which flow from the Object ob will make a large inverted Figure upon a white Paper, of the Object, in moſt beautiful Colours and prodigiouſly magnified.

The Tube muſt be ſo placed that the Suns Rays Ra, may flow directly through the Glaſs aa; or elſe they muſt be made to paſs directly through it, by Means of a plane Mirror, or of a piece of Looking-glaſs, ſet angularly towards the Sun, ſo that the Rays which are reflected by the Looking-glaſs may paſs directly through the Tube, and thence they will tranſmit the Rays of the Object on the white Paper.

The Common Refracting Teleſcope *is thus conſtructed*

Fig. 74. A is the Object Glaſs, its Focal Diſtance Af from One to an Hundred Feet; b, c, d, are three Eye Glaſſes, whoſe Focal Diſtances are from one to ten Inches.

The Glaſſes being thus prepared let them be placed in a Tube in ſuch a Manner, that the Diſtance between any two may be equal to the Sum of their Focal Diſtances, as in the Figure; and the Eye muſt be placed at E one Focal Diſtance of any of the Eye Glaſſes, from the outermoſt one d; then it is plain that the Rays flowing from any vaſtly diſtant Object through the Glaſs A, will make an inverted Figure of it at f; and the Eye Glaſs b being placed within the Focal Diſtance of f, and the Eye again at e the ſame Diſtance from b, the Picture will be ſeen diſtinctly but inverted; ſo that two other Glaſſes are uſed to make it appear erect as before.

The Line mA repreſents the Axis of a Pencil of Rays flowing from the Top of the Object, and nA one flowing from its Bottom: When they enter the Eye either at e or E, it is plain they converge much more than they did before their Entrance into the Glaſs, and therefore the Object will be ſeen under a greater Angle; but the Rays which flow from the ſame Point of a diſtant Object, enter the Eye in Lines parallel to each other, and conſequently the Object will be ſeen diſtinctly.

The magnifying Power of a Teleſcope is found, by dividing the Diſtance of the Glaſs A, by that of any of the other Eye Glaſſes.

In the *Reflecting Teleſcope* a concave Mirror is made uſe of inſtead of a convex Glaſs.

The Picture which is made by a convex Glaſs is always tinged a little with Colours about the Edge; but the Picture made by a concave Mirror will ever be clear; and therefore the reflecting Teleſcope is preferable to the refracting one, ſo long as the Mirrors are kept clean.

CHAP.

CHAP. VII.

Of Aerial METEORS *in general, and of Aqueous* METEORS *in particular.*

1. *Of Aerial Meteors in general.*

THE Phœnomena which ariſe from Bodies that are either ſuſpended, conjoined, or ſeperated in the Atmoſphere; or from ſuch as move, aſcend, deſcend, are driven, or ſet on Fire therein, are called *Meteors.*

Whatever aſcends into the Air from the Earth is called a *Vapour* or *Exhalation*: But the conſtituent Parts of a Vapour are aqueous and moiſt, and thoſe of an Exhalation are not, for they conſiſt of the ſubtileſt Parts of ſolid as well as fluid Bodies.

As Vapours and Exhalations which are continually aſcending in great Quantities, corrupt the Atmoſphere, it therefore follows that various Phœnomena muſt thence neceſſarily ariſe. The Quantity of Water which aſcends in the Form of Vapour in one Day exceeds Belief; for in the *Mediterranean* Sea only, Doctor *Halley* by Experiment found, that many Millions of Buts of Water aſcended in the Form of Vapour in one Day. Such Parts of the Earths Surface, as are thick with Plants, contribute much to the encreaſe of Vapours and Exhalations, as do the Perſpiration of all Animals, the noxious Fumes ariſing from

Vegitables and Animals dead and rotting over the whole Earth, and from Bodies burning for daily Use, as well as from burning Mountains, and those earthy Perspirations which are produced from subterraneous Fires, which abound in the Bowels of the Earth, all conspire to supply the Air with a sufficient Fund for the production of Meteors.

Vapours and Exhalations ascend on Account of various Causes of which these are the chief.

1. They ascend by the Means of Fire, whether it be culinary or earthly, subterraneous or solar produced by the Sun. For Fire by entering into Bodies agitates and rarifies their Particles, and with a rapid Motion drives off the most subtile of them with great Force, which being specifically lighter than Air, are by that Means carried up till they meet with lighter Air.

2. Many Bodies being exposed to the same Fire that Air is, receive more of the Fire and retain it longer than the Air can; on this Account the volatile Parts of Bodies on the Earth may be seen on a Summers Evening to rise and form a Vapour over the Ditches and Meadows, because they are more rarified than the Air about them is. Or if on a frosty Evening, a large Aperture be made in Ice, a watry Vapour much warmer than the Air is, will be found to rise in great plenty.

3. The Particles of some Bodies become volatile and are driven upwards, by the Bodies being fermented, putrified, boild or broken: For Bodies which are in any of these States emit much Vapour and Exhalation. That a Body's being seperated or

broken

broken may occasion a Volatility in some of the Parts, is plain from a Vapour which arises on the descent of the Water falling from an Height, as at *Powers-court*, or at the *Salmon-leap* near *Leixlip*. In *Canada*, the River *Niagara* falls down a steep Rock 156 Feet, with a Noise which is heard by all the Country round about, and forms a Cloud by the Particles that fly off, rising in the Form of a thick Mist, which may be seen at the Distance of five Miles.

4. Water and other Fluids attract, and are attracted by Air. And therefore the Particles of Water and other Fluids which are attracted by Air, ascend into Air, as soon as they are seperated from the Masses to which they belong.

5. Winds raise Vapours from several Bodies, especially from such as are aqueous, and hurry them away. Hence wet Cloths, when exposed to the Wind, are soon dried.

Lastly. Whatever can disunite the rarer Particles of Bodies from the Bodies themselves, or can render the Particles specifically lighter than Air, will be the Cause of their Ascent. If Particles, which are much lighter than Air, meet others heavier than themselves, they will adhere and compose a Mass still lighter than Air, which will continue to ascend on high.

We discover that Vapours issue and ascend from the Earth. 1 When we see the Ground and distant Mountains to throw out a Fume. 2. When the Heads of distant Hills are covered with Clouds though in a serene Sky. 3. When all distant Bodies seem to twinkle. 4. When Mists which are formed

formed by Vapour aſcending from Lakes and Marſhes, will be ſeen to hang over them. 5. When the Sun and Moon riſing and ſetting appear very ruddy.

Becauſe the Denſity as well as the ſpecific Gravity of the Atmoſphere differs at different Diſtances from the Earth's Surface, therefore Vapours and Exhalations may aſcend and continue at various Heights in the Air; thoſe that are rareſt are driven or carried to the greateſt Diſtances, and thoſe which are nearly as heavy as Air, lie near the Earth, and ſuch as are yet lighter are carried higher into the middle Region of the Air.

Hence Clouds and other Meteors which are formed in the Air, are at different Diſtances from the Earth, and hence it alſo is that Vapours and Exhalations will aſcend or deſcend in one and the ſame Place as the Atmoſphere becomes more or leſs denſe.

The more denſe the Atmoſphere is, the more Vapours and Exhalations is it capable to ſuſtain; and the rarer, the more unfit it is for that Purpoſe. Now in Winter the cold Atmoſphere becomes moſt denſe, as is proved by the Barometer, and conſequently is moſt capable to ſupport the greateſt Quantity of Vapours and Exhalations, and therefore in that Seaſon the greateſt Number of Meteors happen. And becauſe this Reaſon chiefly prevails in cold Countries, it is, that more Meteors are obſerved in them, than in warmer Climates.

Vapours and Exhalations deſcend to the Earth from the Atmoſphere, on Account of various Cauſes, the chief of which are theſe.

1. As ſoon as the Denſity of the Air, or its Specific Gravity is diminiſhed, the Exhalations will deſcend by their Gravity, which is manifeſt from the Barometer. And this may be alſo proved by covering moiſt Air with a Receiver: Upon exhauſting ſome Air, a little Cloud is formed under the Receiver, which will fall as the Air is more exhauſted or rarified; and hence we obſerve Rain and other Meteors, when the Mercury in the Barometer is very low, indicate the Air to be very light.

2. When Things which had aſcended by being rarified with Fire, loſe their Heat, they become condenſed and ſpecifically heavier than Air, and ſo deſcend.

3. When Things loſe the Motion they had received from Fire, or from any other Cauſe which drove them upwards, they will deſcend.

4. When Particles are driven by Winds againſt reſiſting Obſtacles, or againſt one another by Winds that blow in oppoſite Directions, or if Particles unite from any other Cauſe, by this Concourſe they become ſpecifically heavier than Air, and therefore deſcend.

5. When ſome different Kinds of Exhalations unite, they will excite a boiling Heat or Efferveſcency with each other, which wearing off, the Body becoming thereby condenſed, is precipitated or hurried downwards.

6. Such Particles as are exhaled or carried off in Winds, are with them again driven downwards.

7. Winds which blow horizontally below that Part of the Atmoſphere in which Exhalations are ſuſpended, drive the Air away which ſuſtains them, and then they deſcend in the Place of the Air that was drove away.

8. When more Vapours and Exhalations aſcend than the Atmoſphere is capable to ſuſtain, thoſe that are ſuperfluous muſt return back, having loſt their Motion by which they aſcended.

Meteors may be conveniently divided into three Kinds, *viz.* firſt, into Aqueous Meteors; ſecondly, into fiery Meteors; thirdly, into airy Meteors or Winds. Theſe we will treat of ſeverally.

2. *Of Watry Meteors,* viz.

Of *Miſts*, *Clouds*, *Dew*, *Rain*, *Froſt*, *Hail*, *Whirl-wind*, *Rain-Bow*, *Halos*, *Parhelii*, *Paraſelenæ*, &c.

A *Miſt* or a *Fog* is occaſioned by a plenty of Vapours or Exhalations which are ſuſpended in the Atmoſphere near the Earth's Surface, and which are conſtituted, diſperſed and ranged in ſuch a Manner as to intercept much Light, and to make the Air darker than uſual.

The Vapours and Exhalations that form Miſts, aſcend ſlowly from and fall ſlowly to the Earth; and therefore they ſeem to be ſuſpended in one Place, and are not eaſily ſeen to advance. When

the

the Vapours which compoſe the Miſt are moiſt and wet, they are neither hurtful to Animals, nor are they offenſive to the ſmell: But ſuch as conſiſt of Exhalations, ſtink, are hurtful to the Health, and often occaſion many Diſeaſes; and others in many Places are of a poiſonous and deadly Nature. It is plain that Miſts are compoſed of ſome other Matter than aqueous Vapours, becauſe when they are diſperſed, we often find a thin Skin or Film floating on the Surface of Water over which they were ſuſpended, which is of a reddiſh and greaſy Nature, ſomething like that which Chemiſts obſerve when they prepare the Golden Sulpher of Antimony.

Miſts are formed in ſerene calm Weather, and never when there is Wind, for that diſperſes them. They are generally obſerved in an Evening, eſpecially if the Sun in the Day has much heated the Earth, which by its ſetting quickly cools the Air, and occaſions the heated Particles of the earthly Bodies to aſcend in great Plenty. In *Ireland* this chiefly happens in the Spring, and in the Autumn; becauſe the difference between the Evening Heat and that of the Day is much greater in theſe Seaſons of the Year, than in Summer or Winter: There are alſo Morning Miſts in Winter, about the Time of Sun riſing, becauſe then the Air is ſooner heated or rarified than the Exhalations which are ſuſpended in it, and therefore they being ſpecifically heavier than Air, deſcend and cauſe the Miſt: Theſe are often ſeen in the Winter Months, *November*, *December*, *January*, *February*, and Miſts are ſeldom seen in the Summer Months, for in them the Exhalations are almost as soon heated as the Air in the Morning, and are almost as soon condensed as it is in the Evening: Hence if you do but breath in the Winter, you see a Mist, which consists of heated Vapours from the Lungs into condensed Air, of which there is no Sign in the Summer. In Places therefore which are near the North-pole, they have Mists for several Days together: These usually happen before or after West or South-west Winds, or with an East Wind, but rarely with any other Winds; for they bring with them many Vapours from the Neighbouring Ocean. Mists happen in a hard and continual Frost, and when the Weather is clear and mild.

Mists which continue for several Days successively, are frequently followed by Rain or Snow, the Vapours uniting and forming grosser Bodies by Condensation.

When a thick Mist falls upon the Earth, it moistens it like Rain, for the Vapours are of the same Consistence, and differ only in the Magnitude of their Globules. They are sometimes so subtile that they cannot be perceived, and sometimes as large as small Drops. A Mist falls indifferently upon all Bodies whether rough or polished; if it be very moist it penetrates into Houses, clings to Walls, and runs down in Drops and damps, or moistens all Kind of Furniture.

The Day-light is intercepted by Mists sometimes to a greater and sometimes to a less Degree. The darkness is sometimes so great, that a Person cannot see any Object that is within a few Yards

of

of him. The diſorderly Situation of the Particles which compoſe the Miſt, cauſes Paſſages of an irregular Figure and Magnitude, on account of the very different Denſity of the Air and the Exhalations; by this Means the Light is obſtructed in its direct Paſſage, and is drove off to either Side. Hence it is that when the Air appears miſty, it ſoon becomes tranſparent upon receiving more Vapours which are diſtributed through it more uniformly.

Sometimes the whole Atmoſphere is replete of very thin Miſts, through which the Sun may be looked on, without offending the Eyes; but it appears wan or pale, as if it were unable to ſhoot forth its Beams, and yet the Atmoſphere looks as clear as if it were almoſt in a quite ſerene and undiſturbed State.

Serene Weather follows the Morning Miſts in Summer; for they being thin and rare, are readily diſperſed, driven or attenuated through the Atmoſphere by Means of the Sun's Beams.

Winds by ſtriking againſt Mountains frequently condenſe the Vapours they drive forward, and cauſe ſudden Miſts to ariſe at the Mountains.

A Perſon in a Valley who looks on the Sides of Mountains which are illuminated with the Sun, will obſerve thick ſmoaky Miſts to ariſe from them; becauſe the Spectator views the Sun Beams that ſtrike againſt the Mountain, laterally and obliquely, through which Beams the aſcending Vapours may eaſily be ſeen; as we ſee ſmall Particles of Duſt floating in the Air in the Sun's

Beams, when we look upon it obliquely or Sideways.

A *Cloud* is nothing but a Miſt which has aſcended: For Smoak which ariſes from the burning of any Bodies, forms a Cloud. Many have had the Curioſity to go up into the Clouds, which cover the Tops of Mountains, and have found them to be Miſts only; and others have gone to the Tops of Mountains, which were above the Clouds, and have ſeen the Cloud or Miſt under them. Some Travellers have gone into the Clouds on the Tops of the higheſt Mountains, and yet have found the Clouds were nothing but Miſts, which do not conſiſt of Snow, Ice or any firm Body.

Clouds are continually changing their Shape, and therefore it follows that they muſt conſiſt of thin fluid Exhalations, and not of ſolid and concrete Bodies; for ſhould Clouds cohere into firm Maſſes, they would ſoon become ſpecifically heavier than the Air, and would fall on the Earth, if very rapid Winds did not hurry them away; but as this has not yet happened, the Clouds therefore are not ſolid, though they ſeem to be ſo.

Some Clouds appear to be more opaque, or darker than Miſts; and again others are ſo white, that they ſeem to be compoſed of pure Snow, or of ſome ſuch white and ſolid Bodies: Yet theſe different Appearances do not proceed from any Difference in the conſtituent Parts of either, but becauſe the Spectator is ſurrounded with a Miſt through which he views the Cloud, and therefore

as

as he then views it through a thicker Medium, it will appear darker, than when he views it after the Mift is difperfed through clear Air, or through a thinner Medium.

Clouds are fufpended in the Atmofphere at different Heights, according to their different Specific Gravities; and hence they are feen to move over one another, and though the higheft Clouds feem to be at a great Diftance from us, yet few of thefe exceed the Diftance of one Mile. Very thin Exhalations may arife to a much greater Height, but on account of their great rarity and tranfparency they do not appear as Clouds to us.

Becaufe the Air is never quite at reft, the Figure and magnitude of Clouds are conftantly changing, fome Parts feperate, and others approach them; Winds hurry them away with a very great Velocity and often rend them to Pieces and they vanifh: Hence when Tempefts rage, the Heaven is clear. The Beams of the Sun often attenuate the groffer Vapours which compofe the Clouds, and diftribute them through other Air, fo as they become tranfparent with it; and Clouds when they are thus diffipating, have been feen to emit Vapours, which appear like a rifing Smoak; and Clouds are alfo difperfed when the Atmofphere becomes more condenfed and weighty; for then they afcend, and being carried into purer Air, they are diffolved infenfibly.

The Parts which compofe a Cloud are not conjoined and united, becaufe the Extremities of Clouds are irregular and uneven: For were they one united Fluid, as they fwim in another Fluid,

they

they would aſſume a ſpherical or globular Figure, which would continue if that Fluid were converted into a Solid.

Clouds are ſometimes tinged with various Colours, yet they generally appear white, becauſe their external parts reflect the pure Light of the Sun, not ſeperated in its Colours. There are alſo Clouds which are brown and black, particularly when it thunders, which abſorb the light and reflect but little of it. The Clouds are uſually red about the riſing and ſetting of the Sun, which when the Sun is nearer the Horiſon appear violet, and afterwards blue, for the Light ſtriking upon the Globules of Vapour, and being by them reflected and refracted, parts into different Colours, according to the various Altitudes of the Sun.

The Clouds deſcend and gather together as the Atmoſphere becomes lighter and make the Heaven dark, which betokeneth Rain; and then the Mercury in the Barometer falls, as hath been already ſhewn.

The Clouds are of great Uſe. 1. By conveying Rain to all the Parts of the Earth. 2. By cooling the Earth, and thereby preventing its being parched by the violent Heat of the Sun. 3. They are a principal Cauſe of Winds. 4. They reflect and refract the Suns Rays in very different Directions, by which Means we ſee many Bodies, which are not directly illuminated by the Sun.

Dew is occaſioned by Steams and Vapours of the Earth which aſcend on high like a Miſt, and being extreamly rare cannot be ſeen; when theſe deſcend

descend to the Earth they leave a light Moisture which we call Dew.

There are Drops of Water found on Plants in the Evening, and Morning which have been supposed to be Dew; but by many accurate Observations, these Drops have been found to be the Sweat of the Plants, which expires through the Orifices of their Vessels. For every Plant emits this Sweat or Dew according to its Nature, or according to the different Situation of its Orifices; and Plants which have been covered with Glasses, or otherwise secured by Vessels which cover them from the Dew, have collected in one Night more Drops than those which have been exposed to the Air and Dew: And it has also been observed, that the Drops are only found where the Orifices of the Vessels are manifestly open, and not all over the Leaf, nor in the hollower Parts of the Plant, which must be if it were produced by the Descent of Dew or Vapour. This Sweat is soon dispersed by the Wind, or by the Heat of the Day, and of a calm hot Day it is emitted copiously from the Vessels.

The Earth is greatly heated by the Sun, which as before, causes many Vapours and Exhalations to arise. Whatever rises in the Day escapes our Sight for the most Part, and is quickly dispersed in the Air: But when the Air cools after Sun set, the warm Steams arise in greater plenty with a slow Motion; by which Means they adhere first to Bodies that are near the Ground, and then to those that are higher: For they have often been

been obſerved to riſe no higher than 31 Feet in an Hour and half.

The aſcending Dew muſt manifeſtly differ according to the different Soils of Places; as abounding here and there with aqueous, ſpirituous, oleaginous, ſaline and metallic Qualities of the Earth's, from whence they aroſe; and therefore in different Soils it is plain they muſt produce different Phœnomena, and occaſion different Diſtempers to Animals. Hence Dew never adheres to polliſhed Metals in ſome Countries, yet in others it adheres to them, ſo as to ruſt them daily; and again in other Places, it adheres to all Bodies without Exception.

In ſome Places the Dew has been found to aſcend but not to return, being diſſipated by ſudden Winds: In other Places it aſcends and ſettles by retaining its Heat; and again much greater Quantities aſcend than deſcend, for the upward Parts are drove forward by Winds, which do not affect the lower.

The Winds, Rains, and other Inconveniences render it impoſſible to determine the Quantity of Dew that ariſes every Night or in a Year, and this muſt differ with reſpect to the different Soils, as well as with Reſpect of the different Degrees of Heat in different Countries.

Oily or *Honey-dew* is produced by the violent Heat of the Sun on Trees, and Herbs, which emit an oily Sweat, and riſing as dew, afterwards falls on Water and makes its Surface appear oily and fat. This may be ſeen on Rivers near Places where there are many Trees planted.

Rain is a Multitude of Drops which for the moſt Part fall from Clouds: But in Summer after calm Weather when the Sun is violently hot, ſmall Quantities of Rain fall in ſmall Drops; for the great Heat hurries the Vapours upwards with an uncommon Velocity into cool Air, where being quickly condenſed, they return in Drops without forming a Cloud.

When the Particles of Vapour that form a Cloud, approach each other ſo nearly as to attract each other, they cohere and form a Drop, which becoming ſpecifically heavier than the Air that before ſuſtained them, falls downward, and meeting other Drops is united with them, and ſo increaſes in Magnitude, till it falls on the Earth.

When the Parts of a Cloud are changed equably, but ſlowly, ſo that the Vapours unite gradually; then they will fall down in very ſmall Drops, the Specific Gravity of which, do but little exceed that of the ambient Air, and therefore deſcend through it gently, in Form of every thin dewy Rain called *Pſecas*, or vulgarly a *Scotch Miſt*; but theſe are not very frequent: The like will alſo happen, when the Cloud firſt changes its lower Parts, and proceeds gently upwards, for in this Caſe the Vapours uniting into ſmall Drops will deſcend gently, and will come to the Earth in the ſame Magnitude, as when they left the Cloud: But if the upper Part of a Cloud be firſt changed, it is plain the Drops muſt increaſe by attracting Vapours, the further they deſcend till they fall in large Drops. This is frequent; and a heavy Shower has been obſerved by ſome in a Vale, when others on the adjoining Hill, and in, or under the ſame Cloud, have found the Shower but light.

Notwithſtanding what has been already ſaid concerning Rains, yet the Winds ſeem to be the principal Cauſe of them; for when the Wind blows downwards upon a Cloud, it thereby forces the Vapours to unite and to fall in Rain; and vapourous Clouds which ariſe from the Ocean, are carried by the Winds over terreſtrial Regions, and being daſhed againſt Hills, or againſt other Clouds, which have been driven in an oppoſite Direction, they are thereby forced into Rain; for Winds which blow between the Weſt and South, or from either the great *Weſtern Ocean*, or from the *Atlantic Ocean*, are generally productive of Rain; but Winds from the Continent, ſeldom produce Rain, unleſs they are met with Winds in contrary Directions, and then Rain enſues with us. Theſe Obſervations or Rules for Rain, are far from being univerſal, for every Country, from its own Obſervations, is beſt able to account for Rains being produced by this or that Wind.

Since the Air is infected with all Kinds of Exhalations, and is defiled with Salts, Spirits, Oils, Earths, Metals, *&c.* it is plain that Rain in its Deſcent, muſt alſo be defiled by paſſing through it, and therefore that it cannot be pure Water; and that it muſt be better or worſe as the different Soils are from whence the Exhalations aroſe, as well as according to the different Seaſons of the Year; and becauſe the Seeds of very ſmall Plants, and the Eggs of innumerable Inſects float in the Air, they muſt be carried down with the Rain.

Hence

Hence it is that Greens of different Kinds, vegitate in Ditches, Ponds, Lakes and Rivers; and that Rain Water is ſoon corrupted, by the Means of innumerable Animalcula, which quickly die and ſtink.

If Rain Water be ever ſo carefully cloſed in a Veſſel, it will be full of ſmall white Spots or Clouds, from the Quantity of Corpuſcles or Animalcula it contains, which by Degrees increaſe, and the Water will become more opaque. Theſe in a little Time degenerate into a thin, ſtiff, glutinous *Mucus* or *Muck*, which occaſions the Water to be of a ropy Nature.

From what has been ſaid we may partly account for Showers of a miraculous and uncommon Nature; for the ſeveral Exhalations came down with them as they fell. *Moſes* (in XIX *Chap. of Gen. and* 24*th Verſe*) tells us, it rained Brimſtone; and *Scheuch Zerus* relates, that in the Year 1677, there was a yellow Rain fell near *Zurich*, which was found ſwimming in the Form of Powder upon an adjacent Lake. It was imagined that this Powder was carried by the Wind from the Pines into the Air, where it mingled with Rain.

We have had frequent Acounts both from the Antients and Moderns of *Drops of Blood* falling in Showers: But ſome curious Perſons upon Examination found the Drops were full of Red Inſects.

We are alſo told of a *Salt Shower* occaſioned by a raging Tempeſt at *Suſſex* in *England*: (*Philoſ. Tranſ.* No. 289) for the Sprays or extream Drops of the Surges of the Sea, which aroſe from its being dashed against the Rocks, were carried a loft in the Air, and fell on the adjoining Lands.

Hence therefore it is, that after a Shower of Rain, we plainly discern the Air to be pure and transparent, so that very distant Objects may be seen clearly and distinctly; and that the Colours of Plants are then most bright and beautiful, and that the vegitable and animal World seem to be renewed by the fresh vivifying Air.

Though Rain falls from high Clouds, yet it does not come to the Earth with so great a Velocity as may be expected by the Law of Gravitation, on Account of the great Resistance of the Air. This is so ordered that tender Plants may not suffer by the Drops, which otherwise would be destroyed.

Rain is of Use, to moisten and soften the Earth which is dried up by the Sun, and thereby it becomes fruitful by nourishing all Kinds of Vegitables; it washes and cleanses the Air, from filthy Exhalations, and from the hurtful or useless Respiration of Animals: It cools the Air that is near the Earth, by falling from higher and cooler Air: It is the Origin of Fountains, Springs, Brooks, and therefore of Rivers, but not the only Cause; for the Vapours cooling in the Night unite on the Surfaces of Mountains, and convert into Water, which distilling downwards, supplies Springs and Rivers with an incredible Quantity of Water.

A *Water-spout* or *Whirl-pool* is occasioned by two Winds blowing in opposite Directions, which do not meet with, or touch each other, but leave a Calm between them. Such Winds whirl a Cloud about

that

that falls between them, condenſe it and roll it into a cylindrical or conical Form, which deſcends by its Gravity, but its Baſe ſtill adheres to the remaining thick and black Cloud, and its Vertex is downwards. Water-ſpouts are of very different thickneſſes, ſometimes they are more than 50 Fathoms, and at other Times not of above 4 or 5 Fathoms.

Water-ſpouts have been found to be empty within, the Parts receding from the Center, by the centrifugal Force, and the Particles which fly off from the external Surfaces form Rain. They are hurried over Sea and Land. When they are over Sea they ſink almoſt to its Surface, and then by the Preſſure of the Atmoſphere, Part of the Sea Water riſes into the Middle of them, where the Air is rarified by the centrifugal Force of the Water; and light Bodies are ſeen to riſe through the Middle of them. Now becauſe about the ariſing Column there is a vaſt Quantity of the Water of the Spout falling on all Sides with Violence on the Sea; it exhibits about the Surface of the Sea, the Appearance of thin Rain, ſo that the Sea ſeems to rage and foam. Wherever a Whirl-pool ſettles, it ſtrips the Ground, deſtroys and beats down every Thing in its way, as Buildings, Trees, Ships, *&c.* with more Violence than the moſt rapid Winds; ſending forth a Noiſe nearly reſembling that which is made by a Multitude of Carriages rolling over Pavements, which does not ceaſe till the Cloud is quite fallen down. The greater the Spout is, the ſooner it is ſpent, and the Continuance of any of them is but ſhort,

that

that is, they are not of ſo long as of an Hours Duration.

Immenſe Quantities of Water fall upon the Earth when a Cloud breaks, ſo as to overflow it with immoderate Showers. Indeed when Clouds are ſqueezed together by Winds, meeting in oppoſite Directions, or when Winds drive the Clouds with Violence againſt Mountains, the Clouds break and fall in heavy Rain. Hence Rain is more frequent in hilly or Mountainous, than in flat and champain Countries.

Hoar-froſt is a light Dew or Vapour which iſſuing out of the Veſſels of Plants, and from the Earth is ſoon condenſed by the cold Air in the Winter, and being changed into Ice, covers the Face of the Earth and all Things on it that are low.

Hail is nothing elſe but Drops of Rain which are frozen in their Paſſage through cold Air, and become hard Bodies; and juſt as Drops of Rain differ at different Times in their Magnitude, ſo do Hail-ſtones alſo differ in their Size.

Hail-ſtones are ſeldom in the Form of a perfect Sphere, but are for the moſt Part flattened, compreſſed, full of Angles, concave; and they are generally ſo, if the Wind blows hard; for they by unequal Preſſure compreſs the Drops of Rain and reduce them into various Figures, which they retain after Congelation, or being frozen.

Sometimes Hail is ſoft, and its Surface is as if it were ſprinkled with Meal: But this being ſmall ſoon melts, becauſe it falls when the Sky is calm, moiſt, and warmiſh.

Hail

Hail has often a white *Nucleus* or *Kernel* in its Middle, which is not tranſparent, but opaque, being covered with a hard tranſparent Shell. This Nucleus ſeems to be firſt produced, and falling into a Drop of Rain is ſurrounded by it and turned into Ice. This Kind of Hail generally falls in a Mixture of Rain.

Hail ſometimes puts on very different Figures, and again every of its Stones or Grains is of the ſame Figure, which is either pyramidical, half round, full of Angles or ſqueezed flat; this ſeems to be occaſioned by Exhalations, which are of a different Nature mingling with the Drops, and being turned into Ice, aſſume different Shapes and Colours; but being of the ſame Nature will be of the ſame Figure.

Snow is a Collection of long ſlender Drops of Vapour, which falling from a Cloud and being congealed, meet each other, and compoſe various Fleeces of various Magnitudes. Indeed the various Forms of Fleeces are truly wonderful; ſome being irregular, and others for the moſt Part being of a regular Form; ſome are like Spikes croſſing each other; others are of a pentagonal or hexagonal Form, with beautiful Branches iſſuing in great variety from their Centers; others repreſent the Leaves of Flowers; and again, others are in the Form of Stars. Theſe Differences ſeem to depend upon the Exhalations, being mingled with Vapours, which in falling from a Cloud are congealed; as Salt diſſolved in Water may be cryſtallized into various Figures; for otherwiſe it would be difficult to conceive, how all the Fleeces ſhould be

formed

formed in the Air at ſome Times, of the ſame regular Figure.

Snow juſt fallen is generally very rare, but large flakey Snow is not ſo rare; becauſe a Quantity of the latter, will yield more Water than a like Quantity of the former.

If after a great fall of Snow, a Froſt comes on and continues with ſerene Weather, the Snow will by Degrees ſubſide, and continually decreaſe by Evaporation, 'till at length it vaniſhes into Air: For the ſolar Heat continually ſoftens and melts it, and making the diſſolved Parts volatile, thus conſumes it.

The Fleeces of Snow that fall while a Froſt continues are always leſs than thoſe that fall in warmer Air: For as the Air becomes warmer ſometimes Snow and Rain fall together.

Snow is very white and reflects the Light ſtrongly, though every Particle of it is tranſparent Ice, of which we are confirmed by viewing it through a Microſcope. But becauſe there are very irregular Pores between the ſeveral *Spicula* or *Darts*, the Light cannot paſs through them, but is ſtrongly reflected, as if it were tranſparent Glaſs beat to Powder.

Snow preſerves the Herbs in Winter, by covering and ſecuring them againſt the inclemency and and ſeverity of the Froſt, and ſupplies Brooks and Rivers: If a ſudden Thaw ſucceeds a great fall of Snow, the Snow-waters from the Mountains ſwell the Rivers, ſometimes ſo as to overflow the adjacent Lands, and to do much Damage, by

ſweeping

ſweeping away Cattle, Corn, Mills, Bridges or whatſoever elſe happens to be in its Way.

An *Iris* or *Rain-bow* appears when the Sun ſhines at the Back of the Spectator, and at the ſame Time there is a dark Cloud before him, with Rain falling between him and the Cloud.

Sometimes two or three Rain-bows have been ſeen together, concentric to each other. The internal Bow, which is moſt lively in its Colours is called *Primary*, the external being more languid, is called *Secondary*; if there is a third it appears extreamly languid.

The Order of the Colours in the two Bows is inverted. In the primary counting from the inward Part of the Bow, they follow in this Order; Violet, Purple, Blue, Green, Yellow, Orange, Red; and in the ſecondary Bow, begining from the inſide as before, you will have Red, Orange, Yellow, Green, Blue, Purple, Violet, being the Colours that are exhibited through a glaſs Priſm as before.

Fig. 75. That the primary Iris may be underſtood, let a Drop of Rain be repreſented by BNFG, upon which let AN a Ray of the Sun fall, which is refracted at N to F, where let it go out of the Sphere by Refraction towards V, or be reflected to G, from whence let it go out by Refraction towards R, or be reflected to H, and there let it go out by Refraction towards S, and cut the incident Ray in Y: Let AN and RG be produced till they meet in X.

Parrallel to the incident Ray AN, draw the Diameter BQ, and let BL be a Quadrant next the Sun, upon which let us ſuppoſe many Rays to fall parallel to AN or BQ: As the Point of Incidence removes from B towards L, the Angle AXR, which is contained by the Rays AN and RG, will increaſe at firſt, and then decreaſe; and on the contrary, the Angle AYS will firſt decreaſe and then increaſe.

Let N be that Point of the Quadrant BL on which, if the incident Ray falls, it makes the greateſt Angle poſſible with the Ray RG, which emerges after one Reflection: Then all the Rays that fall a little on each Side of N, and go out after Reflection, will emerge parallel, or nearly parallel to GR; but thoſe that fall on the Quadrant, at greater Diſtances from N, though they are parallel before their Incidence, will diverge after their Emergence. Therefore if an Eye be placed in the Direction of the emerging parallel Rays, a diſtinct Image of the Sun will be ſeen in the Drop, but if it be placed amongſt the diverging Rays, it will not appear in the Drop.

Again if N were that Point of the Quadrant upon which if the incident Ray AN falls, it makes the leaſt Angle with the Ray HS which emerges after two Reflections: Then as before, all the Rays which fall near N, will after two Reflections emerge parallel or nearly ſo, and will exhibit the Suns Image in the Drop, to an Eye placed in the emerging Rays; but thoſe which fall at a ſenſible Diſtance from N, will, after two Reflections, emerge with diverging or ſcattering Rays, which are too feeble to ſhew the Suns Image in the Drop, to an Eye which is placed amongſt them.

Now

Now, becauſe Rays of different Colours have different Degrees of Refrangebility, the greateſt Angle AXR, which can be made by the incident Rays, and thoſe that go out after one Reflection, will be of different Magnitudes, in Rays of different Colours; and the ſmalleſt Angle AYS that can be made by the incident Rays, and thoſe that go out after two Reflections, will alſo be of different Magnitudes in Rays of different Colours; and it has been found, that the greateſt Angle AXR is 42 Degrees and two Minutes in Red Rays, which are leaſt refrangible, and the leaſt Angle AYS is 50 Degrees and 57 Minutes; and that the greateſt Angle has been found to be 40 Degrees and 17 Minutes in Violet Rays, which are moſt refrangible, and the leaſt Angle is 54 Degrees and 7 Minutes.

Fig. 76. Through O the Spectators Eye, let OP be drawn parallel to the Suns Rays, and let POE be an Angle of 40 Degrees 17 Minutes, and POF an Angle of 42 Degrees 2 Minutes: POG one of 50 Degrees 57 Minutes, and POH one of 54 Degrees 7 Minutes; if theſe reſpective Angles be turned about on their common Side OP, they will deſcribe the Verges of the two Rainbows AFBE, and CHDG.

For the Drop E, and all theſe in the concave Part of the leſſer Rainbow, whoſe Angle POE is 40 Degrees 17 Minutes, being the greateſt Angle in which the moſt refrangible Rays, can after one Reflection be refracted to the Eye, will ſtrike the Senſes with the deepeſt Violet Colour, in that Region. And the Drop F, as well as all the other Drops, which are on the convex Part of the leſſer Rainbow, whoſe Angle POF is 42 Degrees 2 Minutes, being the greateſt Angle in which the leaſt refrangible Rays after one Reflection meet the Eye, will ſtrike the Senſes with the deepeſt Red Colour in that Region: Therefore all the intermediate Drops between E and F, or between the Concave and convex Parts of the leſſer Bow, will exhibit all the intermediate Colours between Violet and Red; ſo that from the inſide to the outſide of this Bow, which is the primary Bow, they will be in this Order, Violet, Purple, Blue, Green, Yellow, Orange and Red.

Again, the Angle SGO which is equal to POG, being an Angle of 50 Degrees 57 Minutes, and being the leaſt Angle in which the moſt refrangible Rays, after two Reflections meet the Eye, the Drop G, and all the other Drops which are on the inſide of the greateſt Bow, will ſtrike the Senſes with the deepeſt Red in that Region. And the Angle SHO, which is equal to POH of 54 Degrees 7 Minutes, being the leaſt Angle in which the moſt refrangible Rays after two Reflections, ſhall meet the Eye; the Drop H, and all the other Drops, which are on the convex Part of the greateſt Bow, will ſtrike the Senſes with the deepeſt Violet in that Region. Therefore all the intermediate Drops between G and H, and all the other Drops that are between the inſide and the outſide of the greateſt Bow, will exhibit all the intermediate Colours between Red and Violet; ſo that the Colours of the ſecondary Bow, counting from the

the inside, will be in this Order; Red, Orange, Yellow, Green, Blue, Purple and Violet.

Thus then there are two Bows, a primary and a secondary one, in which the Order of their Colours are inverted; the Breadth of the Primary will be 1 Degree and 45 Minutes, and that of the Secondary, will be 3 Degrees 10 Minutes; and the Distance between the Bows, will be 8 Degrees 55 Minutes.

Hence it must be abundantly manifest, that a greater or less Portion of a Bow must appear, according to the different Height, both of the Sun and the Spectator above the Horizon. For if the Spectator and Sun be both in the Horizon, OP will be parallel to the Horizon; but as the Sun ascends, OP will be depressed, and therefore the Center of the Bow will be below the Horizon, and consequently a less Portion of it can be seen: But when the Sun is 42 Degrees 2 Minutes high, the Line OE will be parallel to the Horizon, and then but a very small Part of an Arch of the Bow will be seen above it; after which if the Sun ascends but a little, the whole Arch or Bow will vanish.

If Rain passes over the Head of a Spectator, who is in the Middle of a Plane, in its Progress many Drops will adhere to Grass and other Plants, and the Legs of the Bow will then seem to cover a large Tract. For the Suns Rays are as well refracted by these Drops, and under the same Angle, as if they were any other Part of the Bow, that is equidistant from the Spectator.

Seeing

Seeing therefore that every Part of a Bow that is equidiſtant from its Extreams, as well as the Extreams themſelves, can only be ſeen under the ſame Angles; it muſt neceſſarily follow, that a Bow will either appear to move before a Perſon who goes forward, or to follow one who goes from it.

The Colours of a Bow are more or leſs intenſe, as the Cloud before the Spectator is more or leſs opaque.

In the like Manner the Lunar Iris may be explained, which though very rare, may be obſerved about the full of the Moon when it rains; it is plain that the Colours of this muſt be as much fainter than thoſe of the Solar Iris, as the Rays of the Moon are fainter than thoſe of the Sun.

We have ſhewn that a Bow is equally broad quite through its whole Extent, as it really is; notwithſtanding its interior Legs appear broader, and its Top narrower: And hence the two concentric Bows ſeem to be more diſtant at their Top, than they are between their Legs: but this is only the Imagination of the Spectator.

Halo's or *Crowns* are luminous Circles, ſometimes white, and ſometimes coloured as a Rainbow, which ſurround the Sun, Moon, Planets, and ſome fixed Stars; of which one, or more concentric to it is ſeen: Thoſe about the Planets or Stars, or even about the Moon, are not far diſtant from the Bodies themſelves, their Diameters being from 2 to 5 Degrees; but thoſe about the Sun are found to vary in their Diameters from 12 to 90 Degrees. The Breadth of the Rings and their Diameters are ſubject to many Changes.

The intermediate Space between the Luminary and the Crown, is always of a leſs Degree of Brightneſs than the Crown or Circle itſelf; and the Colours of the Crown are more faint and dilute than thoſe of a Rain-bow, and ſucceed one another in a different Order according to the different Breadth of the Crown. In thoſe Rings Sir ISAAC NEWTON obſerved, that the Colours in the internal Ring, were Blue within, White in the Middle, and Red without; and that thoſe in the ſecond Ring were Purple, Blue, Green, Yellow, Pale-red; and that thoſe in the third Ring, Pale-blue and Pale-red.

That Part of the Atmoſphere which is near the Earth, is the Cauſe of theſe Crowns. For our Minds are deceived in falſly judging or ſuppoſing the Crowns to be about the Stars themſelves, which have either no Atmoſpheres, or ſuch as are but very ſmall; beſides, the Crowns are ſeen but by a few Obſervers at once, and ſeldom at the Diſtance of two or three Miles; they break and diſperſe as the Wind riſes, and are only collected in calm Weather when the Air is ſtagnant and ſluggiſh, and when the Heaven is covered with a thin Cloud.

If in cold Weather we make a ſteam of hot Water to riſe between the Eye, and the Flame of a Candle, a Kind of a Crown will be ſeen in the Steam. Hence it is ſeen in Baths about a Light. If Air be readmitted into a Glaſs Receiver, and a Candle be ſet beyond it, a Crown will be ſeen to be about the Flame with ſeveral Colours: Wherefore Crowns in the Heavens are produced after the ſame Manner of ſome of theſe artificial ones.

This may ariſe either from Light paſſing through the Particles of Vapours, and being twice refracted; or by Light running between the Interſtices of Vapours, and being inflected by the attracting Forces, are thereby ſeperated into Colours. But the former Cauſe ſeems to be the more probable of the two.

Theſe Crowns are neither Prognoſtics of Wind, Rain, or Storms being at Hand, as Doctor *Muſschenbroek* aſſerts from his own Obſervations.

Parhelii or *Mock-ſuns* are Meteors which reſemble the Sun, and are ſeen with it and near it. Their Number varies, for from one to ſix of them have been ſeen at a Time.

The Parhelii ſeem to be of the ſame Magnitude with the Sun, but they are not always round; and though they ſometimes ſeem as bright as the Sun, yet they generally are more faint, and if there are many of them to be ſeen at one Time, ſome are more dull and pale than others. Their Edges are tinged with Colours like a Rain-bow, and many of them have a long Tail of a fiery Colour, which becomes paler as its Length becomes greater; and others are without a Tail, or have the Tail extended in a white horizontal Circle.

The Parhelii are for the moſt Part attended by Halo's or certain Circles, of which ſome have the Colours of the Rainbow, and others are white; and theſe vary both in Number and Magnitude, having

having the ſame Breadth and apparent Diameter of the Sun: And there are ſome coloured Circles, which ſurround the Sun itſelf, that is, placed in their Center, whoſe Diameters vary from 45 to 90 Degrees, the Planes of which are perpendicular to right Lines drawn from the Spectator through the Center of the Sun; therefore their Situation muſt vary, according as the Sun is high or low.

The more lively the Colours of the Parhelii appear, the more languid will be the Light of the Sun. There are beſides theſe Circles, others which are parallel to the Horizon, of which the external one that comprehends all the reſt, as well as all the Parhelii is white. *Hevelius* ſaw one of theſe, whoſe Diameter was 130 Degrees. The other Circles which were concentric to this large one, were here and there tinged as they paſſed over the former coloured ones. Again there were alſo other Circles ſituated obliquely, in reſpect to theſe; ſome of which being tinged, had the Order of their Colours, the ſame as in the Iris; but the inward Part next the Sun, is of the red Colour.

Parhelii have been ſeen from a Quarter to an whole Hour or two, when the Elevation of the Sun has cauſed them to vaniſh.

Becauſe that the coloured Circles or Crowns, which encompaſs the Parhelii, are in the Air: That the Parhelii never appear but when the Heaven is covered with a thin tranſparent Cloud: That in as much as the more lively the Colours of the Circles are, by ſo much the Light of the Sun itſelf is diminiſhed: That finding theſe Parhelii cannot be ſeen at two Places that are but of a very ſmall Diſtance at the ſame Time: That becauſe they are generally obſerved in Winter when there is Froſt, and the Wind at or near the North: And that when they are over, either Snow, Hail or Rain follow; therefore they muſt be only in the Atmoſphere of the Earth.

Seeing the Parhelii do not always produce the ſame Phœnomena, their Cauſes may be ſimilar, though they may not be exactly the ſame, therefore we ſhall ſhew that ſomething muſt be changed, when Circumſtances vary.]

Let us ſuppoſe *Spicula* or *Darts* of Ice, ſuſpended in the Air, which are perfectly fine and Cylindrical, and let theſe begin to melt before the Sun, ſo that the middle Part be not yet melted, and that the melted Part may form a ſmall globular tranſparent Drop, at the Bottom of the Dart, which will adhere to it for ſome Time, and cauſe the Dart to float erect in the Air. Now it is plain that when theſe Darts hang before the Sun, they muſt intercept Part of its Light, and therefore he will be leſs reſplendent than in a clear Air; and Part of the Suns Rays will be reflected by, and others will be refracted, and paſs forwards through them, and will form the white Circle before deſcribed, in that Part of the Atmoſphere which is Horizontal with the Sun.

If then we conceive theſe Spicula in the white Circle, it is plain that many Rays will be tranſmitted to a Spectator by the Spicula that are placed between him and the Sun, and there will

be

be a certain Place, in which the Spicula will ſend the refracted Light to the Spectator in the greateſt plenty. This occaſions a Mock-ſun to appear in the white Circle; which may be reflected by the hinder Part of the Spicula, and be ſeen again in the white Circle *&c.* and ſince the neighbouring Spicula always tranſmit ſo much the leſs Light, as they are more remote from the Sun; therefore a ſhining Tail will ſeem to adhere to the Parhelii, included in the white Circle. And becauſe of the lateral Rays that are refracted into Colours, the Parhelii and their Tails will be ſeen with coloured Edges, and the Tails will become leaſt refulgent at their Exrtemities.

The Parhelii will ſeem to be in Labour and to looſe their Brightneſs upon the leaſt Motion of the Air. He that is deſirous to be fully inſtructed in the Theory of Crowns and Parhelii, may conſult Dr, *Smith*'s Optics.

Paraſelenæ, or *Mock-moons*, alſo appear about the Moon with like Tails and coloured Circles as now mentioned in the Parhelii. Their Cauſe without Doubt is analagous to that of the Parhelii, and their Phœnomena may be explained in the ſame Manner.

Virgæ or *luminous-Streams* ſeem ſometimes to be emitted by the Sun, through the Clouds, which extend in a conical Form, as far as the Earth. They are generally ſeen in an Afternoon after hot Weather. They ſhew themſelves when the Clouds prevent us to ſee the Sun, but the thin and diſtant Rays are directed to the Earth, through the narrow Interſtices of Clouds. Theſe

Rays meet the aſcending Vapours, and being viewed laterally affect the Sight, in the ſame Manner, as when the Sun-Beams are admitted through a Hole in a Window-ſhutter, into a cloſe Room; we ſee ſeveral Corpuſcules or little Bodies floating up and down, and meeting each other in all manner of Directions. But when theſe Rays which are thus reflected by the Corpuſcules, are viewed ſideways, they appear in the Form of *Virgæ*.

Having thus explained the principal of the watry Meteors, we proceed now to the fiery ones.

CHAP.

CHAP. VIII.

Of *fiery* METEORS *viz.*

Of the *Aurora Borealis*, *Ignis Fatuus*, *Lambent Fire*, *Bolis*, *Thunder*, and *Lightning* &c.

FIERY Meteors either emit a faint or rather a ſhining Light, or they dart out a bright Light and burn. To the firſt of theſe belong all Species of the *Auroræ Boreales*, and to the latter Thunder, Lightning, and ſuch like; and of theſe in their Order.

The *Aurora Borealis* or what is vulgarly called the flaſhing *Northern Lights* is no new Meteor for it has been deſcribed by *Ariſtotle*, *Pliny*, *Seneca*, and others after them. They are not ſo frequent to thoſe who are remote from the North Pole, as to others nearer to it. And tho' they have not always the ſame Appearances, but very different ones, yet they are generally in this Manner.

A Cloud is found to appear either in the North or in the North-Eaſt, or North-Weſt Parts of the Heaven, which either lies in the Horizon or is elevated above it a few Degrees, ſeldom ſo high as 40; or elſe the Cloud is ſeperated from the Horizon, ſo that a blue Sky can be ſeen between. The Length the Cloud poſſeſſes is very variable, ſometimes

ſometimes taking up but 5 or 6 Degrees, and again extending as far as 100 or more.

The Cloud we here mention is white, and not very bright, but oftner thick and dark: It's upper Limb is for the moſt Part parallel to the Horizon, yet it is ſometimes a little higher in the Middle than at the Sides. Sometimes to the upper Margin of the black Cloud a white and bright Limb has been obſerved to adhere, that is concentric to it; and this lucid Limb has been obſerved to adhere to the lower Margin of the black Cloud, when one black Cloud was higher than another. The black Part has been obſerved to change into a white ſhining Cloud, after the Aurora has ſhined for ſome Time, and has thrown out many flaſhing Streams; and it then has returned to it's former Opacity. And though the Heaven appears brighter above the upper Limb of the Crown, yet this Brightneſs is ſoon changed, by being either increaſed or diminiſhed.

From the upper Limb, more or leſs Streams of Light are emitted near one another which are very bright and ſhining; or they are ſhining Jets of Fire that become rarer, broader, and leſs ſhining, the farther they proceed. When one Jet is dying away, another iſſues out of the ſame Limb, which is not ſo bright, ſomething like Smoak. This again is ſoon followed by a brighter, which in breaking forth, ſeems to be choaked or interrupted by ſome Impediment, and therefore guſhes out at Intervals.

This luminous Matter is exploded with great Rapidity, and often increaſes ſlowly by Degrees with

with an equable Motion, and becomes the wider, as it continues to riſe from the Aperture in the Cloud. Some Jets continue only for 10 or 20 Seconds, and others for 4 or 5 Minutes; but this is not uſual; nor are Streams which adhere to the Cloud, with a wider Baſe and mount upwards in a conical Form.

There are Columns which cannot be ſeen to iſſue from a Limb, and therefore ſeem to be produced from ſerene Air. Some Columns are perpendicular to the Horizon, others are oblique, others are Arch-ways; and their Lengths are very different: Some ſhoot from the Cloud with ſo great a Rapidity as to carry them to the *Zenith*, or Point of the Heaven which is over us; and again, others with a Rapidity ſtill greater, which will carry them far beyond the Zenith, almoſt to the South. They do not always aſcend to the Zenith directly out of the Cloud, but they are inclined, eſpecially if an illuminated Cloud be ſuppended in the Middle, between the North and the Eaſt, or Weſt.

The lucid Columns contain a white Light, reddiſh, or blood Colour. As they advance the Colours change ſo as to reſemble the Iris. When ſeveral which are emitted from different Parts of the Limb meet in the Zenith, they mingle, and form a pretty thick Cloud or Miſt, which preſently taking Fire, burns furiouſly, and ſpreads a green, blue, or purple Light. New Columns ſoon follow thoſe that went before and vaniſhed, and ſometimes they will deſiſt for a few Minutes, before new ones are produced. The lucid Columns

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are ſo tranſparent, that Stars of the firſt and ſecond Magnitude are ſeen to ſhine through them: Indeed they may be ſometimes ſeen through the Limb of a white Cloud, but very ſeldom through a black one. No ſooner ſeveral Columns are diſperſed inſenſibly in the Sky, but others often break forth in thoſe Places, where the former ceaſed. They are ſometimes carried in little Clouds, from North to South; therefore after the Meteors ceaſe, great Part of the Sky is filled with thin Clouds.

There will ſometimes iſſue from a Cloud with great Rapidity, a very thin ſhining Matter, which will not obſcure Stars of the ſixth Magnitude. This ſhining Matter comes by Fits, and is more opaque in aſcending than in deſcending, and is thought to be what the Antients called the *Capra Saltans* or the *dancing Goat*; it moves in a very broad Tract, and extends itſelf far beyond the Zenith. Little lucid Clouds have been ſeen to break from the Limb of the ſhining Cloud, and have been carried away from North to South, without any Streams of Light.

All flaſhing Columns do not ſeem to iſſue from a Cloud; for when the whole Horizon is ſhining with very bright Light, ſhort lucid Columns will be ſeen to riſe therefrom. This may be occaſioned by the Cloud which is the Source of Light, being ſuſpended a little below the Horizon; or it muſt be ſo ſmall and thin, that it cannot be perceived by the Eye.

This Meteor ſometimes appears for a Night, and ſometimes for two, three, or more Nights ſucceſſively. It has been obſerved in one Place, and has not been ſeen from another, of but a few Miles Diſtance. Sometimes there is ſo great a Quantity of it, that it has been ſeen almoſt over all Europe in one and the ſame Time; yet in different Countries it is ſeen with very different Circumſtances. Some *Auroræ* are but of a few Minutes continuance.

The Cloud which is the Source of this Meteor continues unchanged for many Hours, and neither ſeems to riſe above, or to fall towards the Horizon, yet it ſometimes moves from the North towards the Eaſt or Weſt, and ſometimes from the North to the Eaſt and Weſt. It has been ſeen to aſcend above the Horizon, and to be converted into a white ſhining Cloud.

This *Aurora* does not forbode any bad Weather, or dire Calamities, as it is vulgarly ſuppoſed to do; for upon the ſtricteſt and moſt critical Obſervations, neither changes of Winds or of Rains, of Heat or of Cold, of moiſt or of dry, either preſage their coming, or are preſaged by it; nor are they the Sign of Diſeaſes or of Wars.

That the *Aurora Borealis* is in the Atmoſphere of the Earth, may be thus proved.

Since it appears in the form of a Cloud, which is like the other Clouds in the Atmoſphere; ſince the flaſhing Cloud continues at the ſame Height above the Horizon for many Hours or Days, and therefore revolves about the Earth's Axis, together with the Earth and the reſt of the Atmoſphere; and ſince the *Aurora* is not ſeen in two different Places at the ſame Time, which are but a few Miles

Diſtance; it manifeſtly follows, that it muſt be within the Atmoſphere of the Earth.

The Diſtance of this Meteor from the Surface of the Earth, has not yet been determined, though often attempted by very good Mathematicians. For we are not certain that it is the ſame Light that is ſeen from different Places at the ſame Time; if we were, by having the different Angles, under which the Top of the Cloud is ſeen from any two Places whoſe Diſtance is known, we could eaſily determine its Diſtance from either.

Though the Matter of the *Aurora* is a Fire of ſuch a Nature, as to produce ſo clear a Light; that Stars may be ſeen through it; yet who can pretend to aſſign it's Nature and Properties with ſafety? Chemiſts can give numberleſs Specimens of inflammable and Phoſphorean Matter; and Nature has ſhut up many others in the Bowels of the Earth, which Art cannot arrive to.

The Matter of the *Aurora* ſeems to expire from the Bowels of the Earth, out of the Northern Quarter thereof: They have been more frequent, and have been found to extend farther than before the Year 1716; for it's Nutriment may have found its Way, by Means of an Earthquake, and when this is conſumed, they will perhaps ceaſe for many Ages.

This perſpiring Matter aſcends, and compoſes one or more Clouds, which are carried over different Regions, and will not be inflamed till it meets with other Matter, from whence a hot and fiery Effervefcence, Steam, or Fume ariſes, of which many have been diſcovered by Art. If then a Cloud

conſiſting

consisting of this perspirable Matter, be carried from the North whence it had its Being, by a Northerly Wind to other Distant Regions, and there meets with Exhalations, with which it will cause an Effervescence ; it will be inflamed in that part: Therefore a Spectator who is to the South, or to the South-East, or South-West, of the Effervescence, will have the Light to the North, or to the North-West, or North East of him, bursting forth into Streams and Columns variously situated with respect of the Horizon, and of various Colours; as different Exhalations mingle with the effervescent ones.

The Cloud out of which an *Aurora* rises may continue immoveable for some time in respect to the Horizon, if it be carried with an equal Force from the North towards the South, as that with which the Exhalations are carried from the South towards the North. And many of its Phænomena seem easily explicable, from Sources which may not be far from Truth. Perhaps the Matter it self by falling from the Sky, may furnish an Opportunity for Examination; or Art may prepare something like it, by which it may be known; or its native Place may be discovered in the Surface of the Earth. The Lake *Weter* in *Sweden*, sends forth a Matter not unlike it.

A small fiery Ball resembling a Star, and of the same apparent Magnitude is often seen to move through the Atmosphere in a clear Sky, and to fall on the Earth; and it is called a *Shooting-Star*, or a *Falling-Star*.

These are generally obſerved in Spring and Autumn in the Night only; and it is not improbable that they float in the Atmoſphere and fall alſo in the Day, though of this we cannot be certain, on account that the Light of the Day obſcures them.

They are ſeen on the Earth to conſiſt of a ſtiff and clammy Matter, of a wateriſh Colour inclining to Yellow, and covered with black Spots and have Points on their Surface ſomething reſembling theſe of a Mariners Compaſs; but they have loſt all their inflammable Subſtance, which when on Fire run through the Tracts in the Atmoſphere wherein the inflammable Matter floats.

Theſe Stars may be imitated by Art, thus. If a Ball made with Camphire, Nitre, and earthy Mud, macerated with Spirits of Wine, be ſet on Fire and thrown into the Air; it will perfectly repreſent a *Shooting-Star*, with a like remaining tenacious Dreg. Many other like inflammable Subſtances, are found to be in the Atmoſphere.

There is a Phænomenon obſerved by Sailors at Sea, which is called *Caſtor* and *Pollux*; it is a ſmall Flame, which adheres to the Maſts and Rigging. Of theſe ſometimes two or three may be ſeen at a Time. Many Sea-faring Perſons are ſo weak, as to think that one of theſe only is a bad Omen, but that two are propitious, denoting that the Storm will ceaſe. Theſe are little ſhining Fiſhes, which being drove up with the Sprays of the Sea, adhere to whatever they fall on, and there ſhine.

Ignis Fatui or *Wandering Fires* are Phœnomena, which emit Light, reſembling that of Bundles of Sticks ſet on Fire, they are of a round Figure and are about as large as the Flame of a Candle, ſometimes they yield a bright Light, at other Times they are more obſcure, and of a purple Colour, and they ſhine leaſt when they are at the leaſt Diſtance. They are carried through the Air not far from the Surface of the Earth, and are moſt frequent about Places that are unctuous, muddy, marſhy, and about Church Yards, and Dunghills. They are ſeen at all Seaſons of the Year, but they are moſt conſpicuous on dark Nights, and are moſt frequent in Winter. Sometimes they vaniſh and ſuddenly appear in another Place, and they are generally about ſix Feet from the Ground. They dilate and contract themſelves very frequently, and move on in Waves, with Sparks of Fire, but burn Nothing. They follow thoſe that ſhun them, and ſhun thoſe that follow them.

Some that have been catched, have been found to conſiſt of a ſhining, viſcous Matter, like the Spawn of Frogs, not hot nor burning, but only ſhining; ſo that the Matter ſeems to be Phoſphorus, which is raiſed and prepared by the Heat of the Sun, from putrified Plants, and Carcaſſes; which being condenſed by the Cold in the Evening, then ſhines.

Theſe Fires have been ſaid to be evil Spirits, who miſlead Travellers out of ſpite, to plunge themſelves into Ditches and Bogs; but this is all mere Fiction.

Lambent

Lambent Fire is that which ſometimes adheres to the Hairs of Children, to adult Perſons, and to the Manes of Horſes, eſpecially if they are well combed.

Theſe Fires are a real Phoſphorus, ſuch as is prepared by Art, from the Parts of Animals. This expiring from the Body, clings to the Hair with the Sweat, and is inflamed by rubbing or combing the Hair. Hence ſweaty Workmen, or foul Linen, will ſhine by rubbing.

Sometimes luminous Tracts appear in the Air which move ſuddenly from Place to Place, which ſome imagine to be a Meteor. But this ariſes from Flies, which fly by Companies in the Night Time, and expire a phoſphorean Light from their Bodies.

A *Bolis* is a great fiery Ball which is hurried ſwiftly through the Air, having generally a Tail. Some have been obſerved as big as the Moon, and again others, which were but equal to half the Moon's Diameter, illuminated the Earth ſo ſtrongly by Night, that a Perſon could ſee to read by them. One of theſe as big as the Moon, was found to enlighten the Earth as ſtrongly as a riſing Sun does; and in it there appeared to be four Gulphs, which emitted much Smoke, and many little burning Flames were ſeen on the Ball. Its Tail was ſeven Times its Diameter.

When Balls of this Kind vaniſh, a little Aſh-Colour ſometimes remains behind in the Air. Some advance, and ſome few appear to ſtand ſtill, yet they all ſhine with a brighter Light than that of the Moon.

As a *Bolis* paſſing over Places, leaves a ſmell of Sulphur behind it, we may reaſonably ſuppoſe it chiefly to conſiſt of Sulphureous and other inflammable Exhalations, which are ſet on Fire by meeting with other Exhalations. The Fluid Matter aſſuming a globular Form by being in the Fluid Air.

Lightning is a ſudden bright Flame, which extends itſelf every Way to a great Diſtance in a Moment.

Lightning is ſeen when the Sky is clear, though not ſo frequent as when it is cloudy. It happens after hot Weather, and before Thunder, but this generally attends it; and it ſeldom does Damage to any Things upon the Earth, becauſe it is in high Air.

The Oil of Plants being attenuated by the Sun's Heat, produces Matter for this Fire, and whatever elſe that is ſulphureous or oily, which is diſperſed through the Atmoſphere, and is ſet on Fire with it by Turns; and the Flame extends itſelf on all Sides, as far as the Exhalations are diſperſed. Some other Kind of Subſtances which float in the Atmoſphere, take Fire and flaſh with the reſt.

Thunder is a moſt bright Flame which riſes ſuddenly, and moves with a moſt rapid Velocity through the Air, according to its Determination. For ſometimes it runs upwards, again, horizontally, obliquely, downwards, in Curves, in right Lines, or in ſerpentine Tracts, and commonly ends with a loud Noiſe or Ratling.

Thunder

Thunder is ſeldom known with us before *May*, nor does it continue after *September*; but in the intermediate Months *June*, *July*, *Auguſt*, it is moſt frequent. It comes from every Quarter; but moſt frequently from the South Wind, and then it is very loud; and almoſt as frequent and loud, when the Wind blows between the South and Eaſt, or between the South and Weſt; and moſt ſeldom when the Wind blows from the North, or from between the North and Eaſt, or North and Weſt. But theſe Circumſtances are only peculiar to certain Places.

No doubt, Sulphur is the principal inflammatory Ingredient in the Compoſition for Thunder, becauſe Places that have been ſtruck by it ſmell ſtrongly of it. The Colour of the Flame, and the cracking and roaring Noiſe that follows it, ſhew, that it cannot be Sulphur only; but that it muſt be impregnated with ſome other Exhalations, which being ſet on Fire explode with a Crack.

Art has diſcovered, that *Balſam of Sulphur* is of the ſame Nature, when agitated by too much Fire in cloſe Veſſels, and then caſt out. Such are *Aurum Fulminans*; *Orpiment*, with *Nitre* and *Salt* of *Tartar*; *Diaphoretic Antimony*, with *Black Soap*; *Pulvis Fulminans*; *Iron* diſſolved in *Aqua-Regia*, and mingled with *Salt* of *Tartar*; *Lead* diſſolved in *Spirit* of *Nitre* &c.

And we know of many other Things, which being ſet on Fire in a cloſe Place, will flaſh with a Noiſe: As *Gunpowder*, *Arſenic* digeſted with *Spirit* of *Nitre*; *Geoffrey's Spirit* of *Nitre* mingled

mingled with any diſtilled Oil; and alſo all *Oils* and *Spirits* which are forced in cloſe Veſſels by too vehement a Fire.

Nature no doubt makes Uſe of many other Exhalations and inflammable Subſtances mingled with Sulphur to produce the like Effects; and therefore all Thunder will not be the ſame, but will differ according to the different Exhalations in different Countries.

It is moſt certain that ſulphureous Steams exude from the Earth into the Atmoſphere with other Exhalations in every Country, which may enter the Compoſition of Thunder. Great Plenty of Salts float in the Air, eſpecially the *Matrix* of Nitre, and they impregnate with ſulphureous and other Exhalations. Theſe whatever they are, compoſe the *Matter of Thunder*. This Matter is formed in the Interſtices of the Atmoſphere in Tracts or Trains, which run in all Manner of Directions; ſo that when any Part of a Tract or a Train takes Fire, the Flaſh and Flame will run from one Extream to the other of that Tract, or as far as the Vein of Nouriſhment leads. Hence the Thunder runs at one Time Horizontally, then upwards, obliquely, downwards and in all Manner of Directions as the Train happens to lie. If a Train were ſet on Fire at its upward End, the Flame will move downwards, and the Thunder will ſeem to deſcend from the Sky.

Thunder therefore is obſerved to be moſt frequent in thoſe Places, where the fulmineous Matter expires from the Ground, yet this may be carried to other Countries by the Wind, and there take Fire. Hence Thunder is much more frequent in ſome Countries than in others, but moſt frequent in the hot Countries, whoſe Soil is parched up by the Sun, whence various Oils and much Sulphur are exhaled. And it happens but ſeldom in Places, which produce neither Oil nor Sulphur, or in Places that are cold, watry, or moiſt.

The Flame which begins at one End of a fulmineous Tract, in running through, ſeems to carry with it, ſome Parts which could not readily take Fire. When a Quantity of theſe are accumulated they will in ſome Time take Fire, and diſplode with great Violence, and thus the Report or craking Noiſe of the *Thunder-clap* is made; for after the Thunder or Flaſh is ceaſed, the Thunder-clap ſoon takes Fire.

It ſeems probable that ſome accumulated fulmineous Matter not yet on Fire, form thoſe fiery Balls, which have been obſerved to fall on the Earth in Places that have been Thunder-ſtruck. For theſe have heated ſo afterwards, as to take Fire ſuddenly through their whole Maſs, and by their Diſploſion have done much Miſchief, and have occaſioned great Deſtruction and Deſolation about them. But theſe Balls are not ſeen every Time it thunders, for they are either too ſmall or too far off to be always ſeen, and the Matter of Thunder is different to it.

Though a Thunder-clap is but a ſingle Report, yet it is often heard for 20 or 30 Seconds, with a rumbling muttering Noiſe, by various Repercuſſions of the Clouds, Hills, and other Obſticles. Hence in Vales there are long continued bellowing

Thunder-

Thunder-claps; whereas for one Explosion, it has been observed that there is but one Clap. When more fulmineous Tracts than one take Fire, each will end in a Clap, and thus several Sounds may be heard together, or may quickly succeed each other.

From what has been said we may perceive. 1. Why it may fulminate and thunder when the Sky is clear, though this seldom happens, yet the sulphureous Exhalations may always take Fire, as soon as they have burst out of the Earth, whether the Sky be serene or cloudy.

2. It is plain that Thunder and Thunder-claps are not always generated in the Clouds, unless fulmineous Exhalations ascend thither; for Thunder has been seen to mount from the Earth into the Atmosphere. And the burning Mountain *Vesuvius* has been seen to emit Thunder; and such Fires are frequent in Mines, particularly in these about *Whitehaven*. But because Lightning immediately follows a Thunder-clap, it is plain, the Noise is not in the Clouds, but is excited in that Place where the Thunder ceased. This is confirmed by the fulmineous Ball, which excites a Thunder-clap by its Explosion.

3. Before it begins to fulminate and thunder, the Sky is generally covered with black Clouds, which fly in all Directions before the Thunder begins, as also during the Tempest; from this Appearance we presage the coming of Thunder. These arise from the Effervescency, when they meet with the fulmineous Exhalations, which expel and condense the scattered Vapours in

the Interstices of the Air, into thick and black Clouds; and when these are more compressed by the inflamed Thunder, they are thickened into hard Rain, which generally attends Thunder.

4. The Displosions of Thunder repel the Air from about them on all Sides, with great Violence and cause a Vacuity, into which the Air again rushes when it has recovered its Elasticity. Hence those various Winds and Storms, which usually accompany Thunder.

5. Men and other Animals are frequently killed by Thunder; either through Terror or dreadful Apprehensions which seize them; or they are suffocated by the Spirit of the burning Sulphur, which is a mortal Poison to all Animals; or that the Thunder causes a *Vacuum* in that Place, or at least leaves the Air in it too thin and rare for Respiration; or perhaps all these three Causes concur. Animals that are killed by Thunder, have sometimes deadly Wounds and Contusions, which are conspicuous, but the Cause of their Death is manifest.

6. It is not to be wondered at, that combustible Bodies are set on fire by Thunder; since Thunder is a Flame of fulmineous Matter. That it should melt Metals, that it should rend, beat down, pull up, and cleave Bodies of any Resistance. And since Exhalations are found to penetrate through Wood, Bricks, Walls, *&c.* it is plain that Thunder being much more subtile, may easily run through Roofs, Ceilings, Floors, *&c.* If we would know how far we are distant from the Place of

Explosion, this is easily done by what is said in Page 106.

Thunder and Thunder-claps purifie the Air of its noxious inflammable Exhalations; it moderates the Heat of the Atmosphere, and the Rain that falls at that Time, is thought to be more fertile than other Rain.

Earthquakes are produced by some such Matter as that of Thunder, kindling and taking Fire, in the Bowels of the Earth, where there is little or no Vent, which rushing backwards and forwards, affects the Earth as it were with Convulsions, and causes some Parts of it to shake.

Something resembling an Earthquake may be made by mixing 10 or 15 Pounds of Sulphur, and as much Filings of Iron, and making them into a Kind of Paste with common Water; this being buried under Ground, will in 8 or 10 Hours throw out a Flame, and cause the Earth about it to shake, to a considerable Distance.

Hence we may account for the Fires of Mount *Ætna*, *Vesuvius* and other *Vulcano's*; for it is not improbable that certain metalline and sulphureous Particles were set on Fire under these Mountains, which wanting Vent burst forth, and continue to burn so long as they are supplied with Nourishment. And from such like Causes proceeds the Heat of Bath-water, and other hot Springs.

What has been already said in Pages 102, 103 and 104, may suffice for *Airy-meteors* or *Winds*.

CHAP.

CHAP. IX.

The ELEMENTS *of* ASTRONOMY.

ASTRONOMY is that Science which explains the Motions, and *Phænomena* or Appearances, of the heavenly Bodies.

The *Copernican System of the Universe*, or that which is generally received, by the lateſt and moſt able *Aſtronomers*, ſuppoſes ſix opaque dark ſpherical Bodies called *Planets*, which have no immediate Light of their own, but what they borrow from the Sun, to perform their Periods round him at different Diſtances and in different Times: The Names of theſe Planets, and the Characters by which they are expreſſed are theſe, *Mercury* ☿, *Venus* ♀, the *Earth* ⊙, *Mars* ♂, *Jupiter* ♃, and *Saturn* ♄. Theſe all move round the Sun in Orbits which lie in Planes that have but a ſmall Inclination to each other, and theſe Planes cut one another in Lines, which paſs through the Center of the Sun; therefore a Spectator in the Center of the Sun will be in the Plane of each of their Orbits, and will ſee them revolving round him and performing their Periods from Weſt to Eaſt in their ſtated and appointed Times, according to the Order of the Letters ABCD, in ſuch a Manner as they are repreſented in *Fig* 77.

Where

Where the Sun is placed in the Center of all their Orbits, and next to him is the Planet *Mercury* ☿, which finiſhes his Courſe in 87 Days or about three Months: *Venus* ♀ being next in Order, performs her Period in 224 Days and 17 Hours, or in about 7½ Months; the Planet next in order beyond the Orbit of *Venus* is the *Earth* ⊙, which performs its Circuit in 365 Days, 5 Hours, 49 Minutes, or in a Year: Next to the Earth is *Mars* ♂ who takes 686 Days and 23 Hours or about 2 Years to compleat his Circulation; then in an Orbit vaſtly extended beyond *Mars*, moves *Jupiter* ♃ who compleats his Period in 4322 Days, 12 Hours, or in about 12 Years; and laſtly, *Saturn* ♄ which is very far beyond Jupiter, compleats his Revolution in 10759 Days and 7 Hours, or in about 30 Years. Their real Diſtances from the Sun are nearly expreſſed in the Scheme.

This was the ancient Syſtem which was introduced into *Greece* by *Pythagoras* and his Diſciples, who had learned it from the wiſe Men of the Eaſt. 'Tis true, the *Ptolemaic Syſtem* which ſuppoſes the Earth immoveable, and the heavenly Bodies to revolve about it, was embraced by the Vulgar and illiterate Part of Mankind, yet the Philoſophers ſtill retained the true Syſtem; till *Ariſtotle* and ſome of his followers, not being aquainted with true Philoſophy, gave way to the vulgar Opinion that prevailed in favour of the *Ptolemaic Syſtem*: So that the ancient Syſtem became quite neglected till the Time of *Nicalaus Copernicus*, who by ſolid Reaſons and Arguments, reſtored it to a more flouriſhing State than ever, from the

Jaws

Jaws of Death, and perpetual Oblivion: Whence this Syſtem is called the *Copernican Syſtem.*

Theſe before mentioned Planets *Mercury, Venus,* the *Earth, Mars, Jupiter* and *Saturn*, are called *Primary Planets*, being firſt diſcovered and reſpecting the Sun as their Center; and of theſe *Mars, Jupiter* and *Saturn* are called *Superior Planets*, becauſe their Orbits are ſuperior to, or beyond the Orbit of the Earth; but *Mercury* and *Venus* are called *Inferior Planets*, becauſe their Orbits are inferior to the Earths Orbit, or between it and the Sun.

After the Invention of Teleſcopes, the Secondary Planets, with many other unthought Appearances, were obſerved by *Aſtronomers*, which wonderfully enlarged the ancient Syſtem, and confirmed it by invincible Demonſtrations.

Thus it was that the *Secondary Planets, Moons*, or *Satellites of Saturn*, and *Jupiter* were found always to attend and revolve about their Primaries, and to reſpect them as their Centers, as they are carried about the Sun, juſt as the Moon which attends and revolves about the Earth, reſpects it in its annual Revolution about the Sun, in about 27 Days and 7 Hours.

Saturn is accompanied with no leſs than five Satellites or Attendants, which at different Diſtances move round him in different Times: The Diſtances of theſe Bodies from *Saturn*, and their periodical Times are as follow. That which is innermoſt or neareſt to *Saturn* is $4\frac{3}{8}$ of his Semidiameters from him, and compleats its Revolution in 1 Day 21 Hours; the next is $5\frac{3}{5}$ of *Saturn's* Semidiameters

Semidiameters diſtant from the Center, and deſcribes its Orbit in two Days and 17 Hours; the third is at the Diſtance of 8 Semidiameters and finiſhes its Revolution in 4 Days 13 Hours; the fourth is at the Diſtance of 18 Semidiameters from *Saturn*, and finiſhes its Period in 15 Days 22 Hours; and the fifth and outermoſt is at the Diſtance of 54 Semidiameters, and finiſhes it's Courſe in 79 Days 8 Hours.

Jupiter has four *Satellites*, which move round him at different Diſtances, and in different Times; thus the firſt, or that which is next to *Jupiter* is at $2\frac{5}{6}$ of his own Diameters from his Center, and deſcribes it's Orbit in 1 Day 18 Hours; the ſecond is at the Diſtance of $4\frac{1}{2}$ Diameters, and performs it's Period in 3 Days and 13 Hours; the third is at the Diſtance of $7\frac{1}{6}$ Diameters, and performs it's Circuit in 7 Days 4 Hours; and the fourth and laſt is at the Diſtance of $12\frac{2}{3}$ Diameters, and compleats it's Revolution in 16 Days 18 Hours.

Beſides theſe Attendants, *Saturn* is peculiarly ornamented with a Ring which ſurrounds his Middle, without touching his Body, the Diameter of which is more than double that of his Body, and though the thickneſs of this Ring be but ſmall, yet the Breadth thereof takes up half the Space that is between it's outward Surface and the Body of *Saturn*; the Reſt of the Space remaining void; ſo that ſometimes we can ſee the Heavens between the Ring and the Body.

Galileus, a noble *Italian* Philoſopher, who was the firſt Inventor of Teleſcopes, was by their Help, the firſt that obſerved the *Satellites* of *Jupiter*, and called them *Medician Stars*, in honour to the Dukes of *Tuſcany* of that Name, and Mr. *Coſſini* the *French* King's *Aſtronomer*, firſt reached all the reſt that have been ſince diſcovered.

Far beyond theſe *Planets* the Heavens are decorated and beſpangled with a vaſt Multitude of fixed Stars, which are ſo called, becauſe they always keep at the ſame Diſtance from each other: The *fixed Stars* are ſuppoſed to be of the ſame Matter with the Sun, and to be made for the ſame Purpoſes; that is, that each of them is the Center to a Syſtem of Planets, which move round it; and of Courſe, that the Number of Syſtems, which are contained in the Heavens, are infinitely more in Number than it is poſſible for us to conceive.

The foregoing Syſtem proved to be the true Syſtem.

The firſt Thing that ſeems neceſſary to be proved is, that the inferior Planets *Mercury* and *Venus* revolve about the Sun, and that they are contained within the Orbit of the *Earth.*

Fig. 78. Let S repreſent the Sun, E the Earth, and let NGFH repreſent the Orbit of *Venus*; if *Venus* be at F, ſhe will appear to a Spectator on the Earth, to have a full round ſhining Face; becauſe that half of her which is illuminated by the Sun's Rays, is turned to the Earth; and therefore when *Venus* appears full, ſhe muſt neceſſarily be beyond, or above the Sun. When *Venus* is at N, her illuminated Side being neceſſarily towards the Sun, leaves the darkened Side next the Earth,

and

and then ſhe diſappears; and therefore when *Venus* diſappears ſhe muſt be between the Sun and the Earth, or the Sun muſt be beyond or above her; When *Venus* is at H near the Place of her Change, ſhe will appear like an horned Moon, and when ſhe is at G, ſhe will appear to have a Gibbous or humped Form; in ſhort *Venus* in one Revolution round her Orbit, will aſſume all the *Phaſes* of the Moon.

Mr. *Horrox* in the Year 1639 with his Teleſcope, obſerved *Venus* upon the Diſk or Face of the Sun; and the *Phaſes* of *Venus* may eaſily be ſeen by help of a Teleſcope.

Since therefore *Venus* has thoſe Appearances, that is, ſince ſhe has a ſuperior Conjunction with the Sun at F, an inferior Conjunction with him at N, ſince ſhe is, horned at H and Gibbous at G, ſhe muſt neceſſarily move round the Sun, and the Earth muſt be withoutſide of her Orbit; for were the Earth withinſide of her Orbit, her Appearances would be very different from what they really are, for ſhe would then never appear horned.

Beſides *Venus* is obſerved to keep always near the Sun, for ſhe is never found to be above 45 Degrees from him; ſo that ſhe never comes in Oppoſition to the Sun, or to be ſeen in the *Eaſt*, when the Sun is in the *Weſt*; nay ſhe can never arrive at a quartile Aſpect with him, or to have one fourth Part of the Heavens between them, which muſt neceſſarily happen if ſhe moved round the Earth, either in a longer or ſhorter Time than the Sun.

Mercury is obſerved to keep nearer the Sun than *Venus*, and never to recede from him ſo much as ſhe does; from his Proximity to the Sun, he is generally hid in the Sun's Rays, ſo that he is to be but ſeldom ſeen; he has been obſerved ſince the Invention of Teleſcopes, to appear like a Spot on the Suns Diſk. The extraordinary Brightneſs by which *Mercury* out-ſhines all the Planets, is a ſtrong Confirmation that he is nearer the Sun than they; for the nearer any Body is to the Sun, the more it muſt be illuſtrated.

Hence it is evident that *Mercury* moves round the Sun in an Orbit which is included within the Orbit of *Venus*.

Having now ſhewn that *Mercury* and *Venus* revolve about the Sun, and that they are contained within the Orbit of the Earth; we will next proceed to prove that the ſuperior Planets *Mars*, *Jupiter* and *Saturn* revolve alſo round the Sun, and that the Earth's Orbit is contained within the Orbit of *Mars*.

Fig. 79. Let S repreſent the Sun, E the Earth, and the Circle ABCD the Orbit of *Mars*; it is plain that when *Mars* is at A or at C, that his enlightened Hemiſphere is turned towards the Earth, and ſo he muſt ſhine with a full Face, upon the Inhabitants of the Earth; but at B and at D he will appear a little Gibbous or not quite full. Beſides when *Mars* is ſeen at C or in Oppoſition to the Earth, he appears to be almoſt ſeven Times larger in Diameter than when he is at A or in Conjunction with the Sun, and therefore he muſt be almoſt ſeven Times nearer the Earth in one Poſition

Position than in the other: Hence it is plain, that not only the Earth lies within the Orbit of *Mars*, but that it is far removed from the Center of his Orbit; therefore it cannot respect the Earth as a Center, but the Sun; for by this Hypothesis only, the Phænomena of *Mars* can be accounted for.

In the same Manner we account for the Appearances of *Jupiter* and *Saturn*, tho' the Proportion of the Difference of the Distances in *Jupiter* between the Earth, and he when in Opposition, is not so great as between *Mars* and the Earth, when they are also in Opposition; now did *Mars* as well as *Jupiter* and *Saturn* respect the Earth as a Center, they would seem to move uniformly and regularly round their Orbits; but they do not seem to move regularly, but to be sometimes slow in their Motion, at other Times quicker, and sometimes to stand still, and at other Times to move backwards, which could never happen, if they respected the Earth as a Center, as will be more fully and particularly explained hereafter; but upon supposing or making the Sun their Center, all these Phænomena can readily be accounted for.

All that now remains to be proved is, that the Earth moves round the Sun, as the rest have been proved to do.

We have demonstrated that the Earth is without the Orbit of *Venus*, and within that of *Mars*; from whence it will follow, that the Earth revolves about the Sun; for if it stood still, seeing it lies within the Orbits of the superior Planets *Mars*, *Jupiter* and *Saturn*, their Motions might appear to be unequal and irregular, but they

would

would never appear to move backwards, or to ſtand ſtill; which may be eaſily conceived by the help of the Scheme. And as the Earth lies between *Venus* and *Mars*, ſo is its Period round the Sun is alſo between the Periods of *Venus* and *Mars*, as being greater than the one and leſs than the other; whence we have Reaſon to conclude that the Earth moves round the Sun.

Common Obſervations convince us, that either the Earth moves about the Sun, or the Sun about the Earth, in ſuch a Manner as to *deſcribe equal Areas in equal Times*: But Sir ISAAC NEWTON has demonſtrated, that whenever Bodies are regulated by that Law, the one muſt gravitate the other; and therefore if the Sun in its Motion, gravitates the Earth, Action and Reaction being equal and contrary, the Earth muſt alſo gravitate the Sun: He has alſo demonſtrated that when two Bodies gravitate each other, without directly approaching each other in Right Lines, they muſt both of them move round their common Center of Gravity; therefore the Sun and Earth, turn round their common Center of Gravity. But the Earth being only as a Point when compared to the Sun, their common Center of Gravity will not only fall within the Suns Center, but very near it: The Earth therefore turns round a Point, that is within the Body of the Sun, and therefore turns round the Sun. This phyſical Argument is looked upon to be unanſwerable.

By comparing the Periods of the Planets, and their Diſtances from the Sun to each other we find, that the nearer any Planet is to the Sun the

ſooner

ſooner does it revolve through it's Orbit, and it's Motion is the quicker; this Obſervation no doubt, ſet the ſagacious *Kepler* upon inveſtigating his great Law of Nature, concerning the primary Planets, viz. *That the Squares of their periodical Times, are as the Cubes of their Diſtances from the Sun*; and though he found this Law to obtain in the primary Planets only, yet *Aſtronomers* found that the ſecondary Planets were regulated in their Periods and Diſtances from the primary ones they reſpected, by the ſame immutable Law.

It is not eaſy to conceive how *Kepler* hit upon this Law; for though he diſcovered it to obtain, yet he was unable to demon ſtrate it's proper Cauſe, or to deduce the phyſical neceſſity of ſuch a Law; this Taſk was reſerved for the great Sir ISAAC NEWTON, who has demonſtrated, that without a total Subverſion of the Laws of Nature, no other Rule could take Place.

Were the Sun to revolve about the Earth, this univerſal Law would thereby be violated, the Harmony and Proportion of the Motions deſtroyed, and the whole Frame of the Earth be rendered an Heap of Confuſion and Diſorder; but by the Earth's Motion round the Sun, a perfect Harmony is preſerved through the whole Frame of Nature.

Of the *Rotation* of the *Sun* and *Planets* round their *Axes*.

If the *Sun* were equally bright in all it's Parts, it would be impoſſible to perceive that it had any

any Motion round its *Axis*; but from the Motion of certain black Spots that are on his Disk or Face, the Rotation round his *Axis*, has been discovered to be performed in 25 Days; thus a certain Spot has been observed to appear on his western Margin, and by Degrees to creep near the middle or center of the Disk, and so on, to the eastern Margin, where it has set or disappeared in 12½ Days, and in 12½ Days more, the Spot has been found again to appear on its western Limb.

If the Motion of the solar Spots from *West* to *East*, seemed to describe right Lines, we might conclude that the *Sun*'s *Axis* would be perpendicular to the Plane of the *Earth*'s *Orbit*, which is called the Plane of the *Ecliptic*: Now since the Spots do not seem to describe right, but curved Lines, therefore the *Sun*'s *Axis* is not perpendicular to the *Plane of the Ecliptic*, but deviates from a Perpendicular thereto, in an Angle of about *seven* Degrees.

Jupiter, *Mars* and *Venus* have also remarkable Spots upon them, when looked at through a Telescope; and it is by the Motions of these Spots, as with those of the Sun, we conclude that they revolve round their *Axes*: By this Means *Venus* is found to perform her Revolution about her *Axis* in 23 Hours: *Mars* performs his Rotation about his *Axis* in 24 Hours and 40 Minutes. The *Earth* in a Day, which we are confirmed in, by the apparent Revolution of the fixed *Stars* about it in that Time.

Jupiter, besides having many Spots on his Disk, seems to be circumscribed with certain Zones,

Belts,

Belts, or Girdles, which are parallel to each other; yet their Diſtances from each other are found ſometimes to recede, and at other Times to approach. In the Year 1665 Mr. *Caſſini* diſcovered a large Spot on the Diſk of *Jupiter*, by which he found that *Jupiter* revolved round his *Axis* in nine Hours and 56 Minutes, or nearly in 10 Hours.

Whether either *Mercury*, or *Saturn* revolve round their *Axes* is uncertain; becauſe the former is ſo hid by the Sun's Rays, and the latter is ſo remote, that the Spots if any, upon either, are not to be diſcovered: Yet we may probably conclude, that they as well as the other Planets, move round their *Axes*, in order that all Parts of their Surface may be cheriſhed with the *Sun's* Rays.

Of the *annual* and *diurnal Motions* of the *Earth*, whereby the *Seaſons* of the *Year*, the *Viciſſitudes* of *Day* and *Night*, and the reſt of the celeſtial *Phænomena*, which ariſe from the apparent Motion of the *Sun*, are fully explained.

Having taken a curſory View of the *Univerſe*, it will here be neceſſary to conſider the *Earth's* Motion more particularly.

Fig. 80. Let S repreſent the *Sun*, ABCD the Orbit of the *Earth*, Let the Surface of the Paper repreſent the *Plane of the Ecliptic*, or that Plane on which the *Earth* moves, and let ♈, ♋, ♎, ♑, be the Heaven of the fixed *Stars*; then if we ſuppoſe a Spectator to be placed in S the Center of the

Sun, and thence to view the Earth in the Point A of its Orbit, it is manifeſt that it muſt appear to him to be at the fixed *Star* ♈; and while the Earth is moving from the Point A to the Point B of its Orbit, that it muſt appear to him to have moved through the fixed *Stars* ♈ ♉ ♊ and that it is now arrived at the *Star* ♋; and while it is moving from B to C, that it muſt appear to have paſſed by the fixed *Stars* ♋ ♌ ♍ and ſo to ♎; in moving from C to D, it ſeems to paſs by ♎ ♏ ♐ and ſo to ♑; and in moving from D to A, it ſeems to paſs by ♑ ♒ ♓ and ſo to ♈.

Now let the Spectator be removed from the *Sun* to the *Earth*; then its plain when the *Earth* is in the Point A of its Orbit, that the Obſerver will ſee the *Sun* S in the oppoſite Point of the Heavens at the fixed *Star* ♎; and that while the *Earth* is moving in it's Orbit from A to B, that the *Sun* will appear to have moved from ♎ through ♏ and ♐ and ſo to ♑; alſo while the *Earth* is moving from B to C, the *Sun* will appear to have moved from ♑ through ♒ and ♓ and ſo to ♈; and in like Manner while the *Earth* moves from C to D and ſo to A, the *Sun* will appear to have moved thro' the *Stars* ♈ ♉ ♊ ♋ ♌ ♍ and ſo to ♎. Therefore the *Sun* to an Inhabitant of the *Earth*, will appear to paſs over the ſame fixed *Stars*, and in the ſame Order from *Weſt* to *Eaſt*, as the *Earth* muſt appear to have paſſed over if viewed from the *Sun*.

Hence ariſes the apparent Motion of the *Sun* from *Weſt* to *Eaſt*; thus, if a *Star* be found to riſe with the *Sun*, a few days after it will riſe be-

fore

fore the *Sun*; and a *Star* which is near the *Sun*'s Path will be found to be a little above the Horizon after *Sun-ſetting*, but in ſome Time after, it will ſet with the *Sun*.

In like Manner if the *Sun* were viewed from any of the other Planets, it would ſeem to move from *Weſt* to *Eaſt*, and to deſcribe the ſame Orbit in the Heavens, or to paſs by the ſame fixed *Stars*, that the Planet would appear to do to an Obſerver in the *Sun*.

If the Plane of the *Earth*'s Orbit ABCD be conceived to extend to the Heavens, it will there lay out the *Ecliptic* ♈ ♋ ♎ ♑ or that Circle which the *Sun* appears to deſcribe in a Year if viewed from the *Earth*, or that the *Earth* would appear to deſcribe if viewed from the *Sun*.

Aſtronomers, have divided this Circle into 12 equal Parts called Signs, which they have named after the Conſtellations which were then near them; ſo that each Sign contains the 12th Part of 360, or 30 Degrees.

The Characters and Names by which the Signs are expreſſed, are theſe.

♈	♉	♊	♋	♌	♍	♎
Aries,	*Taurus*,	*Gemini*,	*Cancer*,	*Leo*,	*Virgo*,	*Libra*,

♏	♐	♑	♒	♓
Scorpio,	*Sagittarius*,	*Capricornus*,	*Aquarius*,	*Piſces*.

Beſides this *annual* Motion of the *Earth*, it has alſo a *diurnal* Motion, or one in 24 Hours from *Weſt* to *Eaſt*: The two Points where the *Axis* meets the Surface of the *Earth* are called it's *Poles*; and if the *Axis* be continued to the Heavens it will there point out the *Celeſtial Poles*: Every Point on the *Earth*'s Surface except the *Poles* will deſcribe a Circle; and that Circle which is deſcibed by a Point that is equally diſtant from the *Poles*, is a great Circle called the *Equator* or *Equinoctial Circle*; but thoſe Circles which are deſcribed by any other Points nearer to the *Poles* are leſſer Circles, and are called *Parallels of Latitude.*

If a Plane, which touches that Part of the *Earth* where a Spectator ſtands, be continued on all Sides to the Heavens; it will there mark out a Circle that is called the *Senſible Horizon.* which will ſeperate the Viſible from the Inviſible part of the Heavens; but if a Plane paſſing through the *Earth*'s Center parallel to the ſenſible Horizon, be continued on all Sides to the Heavens, it will there mark out a Circle which is called the *Rational Horizon.* But though theſe two Circles are diſtant from each other by the *Earth*'s Semidiameter, yet in the Heavens they may be ſaid to coincide, in as much as, that Semidiameter is but a Point in Compariſon of the great Diſtance of the Heavens.

Since the *Earth* turns upon it's *Axis* from *Weſt* to *Eaſt*, a Spectator on it's Surface, muſt be carried the ſame way; therefore all heavenly Bodies which are beneath the eaſtern Edge of the *Horizon* will become Viſible in as much as the Plane of the *Horizon* ſubſides, being carried to the Eaſtward with the Obſerver: and all heavenly Bodies, which are ſeen above the weſtern Edge of the

Horizon,

Horizon, will become inviſible, becauſe that part of the plane of the *Horizon* will Riſe as the Earth is carried Eaſtwardly. Hence it is that all the Heavenly Bodies ſeem to move from *Eaſt* to *Weſt* and to deſcribe a greater or a leſſer Circle, except theſe Points that are the Celeſtial Poles.

If the Plane of the *Earth's Equator* coincided with the Plane of the *Ecliptic*, then the *Earth's Axis* would be perpendicular to both Planes, and in that Caſe the *Sun*'s Rays would enlighten one half of the *Earth* from Pole to Pole, while the other half would remain in darkneſs. ſo that one half of each parallel Circle on the *Earth*'s Surface muſt be always enlightened, and the other half muſt remain dark; and therefore by the *Earth*'s Verticity, all it's Inhabitants would have a conſtant Equallity of Day and Night, or 12 Hours each; and at the *Poles* they would have half the *Sun*'s Body conſtantly appearing to move round their *Horizon*: Seeing then that the Days and Nights are not equal, the *Axis* of the *Earth* is not perpendicular to the Plane of the *Ecliptic*, but it is inclined thereto, at an Angle of 66½ Degrees, and conſequently the Plane of the *Equator* muſt be inclined to that of the *Ecliptic*, at an Angle of 23½ Degrees, the Complement of the former. The *Earth*'s *Axis* alſo in it's annual Motion round the *Sun* keeps always parallel to it ſelf; that is, if a Line be drawn parallel to the *Axis* while it is in any one Poſition, the *Axis* will be always parallel to that Line in whatever Part of it's Orbit it be; at leaſt for a Year or two, the difference is inſenſible: And this muſt neceſſarily be, if the *Earth*

had

had no other Motion than it's annual *Progressive* one round the *Sun*, and its diurnal one round it's *Axis*.

Fig. 81. For let PEpQ be any spherical Body whose Center moves along the Line AB, and while it is at A let it's *Axis* Pp be inclined to the Line AB. Now it's plain if the Body by it's progressive Motion only, were carried to B, that it's *Axis* Pp will still be parallel to it's former Position, while at A; and if the same Body be supposed to move continually about it's *Axis*, though all the Parts of it's Surface except the *Poles* will change their Situations, yet the Inclination of the *Axis* can never be disturbed thereby.

Since the Plane of the *Equator* is inclined to that of the *Ecliptic* at an Angle of 23½ Degrees, they must cut one another in a Right Line, passing through the Centers of the *Sun* and *Earth*; which right Line or common Section will remain parallel to it self, because that the *Earth*'s *Axis* preserves a Parallelism, and that the same right Line is always inclined to the *Axis* of the *Earth* at the same Angle. And that Circle upon the *Earth*'s Surface which is made by the Intersection of the two Planes, will point out the Path of the *Sun* in his annual Motion.

If a perpendicular Line be drawn from the Center of the *Sun* to the Plane of the *Ecliptic*, and if it be continued on both Sides to the Heavens; this Line will be the *Axis*, and it's Extremities will be the *Poles of the Ecliptic*.

That great Circle which passes through the celestial *Poles*, and the Points of Intersection of the *Equator* and *Ecliptic* is called the *Equinoctial*

Colure

Colure; and that other great Circle which is at right Angles with it, is called the *Solſtitial Colure*, and this will be found to paſs through thoſe Points where the *Equator* and *Ecliptic* are wideſt aſunder: The four Points in which theſe *Colures* cut the *Ecliptic*, are called the four *Cardinal Points*, becauſe when the *Sun* is ſeen in them, he determines the four Seaſons of the Year: The Points of Interſection of the *Equinoctial Colure* with the *Ecliptic*, are called *Equinoctial Points*; becauſe when the *Sun* is in either of them, all the Inhabitants of the *Earth* enjoy equal Day and Night: And the Points of Interſection of the *Solſtitial Colure* with the *Ecliptic*, are called *Solſtitial Points*; becauſe when the *Sun* is in either of them, he is then at his greateſt Diſtance from the *Equator*, and ſeems to ſtand before he begins to return again.

To explain the *Phænomena* or Appearances that ariſe from the *Earth*'s annual Motion round the *Sun*, we ſuppoſe the Spectator to be far removed without the *Earth*'s Orbit, ſo as to obſerve all thoſe Appearances which we here give a perſpective View of: Thus, *Fig.* 82. let S repreſent the *Sun*, ♈♋♎♑ the *Earth*'s Orbit on the Plane of the *Ecliptic*; through S let the Line ♈ *S* ♎ be drawn parallel to the common Interſection of the *Ecliptic* and *Equator*, and to it at right Angles, let the Line ♋ S ♑ be drawn; then it's plain, when the *Earth* is in the Point ♎, that the Line S♎ connecting the Centers of the *Sun* and *Earth* will coincide with the common Interſection of the *Ecliptic* and *Equator*, and ſo lie in the plane of the *Equator*, and therefore will be perpendicular

to

to the *Earth*'s *Axis*; but the ſame Line is perpendicular to the Circle that bounds Light and Darkneſs, and therefore the *Axis* of the *Earth* will be in the Plane of that Circle, and ſo it will paſs through the *Poles* of the *Earth*, and cut the *Equator* and all it's Parallels into equal Parts. Alſo the *Sun* will appear in the oppoſite Point of it's Orbit at ♈ or in ♎ S produced, that is, in the Plane of the *Equator*; and conſequently will deſcribe the *Celeſtial Equator* by it's apparent daily Motion. And ſince in this Poſition of the *Earth* the *Sun* will enlighten it from *Pole* to *Pole*, ſo by it's Verticity, all Perſons on it's Surface will enjoy equal Day and Night; and hence the Circle which the *Sun* ſeems to deſcribe, that Day is called the *Equinoctial* Circle.

The *Earth* by it's annual Motion being carried through the Signs ♏ ♐, the Line interſecting the Planes of the *Ecliptic* and *Equator*, remaining always parallel to it ſelf, cannot now paſs through the *Sun*; but when the *Earth* has arrived at ♑ it will make a right Angle with S♑, which connects the Centers of the *Sun* and *Earth*: And ſeeing the ſaid Line S♑ is not in the Plane of the *Equator*, but in that of the *Ecliptic*, the Angle P♑ S, which the *Axis* of the *Earth* Ps makes with it, will be an acute Angle of 66½ Degrees, or the like Number of Degrees that the *Earth's Axis* is inclined to the Plane of the *Ecliptic*. Let the Angle S♑B be a right Angle, then the Circle bounding Light and Darkneſs will paſs through B, and the Arch BP will be 23½ Degrees, the Complement of PC, or of the Angle P♑S. Through the Center ♑ let

let EQ be drawn perpendicular to the *Axis* Ps, and it will be in the Plane of the *Equator*; then if from equal Arches or Quadrants PE and BC, the common Arch PC be taken, there will remain CE equal to PB equal to 23½ Degrees. Make Ec equal to EC, and to the *Equator* through C and c, let the parallel Circles CD, cd be drawn; the firſt is called the *Tropic of Cancer*, and the other the *Tropic of Capricorn*, and the Circle in the Heavens which is concentric to CD is called the *Celeſtial Tropic of Cancer*, becauſe the Sun appears to be then in ♋. When the Earth is in this Situation, the Circle B♑a, bounding Light and Darkneſs, will paſs 23½ Degrees beyond the North Pole P, or as far as B, and conſequently the South Pole muſt be ſo far from a, in the darkened Hemiſphere: To the Equator let the parallel Circles BA, ab, be drawn through the Points B and a, and theſe are called *Polar Circles*; that towards the North is called the *Artic Circle*, and the other that is towards the South, is called the *Antartic Circle.*

Now ſince the *Earth* moves about its *Axis* Ps, it is plain that thoſe Inhabitants of it, who live within the *Artic Circle* AB, will at that Time, have continual Day; and on the contrary, thoſe Inhabitants, if any, who live within the *Antartic Circle* ab, will then have continual Night. Alſo that ſuch as live under the *Tropic of Cancer*, or on the Parallel CD, will have the Sun Vertical to them, when any particular Place in that Parallel comes to the Meridian at C; and ſeeing all the Parallels between the *Equator* and the *Artic Circle* are cut by the Circle bounding Light and Darkneſs, into unequal Portions, leaving a greater Portion of every Parallel in the Light, than in the Darkneſs; therefore the Inhabitants in the *Northern Hemiſphere* will then have their Days at the longeſt, and to them the Seaſon of the Year will be Summer; but on the contrary, thoſe in the *Southern Hemiſphere*, will have their Nights at the longeſt, and to them it will be the Winter Seaſon; and it is eaſy to conceive that according as one Place is more on the North-ſide of the *Equator* than another, that the Day will be longer in the former than in the latter Place; and ſeeing that none of the Parallels, but the *Equator* only, is cut equally by the Circle bounding Light and Darkneſs, therefore it is only thoſe Inhabitants who live in the *Equator*, that have their Days and Nights equal throughout the Year.

The *Earth* being ſtill carried forward in its Orbit from ♑ by ♒ and ♓ to ♈, in which Time the *Sun* will ſeem to move through the Signs ♋ ♌ ♍ and by Degrees to return again towards the *Equator*; and the *Earth* being arrived at ♈, the *Sun* will appear to be at ♎; where the common Interſection of the *Ecliptic* and *Equator* ſtill remaining parallel to the Line ♎S♈, will paſs through the Center of the *Sun*, and then the *Sun* will appear in the celeſtial *Equator*. And therefore the Day and Night will again be equal to all the Inhabitants of the *Earth*, in the ſame Way as when the *Earth* was at ♎, for in this Situation the Circle bounding Light and Darkneſs, will again paſs through the two *Poles*.

The

The *Earth* moving on through the Signs ♈, ♉, ♊, the *Sun* will appear to move through ♎, ♏, ♐, gradually declining from the *Equator* towards the *South*; ſo that when the *Earth* has arrived at ♋, the *Sun* will appear to be at ♑. And becauſe the *Axis* of the *Earth* preſerves it's Paralleliſm, the *Earth* will have the ſame Appearance in reſpect to the *Sun*, that it had when it was in ♑; but with this Difference, that the Tract within the *Polar* Circle AB, which was in continual Light when the *Earth* was at ♑, is by it's being remov'd to ♋ in continual Darkneſs, and all that Part within the *Polar* Circle ab, that before was in continual Darkneſs, is now in continual Light; alſo ſuch as live under the *Tropic of Capricorn* or on the Parallel cd will have the *Sun* Vertical to them, when any particular Place in that parallel, comes to the Meridian at d; and thoſe in the *Southern Hemiſphere* will have their Days at the longeſt, but thoſe in the *Northern Hemiſphere* will have their Nights at the longeſt; therefore it will then be Summer to the former, and Winter to the latter: And the further any Place is to the South, the Day will be longer, becauſe the Circle bounding Light and Darkneſs, leaves a greater Portion of every Parallel in the *Southern Hemiſphere* in Light, than in Darkneſs; and ſince the *Equator* is only biſected by that Circle, the Inhabitants who live in it, are thoſe that only have their Days and Nights equal as before.

All we have ſaid will be much more evident than it is poſſible for Words to expreſs, from a bare View of the *Orrery*, by a *Lamp* being fixed as the *Sun* in it's Center; or in Lieu thereof, if a Candle be lighted in a dark Room, and fixed in the Center of a round Table, and if we take a ſmall Globe of Ivory, of about one or two Inches in Diameter, on which the *Poles*, *Tropics*, *Polar Circles*, and the *Equator* are marked and laid out, and if we carry it with it's *Axis* inclined to the *Table*, or to the Plane of the *Ecliptic* in an Angle of $66\frac{1}{2}$ Degrees; the *Phænomena* before ſet forth, will very abundantly appear.

By the ſame Way of reaſoning, the *Phænomena* ariſing from the Circuit of any other *Planet* that turns round it's *Axis*, may be eaſily accounted for.

If a Line paſſing through the Center of the *Sun* perpendicular to the Plane of the *Ecliptic*, be continued to the Heavens both Ways, it will there point out the *Cæleſtial Poles* as before. Now if great Circles are ſuppoſed to paſs through theſe *Poles* by every *Star* or *Planet*, theſe Circles which are called *Secondaries of the Ecliptic*, will be all perpendicular to the Plane of the *Ecliptic*; and on them is meaſured the *Latitude* of any heavenly Body, or it's Diſtance from the Plane of the *Ecliptic*, which will be *North* or *South*, as it lies on the one or the other Side of the *Ecliptic*: Alſo an Arch of the *Ecliptic*, which is contained between the Point ♈, and the *Secondary* paſſing through the Body; will be the *Longitude* of that Body: And if there be Circles ſuppoſed to paſs through every Place, or Spot on the *Earth's* Surface from *Pole* to *Pole*, ſuch Circles are called *Meridians*: Upon the one of theſe Circles that paſſes through any given Place,

Place, is the *Latitude* of that Place meaſured from the *Equator*; and its *Longitude* is an Arch of the *Equator*, intercepted ſometimes between a *Meridian* paſſing through any particular *Metropolis*, from whence their Inhabitants are pleaſed to count their *Longitude*, or ſometimes from the *Meridian* paſſing through the Point *Aries* , where the *Equator* and *Ecliptic* firſt interſect each other, and the *Meridian* paſſing through the Place.

Fig. 83. Since the *Earth*'s *Axis* retains its Parallelifm, it is plain, that when the *Earth* is at different Points in its Orbit, its *Axis* muſt point towards different fixed *Stars*; thus if the *Earth* be at A, and it's *Axis* points to the fixed *Star* E, when it has arrived to the oppoſite Part of it's Orbit at B, it's *Axis* will not point to the ſame fixed *Star* E, but to ſome other as F, and the Angle EBF which we ſuppoſe poſſible to be meaſured though not very accurately, will be equal to the Angle AEB, and this Angle under which the Diameter of the great Orbit of the *Earth* is ſeen from the fixed *Star* E, is called *the Parallax of the great Orbit*. Now were there Inſtruments nice enough to meaſure this Angle with great certainty, as in Effect there are not; we could eaſily find the Diſtance of the *Star* E from the *Earth*; for we have in the Triangle ABE, the Angle EAB the viſible Diſtance of the *Sun* from the *Pole*, the Angle of the *Parallax of the great Orbit* E, and AB the Diameter of the great *Orbit* given, and thence by *Trigonometry* AE or EB may be eaſily found. Now if we ſuppoſe the *Parallax of the great Orbit* with Mr. *Flamſtead* to be 42 Seconds,

and

and if an Error be committed in Obſervation of 10 or 12 Seconds, and no Man can be ſure he has not committed that Error; the Diſtance of the fixed *Star* thereby remains uncertain.

Of the Preceſſion of the Equinoxes.

Having hitherto ſuppoſed the Paralleliſm of the *Earth's Axis* as immutable, and that the *Earth* had been affected with no other Motions, than it's annual one round the *Sun*, and its diurnal one round it's *Axis.* Yet *Aſtronomers* from many Years Obſervations have found, that the *Axis* of the *Earth* deviated about one Degree to the *Weſt* in 72 Years from it's Paralleliſm, but that it ſtill preſerves its Inclination of 66½ Degrees to the Plane of the *Ecliptic*; and though this ſlow Mutation of the *Earth's Axis* can by no Means diſturb the *Phænomena* already explained in a few Years, yet in a *Century* or two it becomes very remarkable. Thus,

Fig. 84. Let the Line DCH repreſent a Portion of the *Earth*'s Orbit; from the Center of the *Earth* C, let the Line CE be drawn perpendicular to the Plane of the *Ecliptic* meeting the concave Surface of the Heavens in E: This Line CE will be the *Axis* of the *Ecliptic*, and E the *Pole* of it. Let the *Axis* of the *Earth* Cp be continued to the Heavens; then P will be the *Pole* about which the Heavens will ſeem to revolve: Let a great Circle EPA paſs through the *Poles* E and P and be continued to meet the *Ecliptic* in A, it will cut it perpendicularly, and the Arch PA will be the Meaſure of the Angle PCH, which is the Inclination

tion of the *Earths Axis* to the Plane of the *Ecliptic*, that is, it will be 66½ Degrees, and therefore its Complement EP will be 23½ Degrees, and will be the Meaſure of the Angle ECP, that the *Axes* of the *Ecliptic* and *Equator* make with each other. Let then the *Pole* P or Line CP be carried Circularly from *Eaſt* to *Weſt* about the Center C, ſo as that it may conſtantly as it moves round, through PQFG, be inclined to the Plane of the *Ecliptic* in an Angle of 66½ Degrees; by this Means the *Axis* PC deſcribes the Convex Surface of a *Cone*, of which C is the *Vertex*, and the Point P the Circle of its Baſe, which Circle is not compleated in leſs than 25920 Years; after which Time, the Pole having left a *Star* at P, will again return to it; and this is truly the Nature of the Motion of the *Pole* backwards; for if it were not endued with this Motion, but that the *Axis* of the *Earth* retained the ſame Direction; the *Pole* of the Heavens would be found to be conſtantly in the Point P; but we find that *Pole* does as conſtantly change it's Place towards the *Weſt*, ſo that in 72 Years it will proceed one Degree Weſtwardly from its Situation at P to Q, and BQ will be 66½ Degrees, and thus by Degrees it will paſs through every Part of the Circle PQFGP, making PA, QB, FC, CG, equally inclining to the Plane of the *Ecliptic* in an Angle of 66½ Degrees. Hence in half the Period of the Polar Revolution, or whilſt the *Pole* paſſes from P to G, a *Star* which had been at P will in 12960 Years be 47 or twice 23½ Degrees diſtant from it.

Since

Since the *Earth's Axis* changes its Situation by moving backwards; this backward Motion muſt be communicated to the Whole, and occaſion every Point on the *Earths* Surface, alſo to move backwards or towards the Weſt: The *Equinoctial* Points of the Earth, do therefore move continually backwards or towards the Weſt, and thereby will occaſion the Celeſtial Equinoctial Points with which they coincided, to proceed forward in *Conſequentia*, or according to the Order of the *Signs* or fixed *Stars* towards the Eaſt, and this is called the *Preceſſion* of the *Equinoxes*.

Hence it is that the Stars which compoſe Conſtellations have changed their Places ſince they were obſerved by the firſt *Aſtronomers*; thus, the Conſtellation of the Ram, which in the Time of *Hipparchus*, was nearly oppoſite to the Equinoctial Point *Aries* ♈, is now removed a whole Sign towards the *Eaſt*, and is marked upon Celeſtial Globes to be in the Sign or Portion of the *Ecliptic*, *Taurus* ♉; in like manner, *Taurus* now reſides in *Gemini* ♊, *Gemini* in *Cancer* ♋; and ſo every Conſtellation has changed its Place ſince the firſt Obſervation: But though the Conſtellations or Images have left their Places, yet the twelve Portions of the *Ecliptic* which are called *Dodecatimoria* ſtill retain the ſame Names, which they had in the Time of *Hipparchus*: And to diſtinguiſh them from *Starry* Signs or Conſtellations, they are called *Anaſtrous* Signs, or Signs without *Stars*.

The phyſical Cauſe for the Preceſſion of the Equinoxes was unknown, untill Sir ISAAC NEWTON diſcovered that it aroſe from the oblate Spheriodical Figure

Figure of the *Earth*; and that the Figure of the *Earth* ariſes from the Rotation of the *Earth* round it's Axis.

Though the Period of the *Earth's* annual Motion, is always performed in the ſame Time; yet the *Earth* in paſſing along its Orbit does not move uniformly; for if it did, the *Sun* would appear to move alſo uniformly; but the *Suns* apparent Motion being irregular, the *Earth's* Motion muſt be ſo too; for he is found to be eight Days longer paſſing through the Northern Signs, than through the Southern ones, and therefore the Summer is eight Days longer than the Winter: And the *Sun's* apparent Diameter in Winter being greater than in Summer; it therefore follows, that the *Sun* muſt be farther from us in Summer than in Winter. In the Winter it is ſeen under an Angle of 32 Minutes 47 Seconds, and in Summer, under an Angle of 31 Minutes and 40 Seconds.

From hence it is plain, that the *Earth's* Orbit is not a Circle with the *Sun* in it's Center: And the great *Kepler* from the Obſervations of the induſtrious *Tycho Brahe* by unanſwerable Reaſons has ſhewn that the Orbit, of not only the *Earth*, but that of every Planet muſt be an *Ellipſe* and not a Circle; and that the *Sun* is not in the Center of the Elliptical Orbit, but in one of the *Foci* or Points upon which it is deſcribed, as at *S*. *Fig.* 85. The longeſt Diameter or the *Axis* of the Ellipſe AP is called the Line of the *Apſides*; the Point A is termed the higher *Apſis*, or *Aphelion*, being moſt diſtant from the *Sun*; and the neareſt

Point P to the *Sun*, is called the lower *Apſis* or *Perihelion*: The Diſtance ES between the Center of the Ellipſe and the Sun, is called the *Excentricity*: The Line ES drawn from the Extremity of the leſſer Diameter to the *Sun*, is called the *mean Diſtance* of the *Planet* from the *Sun*; which is equal to half the *Axis*; it exceeding the ſhorteſt Diſtance by as much as the longeſt Diſtance exceeds it.

Though the Planetary Orbits are Elliptical, yet they differ but little from Circles; for the Excentricity of the *Earths* Orbit SC is only 17 of ſuch parts, as the mean Diſtance SF is of 1000.

The *Planets* in revolving round their Orbits obſerve this immutable Law, that *they Deſcribe equal Areas in equal Times*; and becauſe their Orbits are Ellipſes the Arches deſcribed in equal Times will be unequal, in order that the Areas may be equal. Thus, if in a given Time a *Planet* moves from A to B, and thereby produces the Area ASB; in order that it may produce the Areas BSD, PSF each equal to ASB, BD muſt be greater than AB, and FB greater than either, or the Areas will be unequal; and theſe Arches will be nearly reciprocal to their Diſtances from the Sun. This Law is demonſtrated by the Sagacious *Kepler*, in his Commentaries on the Motion of the Planet *Mars*.

A *Planet* when at its *Aphelion* moves ſloweſt; but it's Motion becomes quicker daily from thence to its *Perihelion*, where it is quickeſt

of

of all; and from thence again to its *Aphelion* it moves every Day ſlower.

Having ſhewn that the *Earth* is removed farther from the *Sun* in Summer than in Winter; it will be neceſſary here to ſhew and explain the Cauſe of the Summer Seaſon, being warmer than the Winter one: Firſt then, the Force of the *Sun's* Rays is much ſtronger when they fall directly, than when they fall obliquely; now in the Winter, the Rays fall very obliquely upon the Earth, and their Power is thereby diminiſhed, for the Light being not ſo denſe, the fewer muſt the Rays be in any given Space; and of courſe the more they muſt be ſpread and ſcattered, and conſequently the Heat muſt be thereby leſſened. Beſides the *Sun* being much nearer the *Horizon* in the Winter than it is in the Summer, the Rays in the Winter paſs through a much greater Quantity of Atmoſphere than in the Summer, and are thereby more refracted and broke by the Reflections of ſo many Particles of Air; and this alſo is the Reaſon, that we can look at the *Sun* when it is in or near the *Horizon* without hurting our Eyes whereas when it riſes higher, we cannot look at it without being almoſt blinded.

Again, the longer any hard and ſolid Body is expoſed to the Fire, the hotter it grows. Now in the Summer we are heated by the *Sun*, about 16 Hours every Day, and have but 8 Hours of Night to cool, and in the Winter we are heated but 8 Hours, and cool 16; it therefore is plain, that there muſt be a great Difference of Heat and Cold in theſe two Seaſons.

Since the Power or Heat of the *Sun* is greateſt when its Rays fall upon us moſt directly or neareſt to a Perpendicular, it ſhould thence follow, that the Heat ſhould be greateſt when the *Sun* enters ♋ *Cancer*, or about the 20 of *June*, for then it is neareſt our Vertex, and lieth longeſt towards us; but we find it much warmer above a Month after, and warmeſt about the beginning of *Auguſt*, in the *Dog-Days*, though the *Sun* be removed above a whole Sign, from that Place, where he was moſt vertical.

Now to arrive at the true Cauſe of this Effect, it will be neceſſary to obſerve, that the Action of the *Sun's* Heat upon all Bodies, is not tranſient as it's Illumination, but permanent; So that a Body which is once heated, will retain that Heat for ſome Time after the *Sun* has left it, for the Particles of Heat being abſorbed by the Body, cannot at once diſengage themſelves from it, but will continue in it for ſome Time before they can fly off, and looſe their Force, or before the Body can cool; therefore if the heating Particles, which are daily received, exceed thoſe which fly off in the Night, the Body muſt continually encreaſe in Heat. And this is our preſent Caſe, for the Particles of Heat do daily encreaſe for ſome Time after the *Sun* has entered ♋ *Cancer*, ſince there are more entering into the *Earth*, in the Days than there are thrown off in the Night. Thus, let us ſuppoſe 100 Particles to be received in the Day, and 50 of theſe to be thrown off in the Night; there will then remain 50 to excite Heat: If then the next Day the *Sun* will impart 100 Particles,

of

of which one half of them are thrown off in the Night; in the beginning of the third Day, there will remain 100 Particles exciting Heat. In the fame Manner, fo long as there are more Particles of Heat emitted from the *Sun* upon the *Earth* in the Day, than can be diffipated or thrown off in the Night, the Heat muft conftantly encreafe and become more intenfe: But when the Days decreafe, and the Force of the *Sun's* Rays become weaker, there will be more Particles thrown off in the Night than there are received in the Day, and by that Means the Body will be heated lefs every Day, fo that the Earth and Air at length will become extreamly cool.

Of *the* Moon's Phafes *and* Motion.

The *Moon* as it was faid before, is a fecondary Planet which conftantly attends the *Earth* in its annual Motion round the *Sun*, defcribing its Orbit in 27 Days and 7 Hours; it is the moft fplendid of all the heavenly Bodies except the *Sun*, and if viewed from the *Sun*, would never be feen above 10 Minutes diftant from us.

The *Moon* puts on feveral Phafes or Appearances, and is conftantly changing its Figure, being fometimes Horned, then Half Full, afterwards Gibbous or Humped, then Full, again Gibbous, Half Full, and Horned: And thefe different Phafes are eafily accounted for, when we confider that fhe like the *Earth*, is an opaque fpherical Body, which only fhines by the Light fhe receives from the *Sun*, having always that half of her Body, which is next the *Sun*, enlightned while the reft remains involved in Darknefs; but the half which is vi-fible to us, is that which is oppofite to the *Sun*, and therefore according to her various Situations with refpect to the *Sun* and *Earth*, fhe will feem to undergo different Degrees of Illumination, having fometimes a greater, and at other Times a lefs Part of the enlightned Hemifphere turned towards the *Earth*, fometimes the whole, and at other Times no Part of her can be feen from the *Earth*. To explain which, *Fig*. 86. let S repre-fent the *Sun*, T the *Earth*, RTS a Part of the *Earth's* Orbit, which it defcribes in its annual Mo-tion round the *Sun* ABCDEFGH the Orbit of the *Moon*, in which it moves round the *Earth* from Weft to Eaft, PNOM the *Moons* Body, and it's Center L. Let the Centers of the *Sun* and *Moon* be joined by the Right Lines SL, and let MLN be a Plane paffing through the *Moons* Center per-pendicular to the Line SL; then this Plane will cut the *Moon* in a great Circle, which will be the Boundary of Light and Darknefs, which feperates the enlightned from the obfcure Side. In like Man-ner, if the Centers of the *Earth* and *Moon* be join-ed by the Line TL, which is perpendicular to the Plane PLO; that Plane will cut the *Moon* in a great Circle, called the *Circle of Vifion*, which will fepe-rate the Vifible from the Invifible Hemifphere of the *Moon*.

Hence 'tis plain, that if the *Moon* be at the Point A of it's Orbit, that the Circle of Vifion PLO, will coincide with the Circle MLN, which is the Boundary of Light and Darknefs, and fo the enlightned Hemifphere of the *Moon* will be

turned

turned towards the *Earth*, and then with reſpect to us it is called *Full-Moon*; when therefore the *Moon* is full, it muſt conſequently be in *Oppoſition* to the *Sun*, becauſe from the *Earth*, the *Sun* and *Moon* then appear in oppoſite Parts of the Heavens, the one ſetting when the other riſes. When the *Moon* comes to B, 'tis plain that the whole enlightned Diſk or Hemiſphere MPN, is not turned towards the *Earth*, there being a Part of it MP not to be ſeen by us; therefore the viſible illuminated Part, will be deficient of being a Circle, and will be *Gibbous*. When the *Moon* arrives at C, where the Angle CTS is a Right Angle, the Angle TCS will differ very little from being alſo a Right Angle, upon Account of the vaſt Diſtance of the *Sun* from the *Earth* and *Moon*, ſo that CS and TS may be looked upon as parallel; therefore the Circle of Viſion OP, will biſect the Boundary of Light and Darkneſs MN at Right Angles, and ſo half of the enlightned Hemiſphere will only be viſible to us, and then ſhe is called an *Half-Moon*, and is ſaid to be in a *Quadrate-Aſpect*, or to be in one of her *Quadratures*, or within a Quadrants Diſtance of the *Sun*. When the *Moon* has got to D, then only a ſmall Part PN of the enlightned Hemiſphere, is turned towards the *Earth*; and therefore becauſe the *Moon* is of a ſpherical Form, that viſible enlightned Part, will appear horned, with the Horns turned to the *Weſtward*. When the *Moon* arrives at E, the Circle Bounding Light and Darkneſs, will coincide with the Circle of Viſion, and then the *Moon* will diſapppear, having its darkned Hemiſphere turned

towards

towards the *Earth*; and when it is in this Situation it is ſaid to be in *Conjunction* with the *Sun*, and to be *New-Moon*. When the *Moon* advances to F, ſhe again aſſumes an horned Figure; but the Horns which before the *New-Moon* were turned to the *Weſtward*, are now turned to the *Eaſtward*. When the *Moon* arrives at G, ſhe is again in a *Quadrate-Aſpect*, or in one of her *Quadratures*, where ſhe will be an *Half-Moon*, and at H ſhe will be more than half full or *Gibbous*; but in A ſhe will again appear with a *full Face*.

As the *Moon* enlightens the *Earth* by its reflected Light from the *Sun*; ſo the *Earth* enlightens the *Moon* by its reflex Light: And becauſe the Surface of the *Earth* is above fifteen Times greater than that of the *Moon*, therefore the *Earth* may well be ſuppoſed to give the *Moon* a Light, which is fifteen Times greater than that it receives from it.

In *New-Moons* 'tis plain that the enlightned Hemiſphere of the *Earth* is fully turned towards the *Moon*, and will therefore at that Time illuminate the dark Side of the *Moon*; and then the *Lunarians* will have a full *Earth*, as we in a ſimilar Poſition have a *full Moon*. And hence it is that, a dim Light is obſerved in the old and new *Moons* whereby we ſee the reſt of the *Moon's* Body, beſides the bright Part which is horned. When the *Moon* is full, then the *Sun* and *Earth* will appear in *Conjunction* to it, and the *Lunarians* will then have a new *Earth*; after which the *Earth* will appear Horned to them. In ſhort the *Earth* will ſhew

the

the ſame Appearances to the Inhabitants of the *Moon*, as the *Moon* does to us.

Though as before, the *Moon* deſcribes its Orbit in 27 Days and 7 Hours called a *Periodic Month*, yet the Time it takes from one Conjuction to the next, will be nearly 29 Days 12 Hours, which is called a *Synodic Month*. Thus, Fig. 87. let S repreſent the *Sun*: T the *Earth*, AB a Part of the *Earth's* Orbit round the *Sun*, and ALDC the Orbit of the *Moon*: Let the *Earth* be at T, and the *Moon* at L, in Conjunction with the *Sun*: Now while the *Moon* is moving from L round it's Orbit, it's plain that the *Earth* muſt make ſome Progreſs through it's Orbit, carrying the *Moon's* Orbit along with it: So that while the *Moon* has moved quite round it's Orbit, the *Earth* will be carried from T to t, and the *Moon's* Orbit will be in the Situation *l a c d*, and the Point L will be in the Line *t l*, parallel to the former TL, and conſequently the *Moon* will be then in *l*, and will have compleated it's *periodic Month*; but it will not be in Conjunction with the *Sun* 'till it has moved farther on to M, when it will have compleated it's *Synodic Month*.

If the *Moon's* Orbit lay in the Plane of the *Ecliptic*, that is, if the *Earth* and *Moon* moved in the ſame Plane; 'tis manifeſt that in about a Month, the *Moon* would be ſeen to deſcribe the ſame Circle in the Heavens, that the *Sun* appears to do in a Year, that is, it would deſcribe the *Ecliptic* Circle: But becauſe the *Moon's* Orbit, does not lie in the ſame Plane with the *Earth's*, or in the Plane of the *Ecliptic*, but is inclined to it in an Angle of

 about

about five Degrees; the *Moon* is ſeen to be ſometimes above, ſometimes below; and at other Times in the *Ecliptic*. Thus, *Fig*. 88. let AB be a Part of the *Earth's* Orbit, T the *Earth*, CEDF the Orbit of the *Moon*, CGDH a Circle of the ſame Diameter with that of the *Moon's* Orbit, lying in the Plane of the *Ecliptic*. Theſe two Circles being in different Planes, and having the ſame Center T, will interſect each other in the Extremities of the Line DC, which paſſes through the *Earth*; and one half of the *Moon's* Orbit CED, will riſe about five Degrees above the Plane of the Circle CGDH towards the *North*, while the other half DFC, will be as far below it towards the *South*. The Right Line DC at whoſe Extremities the two Circles interſect each other, is called the Line of the *Nodes*; and the Points D and C are called the *Nodes*. The *Node* C where the *Moon* begins to aſcend Northward, is called the *aſcending Node*, or the *Dragon's Head*, and is thus maked ☊; the other *Node* D whence the *Moon* begins to deſcend to the Southward, is called the *deſcending Node*, or the *Dragon's Tail*, and is thus marked ☋. Hence 'tis plain, that the *Moon* cannot appear to be in the *Ecliptic*, but twice in it's Period round the *Earth*, that is when it is in a *Node*; and that the more diſtant it is from a *Node*, it is the farther removed from the Plane of the *Ecliptic*: The two oppoſite Points of it's Orbit E and F that lie in the Middle between the *Nodes*, are called the *Limits*; becauſe they ſhew the utmoſt Diſtance the *Moon* can be from the Plane of the *Ecliptic*.

It

It has been found from Obſervations, that the Line of the *Nodes* changes it's Situation from *Eaſt* to *Weſt*, contrary to the Order of the Signs, and by this retrograde Motion, finiſhes it's Circulation in about 19 Years; after which Time the *Nodes* return to the ſame Points of the *Ecliptic* again.

Of the Inequalities *in the* Moon's *Motions, and of it's Surface.*

Hitherto we have conſidered the *Moon* to move in a Circular Orbit about the *Earth*, but Obſervations have convinced us that ſhe is ſometimes nearer, and at other Times farther from us, and therefore that her Orbit is of an elliptic Form, in one of the *Foci*, of which *Fig.* 89. is the *Earth* T; the greater *Axis* of the Ellipſe AP is called the Line of the *Apſides*, TC is the *Eccentricity*; the Point A or higheſt *Apſis* which is moſt diſtant from the *Earth* is called the *Apogeon* of the *Moon*; and the loweſt *Apſis* P, is called it's *Perigeon*, being that Point of the *Moon's* Orbit, which is neareſt to the *Earth*.

The *Moon*'s Orbit is not only carried with the *Earth* round the *Sun*, but it has a Motion from *Weſt* to *Eaſt* about the *Earth*, in the Space of almoſt nine Years, in which Time it will return to it's former Situation.

The periodical Months are not equal. For when the *Earth* is in it's *Aphelion*, or moſt diſtant from the *Sun*, the *Moon* being ſo likewiſe; ſhe then moves quicker, and performs her Circulation in leſs Time. Again, when the *Earth* is in it's *Perihelion*, or is leaſt diſtant from the *Sun*, the *Moon* being ſo likewiſe; the *Moon* then moves ſlower and performs it's Circulation in a greater Time: Seeing therefore that the *Moon* revolves about the *Earth* in a leſs Time, when the *Earth* is in it's *Aphelion*, than when it is in it's *Perihelion*, the periodical Months cannot be equal.

When the *Moon* is in either of the *Syzyga* A or P, or in thoſe Points of it's Orbit, which are in a Line with the *Sun* and *Earth*, ſhe will then move ſwifter, than when ſhe is in the Quadritures.

According as the *Moon* is removed from the *Syzyga* ſhe ſlackens her Pace, and increaſes it as ſhe goes towards either of them. Thus, from her Change to the firſt Quadrature, ſhe every Day moves ſlower, and from that Quadrature to the Full, ſhe moves quicker daily; again, from the Full to the laſt Quadrature, ſhe every Day moves ſlower, and from the laſt Quadrature to the Change, ſhe daily moves ſwifter. This Inequality is called the *Moon's Variation*, and was firſt diſcovered by *Tycho Brahe.*

The *Moon* moving in an Ellipſe round the *Earth*, deſcribes equal Areas in equal Times, as the primary *Planets* do in moving round the *Sun*; therefore the *Moon* muſt be quickeſt in the *Perigeon*, and ſloweſt in the *Apogeon*.

The Orbit of the *Moon* is changeable, for it increaſes and decreaſes: It is greateſt, for the Excentricity is greateſt, when the Line of the *Apſides* coincides with the *Syzyga*, or when it is in the Line that

that joins the *Sun* and *Earth*; and the Excentricity is leaſt, when the Line of the *Apſides* is at Right Angles with the other. The Difference between the greateſt and leaſt Excentricity is ſo conſiderable, that it is half of the leaſt.

The *Apogeon* of the *Moon* is alſo variable, ſometimes moving forwards, and again backwards. When it coincides with the *Syzygal* Line, it moves forwards, but when it cuts that Line at Right Angles, it moves backwards, and it's Progreſs and Regreſs are very unequal. When the *Moon* is in her Quadratures, the *Apogeon* goes but ſlowly forwards, ſtands ſtill, or moves backwards: But when the *Moon* is in Oppoſition to the *Sun*, the *Apogeon* has a quick Motion forwards.

The Motion of the *Nodes* is alſo variable, for when the Line of the *Nodes* coincides with the *Syzygal* Line, they have no Motion; but when they cut that at Right Angles, they go ſwiftly backwards from *Eaſt* to *Weſt*.

All theſe Irregularities were firſt diſcovered by Sir ISAAC NEWTON, who has ſhewn that they all ariſe from the *Theory of Gravitation* of Matter to Matter.

The only regular Motion the *Moon* is endued with, is, that in one ſingle Rotation round her *Axis*, ſhe moves round her Orbit; by which Means ſhe always keeps the ſame Face to us: Yet this very Regularity is the Cauſe of a ſeeming Irregularity. If indeed the *Moon's* Orbit were a Circle, then we would always ſee the ſame Face: But becauſe it is an Ellipſe, in one of whoſe *Foci* is the *Earth*; we cannot ſee the very ſame Face,

by

by it's defcribing equal Areas in equal Times; but fometimes we fee more of its *Eaftern* Limb, and at other Times more of its *Weftern* Limb; and thefe Appearances are called the *Librations* of the *Moon*.

If the *Moon's* Difk or Face, were fmooth as a convex Mirror, it would only reflect the *Sun's* Rays in certain Directions, which would terminate in a Point, where the *Sun's* Image would be feen very fmall, but with immenfe Luftre: It would not reflect Light as it does by diffufing it on all Sides, if it's Surface were not very rough and uneven.

That the Surface of the *Moon* is not only rough and uneven, but that there are many Hills and Vallies thereon, may be thus proved. If it's Surface were fmooth, the Arch defcribed by the Terminator of Light and Darknefs, either in a horned, or a gibbous *Moon*, would appear to be a regular Curve, free from any Excrefcences; and in the Quadratures, the Terminator of Light and Darknefs, would be a Right Line. But by viewing the *Moon* through a Telefcope, we find there are no fuch regular Curves or Lines to be feen on it's Difk, but that the Confines of them are tinged or illuminated with a Multitude of Spots and Breaks diforderly fcattered. From the third to the fifth or even to the fixth Day of the *Moon*, there may be obferved many fhining Points fcattered in the dark Part near the Light, which being obferved through a Telefcope, will in a few Minutes be found to dilate and expand themfelves gradually, 'till they join the light Part; and in the

the mean Time new Spots again are continually appearing at ſome Diſtance from the light Part, which again expand in a few Minutes and are joined to the Light, and the contrary is found in the laſt ſix Days of the *Moon*. Therefore the Surface of the *Moon* is not ſmooth but rough and uneven.

The Spots which appear without the illuminated Part, are the Tops of very high Mountains, which riſe far above the other Parts of the Surface; and are therefore ſooner illuminated than the lower Parts, and continue longeſt to ſhine. There are alſo in the illuminated Part of the *Moon* many dark Spots, which ſeem to be large Cavities, when the *Sun* ſhines obliquely upon them; but as the *Sun* riſes more and more, the dark Parts become leſs and leſs, and at Length they vaniſh.

Aſtronomers find, that the Mountains in the *Moon* are much higher than thoſe of the *Earth*. They have found ſome of them to be nine Miles high, which is three Times higher than the higheſt Hills on the *Earth*.

A Full *Moon* when viewed through a Teleſcope, is ſeen to abound with a great Number of large dark Spots, intermixed with white ones, which dark Spots are Cavities, and the white ones are Mountains. Some have imagined the dark Spots to be Seas, but they conſiſt of a darker Matter than Water, which does not reflect the Light.

There are neither Clouds nor Vapours about the *Moon*, from whence Rain may be generated: If there were, they would ſometimes cover it's Diſk, or render ſome of its Parts obſcure to us, which

which never happens. It is probable that the *Moon* has not even an Atmoſphere, becauſe the *Planets* and *Stars* which are ſeen near it's Limb, have not their Light refracted, as it is in paſſing through our Atmoſphere. If any Atmoſphere it has, it muſt be of a very extraordinary thin Nature. Hence there is a conſtant Series of fine ſerene Weather in the *Moon*.

Hevelius has given *Geographical* Names to the ſeveral Parts of the *Moon*, by calling ſome Iſlands, Countries, and Seas after thoſe on the *Earth*, without any regard to Situation or Figure.

Of the Eclipſes *of the* Sun *and* Moon.

All opaque Bodies, which are expoſed to the *Sun*, caſt a Shadow behind them, which Shadow is a privation of Light in the Space it poſſeſſes. The *Earth* therefore being an opaque Body, caſts a Shadow into the Heavens in an oppoſite Direction to the *Sun*.

This being premiſed, we will ſhew that the *Sun* is bigger than the *Earth*. Thus,

1. *Fig.* 80. If the *Sun* and *Earth* were of equal Diameters, it is plain that, the Shadow of the *Earth* would form a Cylinder, which would be infinite.

2. *Fig.* 81. If the *Sun* were leſs than the *Earth*, it is alſo plain that, the Shadow would form an infinite truncated Cone, which being farther continued would take up ſtill the greater Space. Now in either of theſe Caſes, becauſe the Shadows are infinite; ſometimes the ſuperior *Planets*, *Mars*, *Jupiter*, and *Saturn* would be involved in them,

and they would by that means ſuffer *Eclipſes*. But theſe *Planets* have never been found to ſuffer *Eclipſes*, therefore the *Sun* is neither equal to, nor is it leſs than the Earth, and conſequently it muſt be greater than the Earth.

Fig. 82. Seeing therefore that the *Sun* is greater than the *Earth*, it is plain the *Earth's* Shadow muſt be in the form of a Cone, and muſt terminate in a Point. And becauſe the *Moon's* Diameter is found to be contained about three Times in the Shadow, it is plain that the *Moon* muſt be leſs than the *Earth*.

Let S repreſent the *Sun*, E the *Earth*, and ABC the conical Shadow. It is plain that there can be no Line drawn from the *Sun*, to any Point in the Space ABC which muſt not fall onthe *Earth*; and ſeeing the *Earth* is an opaque Body, the *Sun's* Rays cannot paſs through it, nor can they illuminate any Part of the Space ABC. Now when the *Moon* being oppoſite to the *Sun*, is involved in this Space, or Shadow, ſhe ſuffers an *Eclipſe* in the very Time of *Full Moon*. Fig 92

The *Sun* being greater than the *Earth*, and the *Earth* again being greater than the *Moon*; the *Sun* muſt therefore be much greater than the *Moon*, and the *Moon's* Shadow muſt form a much leſs Cone than that of the *Earth*. Now if this Shadow of the *Moon* ſhould happen to fall on the *Earth*, which can only happen when the *Moon* is in Conjunction with the *Sun*, then the Inhabitants of the *Earth*, on whom the Shadow falls, will be involved in Darkneſs, and the *Sun* will ſeem to be in an *Eclipſe*, ſo long as the Shadow covers them. *Fig.* 93. But becauſe it's Shadow is much leſs than the *Earth*, it can only cover a ſmall Part of the *Earth*, ſuch as BC; within which Space only a total Eclipſe of the *Sun* will happen; becauſe the Inhabitants in that Space, only are totally deprived of the Light of the *Sun*; whereas the circumjacent Inhabitants, who are near the Shadow, will ſee a Part of the *Sun*, and to ſuch the *Eclipſe* will be partial, and thoſe who live about P, will ſee half the *Sun* eclipſed; But whoever lives between M and N, will at the ſame Time ſee the whole Body of the *Sun*, and will perceive no *Eclipſe*.

Thoſe Inhabitants who ſee a partial *Eclipſe*, are ſaid to be in the *Penumbra* of the Shadow, that is, they are neither in total Light nor Darkneſs; ſuch as are in that Part of the *Penumbra*, which is neareſt to the Shadow, cannot ſee as much of the *Sun's* Body, as thoſe that are farther removed from it; therefore the former will ſee a greater *Eclipſe* than the latter: and thoſe who are without the *Penumbra*, will ſee no *Eclipſe*.

If two Candles be placed a little diſtant from each other on a Table, and a Ball be placed on the Table about a Foot from them, in a Line which is at Right Angles to the Middle of a Line drawn, between the Centers of the Candleſticks; a conical Shadow of the Ball will be exhibited, and on either Side of it a *Penumbra*. In one Side of the *Penumbra*, the Candle on that Side only can be ſeen, and in that of the other Side, the other Candle can be only ſeen; But in the Shadow neither can be ſeen.

From

From what has been ſaid 'tis plain, that there cannot be an *Eclipſe* of the *Moon* but at a full *Moon*, or when the *Moon* is in oppoſition to the *Sun*; nor can there be an *Eclipſe* of the *Sun*, or rather of the *Earth*, but at a new *Moon*, or when the *Moon* is in conjunction with the *Sun*. And Yet the *Sun* and *Moon*, do not ſuffer *Eclipſes* every Month, which they would do if the *Moon's* Orbit were in the plane of the *Ecliptic*. But we have already ſhewn, that the *Moon* is never in the Plane of the *Ecliptic*, but when it is in a *Node*, or in one of thoſe Points, where the Plane of the *Moon's* Orbit interſects the Plane of the *Ecliptic*; and therefore the *Sun*, *Moon* and *Earth* cannot be in the ſame Plane, and in the ſame Right Line, unleſs the *Moon* be in a *Node*, and that *Node* be at the ſame Time in a right Line, connecting the Centers of the *Sun* and *Earth*. When this happens, and the *Moon* be at the *Full*, the *Axis* of the *Earth's* Shadow will paſs through the Center of the *Moon*; and then the *Moon* will ſuffer a total and central *Eclipſe*. The Duration of an *Eclipſe* therefore muſt be juſt as long as the *Moon* takes up in paſſing through the Shadow of the *Earth*, or through a Circle whoſe Diameter is three Times greater than the Diameter of the *Moon*, or ſo long as the *Moon* is paſſing through an Arch, which is equal to four of it's own Diameters, that is, about two Degrees; which Space, the *Moon* generally moves through in four Hours. *Fig.* 94. Thus, if MN repreſents the tranſverſe Section of the *Earth's* Shadow, at the Diſtance of the *Moon*, CD a Part of the *Moon's* Orbit deſcribed in the Time of *Full Moon*, BGA a right Line in the Plane of the *Ecliptic*; F will be the Position of the *Moons* Center, when ſhe firſt touches the Shadow, E the poſition of the ſame when ſhe leaves it; G will be the *Node*, and the Center of the *Moon* when the Axis of the Shadow paſſes through it, I the *Moon's* Center when the whole Body is firſt involved in the Shadow, and H the ſame, when the *Moon* begins to quit the Shadow.

Becauſe the Diameter of the *Earth's* Shadow is much greater than the Diameter of the *Moon*; it is plain, there may be total, Eclipſes of the *Moon*, when the *Moon* is not only in a *Node*, but when it is near one. For the *Node* may be at ſuch a Diſtance from the *Axis* of the Shadow, that the *Moon* may ſuffer a total though not a Central *Eclipſe*; as in Fig. 95. or it may ſuffer a Partial *Eclipſe*, as in *Fig.* 96. 97. But when the *Node* is removed from the *Axis* of the Shadow above twelve Degrees at the Time of *Full Moon*; the *Moon* then will have ſo great a Latitude, or will be removed ſo far above, or beneath the Plane of the Ecliptic that it will paſs over, or under the Shadow and will not be eclipſed. Therefore an Eclipſe of the *Moon* can only happen at a *Full Moon*, and that only when the *Moon* is in a *Node*, or within twelve Degrees of one.

Juſt as the *Earth's* Shadow when caſt upon the *Moon*, produces an *Eclipſe* of the *Moon*; ſo likewiſe will the *Moon's* Shadow when caſt upon the *Earth*, produce an *Eclipſe* of the *Earth* in thoſe Places where the Shadow falls, as was already ſhewn. But thoſe *Eclipſes* of the *Earth*, or as they

are

are more commonly, but improperly called *Eclipſes* of the *Sun*, ſince the *Sun* never ceaſes to ſhine, cannot be total with reſpect to the *Earth*, that is, the *Moon's* Shadow cannot involve the whole *Earth* at once in Darkneſs, ſeeing as before the *Moon* itſelf is much leſs than the *Earth*; and again, the *Moon's* Shadow ſtill leſs: So that to thoſe Inhabitants which are in the *Axis* of the *Moon's* Shadow, the *Sun* can only be totally and centrally *Eclipſed*; to thoſe who are in any Part of the Shadow that is not in the *Axis* of the Shadow, the *Eclipſe* will be total; to thoſe who are in the *Penumbra*, it will be partial; and thoſe who are without the *Penumbra*, will ſee no *Eclipſe*.

It ſometimes happens, that there is a central *Eclipſe* of the *Sun*, which is not total. This happens when the *Moon's* Shadow does not extend ſo far as the *Earth*, for to thoſe Inhabitants of the *Earth* which are immediately under the Vertex or Top of the conical Shadow, the *Moon's* Center will appear to coincide with that of the *Sun*; and the *Moon* will not then obſcure all the *Sun's* Diſk, but will leave a lucid *Annulus* or Ring, between it's Verge, and that of the *Sun*. And ſuch an *Eclipſe* is called an *annular* one.

Of the Directions, Stations *and* Retrogradations *of the* Planets.

From what has been already ſaid concerning *Venus*, it is Plain that ſhe undergoes the ſame *Changes* and *Phaſes* that the *Moon* does, and no doubt *Mercury* alſo does.

Theſe

These inferior Planets are seen more *Easterly* than the *Sun*; from the Time of their superior, to that of their inferior Conjunction; during which Time they set after him, and then they are *Evening Stars*. But from the Time of their inferior, to that of their superior Conjuction, they are seen *Westward* of the *Sun*; and consequently they set and rise before him, and then they are *Morning Stars*.

It is plain that these Planets are continually changing their Distances from the *Earth*, and that their Distances in their superior Conjunctions, must exceed those in their inferior Conjunctions by the Diameter of their respective Orbits. By this Means *Venus* appears six Times nearer us in her inferior, than in her superior Conjunction. but these greatest and least Distances are sometimes changed; because the Planets move in elliptical, and not in circular Orbits, as we have hitherto supposed. For *Venus* is most remote from the *Earth*, when the superior Conjunction happens at the very Time that both she and the Earth are in their Aphelions; and the Distance of *Venus* and the Earth is least, if the inferior Conjunction happens at a Time when *Veuus* is in her Aphelion, and the Earth is in it's Perihelion.

It was before said that *Venus* was observed by Mr. *Horrax*, to appear like a Spot upon the Disk of the *Sun* in 1639, which is a Sight seldom to be seen. But the like may be again seen upon the 26th Day of *May*, 1761 in the Morning, if Clouds do not interpose.

The

The Luſtre of *Venus* decreaſes in a duplicate Proportion as the Diſtance increaſes, therefore ſhe will not appear as bright when ſhe is full as when ſhe is nearer the Earth; Dr. *Halley* has ſhewn that *Venus* is brighteſt when ſhe is about 40 Degrees removed from the Sun, and that then no more than a fourth Part of her lucid Diſk is to be ſeen. In this Situation *Venus* is often ſeen in the Day Time, and even when the Sun is ſhining.

This extraordinary Luſtre of *Venus* is truly admirable, ſince the like is not to be found in any of the other Planets, nor even in the Moon. 'Tis true the Moon's Light is much the greateſt as her apparent Magnitude abundantly exceeds that of *Venus*; yet it's Light is but dead and dull when compared with the ſprightly briſk Light of *Venus*.

The Orbits of the Planets are inclined to the Plane of the Ecliptic in different Angles. Thus, the Orbit of *Saturn* is inclined to the Plane of the Ecliptic in an Angle of 2 Degrees and 30 Minutes; that of *Jupiter* in an Angle of 1 Degree 20 Minutes; that of *Mars* in an Angle of 1 Degree 52 Minutes; that of *Venus* in an Angle of 3 Degrees 24 Minutes; and that of *Mercury* in Angle of 6 Degrees 54 Minutes.

The Line where the Plane of a Planet interſects that of the Ecliptic, is called the *Line of the Nodes*, and the Extremities thereof are the *Nodes*. A Planet therefore can never be ſeen in the Ecliptic, but when it is in the Node. When a Planet is in any other Part of it's Orbit, it is either on the

North

North or South Side of the plane of the Ecliptic. This Deviation from the Plane of the Ecliptic, when viewed from the Earth is called the *Geocentric Latitude* of the Planet, but if viewed from the Sun it is called the *Heliocentric Latitude.* Now whenever a Planet comes to the ſame Point of it's Orbit, the Heliocentric Latitude will be the ſame, and it will be greateſt, when the Planet is 90 Degrees from a Node. But the Geocentric Latitude will vary, becauſe the Earth will be nearer to, or farther from a Planet at one Time than at another, when the Planet is in the ſame Point of it's Orbit.

If a Zone or broad Circle of 8 Degrees be conceived to be carried parrallel to each Side of the Ecliptic; theſe two Zones compoſe one Zone, which is 16 Degrees broad; and this Spaceis called the *Zodiac*, within which the Planets always move.

The fixed Stars that are within the *Zodiac* are thrown into twelve *Conſtellations*, or *Aſteriſms*, viz.

1. ♈ Aries, the *Ram.* 2. ♉ Taurus, the *Bull.* 3. ♊ Gemini, the *Twins.* 4. ♋ Cancer, the *Crab.* 5. ♌ Leo, the *Lion.* 6. ♍ Virgo, the *Virgin.* 7. ♎ Libra, the *Ballance.* 8. ♏ Scorpio, the *Scorpion.* 9. ♐ Sagittarius, the *Archer.* 10. ♑ Capricornus, the *Goat.* 11. ♒ Aquarius, the *Waterer.* 12. ♓ Piſces, the *Fiſhes.*

The Planets *Mercury* and *Venus* move much ſwifter in their Orbits at one Time than at another; and their Motion at ſometimes appears to be direct, or according to the Order the Signs of

A TABLE OF THE DIMENSIONS, MOTIONS, &c. OF THE PLANETS.

	Saturn	Jupiter	Mars	Earth	Venus	Mercu.	Sun	Moon
Periods	y 29 d 167	y 11 d 315	y 1 d 322	d 365 h 6 ′ 9	d 224 h 17	d 87 h 23	-------------	d 27 h 7 ′ 43
Diurnal Revolutions	Not known	h 9 ′ 56	h 24 ′ 40	h 23 ′ 56	h 23 ′ 0	Not known	d 25 h 6	27 7 43
Me. dist. from. Sun. Mil.	777000000	424000000	123000000	81000000	59000000	32000000	-------------	-------------
Diameters in Miles	93450	130600	4875	7970	7906	4240	763000	2175
Proportion of Bulk	161	4400	$\frac{1}{4}$	1	$\frac{39}{40}$	$\frac{1}{7}$	878000	$\frac{1}{50}$
Quantity of Matter	126	827	Not	1	Not	------------	228700	$\frac{1}{40}$
Gravity on the Surface	. 92	5. 08	known	1	known ----	------------	. 24	. 34
Inclination of their Orbits	° 2 ′ 30	° 1 ′ 20	° 1 ′ 52	° 0 ′ 0	° 5 ′ 24	° 6 ′ 54	-------------	° 5. Variab.
Inclination of their Axes	------------	Very little	° 0 ′ 0	° 23 ′ 29	° 75 ′ 0	-------------	° 8 ′ 0	° 3 ′ 10
Propert. of Light and heat	$\frac{1}{100}$	$\frac{1}{28}$	$\frac{3}{7}$	1	$1\frac{3}{4}$	$6\frac{1}{2}$	4500	Variable
Velocities; Miles an Hour	19000	25400	47240	58050	68040	62700	-------------	2300
Place of ascending node	Can. 22°	Can. 8°	Tau. 19°	-------------	Gem. 15°	Ari. 15°	-------------	Variable
Place of the Aphelion	Sag. 28°	Lib. 9°	Vir. 1°	Cap. 8°: 25	Aqu. 5°	Sag. 13°	-------------	Variable
Excentricities; Miles	44320000	20440000	108112000	1368600	606400	6634000	-------------	Variable
Mean Motion in the Eclip.	° 0 ′ 2 ″ 0	° 0 ′ 4 ″ 59	° 0 ′ 31 ″ 27	° 0 ′ 59 ″ 8	° 1 ′ 36 ″ 8	° 4 ′ 5 ″ 32	-------------	° 13 ′ 10 ″ 35

Satel. of Saturn.	Periods round Saturn. d h ″	Distance from Saturn; Miles
1	1 21 19	202800
2	2 17 40	259700
3	4 12 27	362900
4	15 22 41	841000
5	79 22 0	2463000

Satel. of Jupiter.	Periods round Jupiter. d h ′ ″	Dista. from Jupiter Mil.
1	1 18 28 36	363600
2	3 13 17 54	580000
3	7 3 59 36	925000
4	16 18 5 12	1630000
From the Earth to the Moon		240000

Calculated from the most accurate Observations by the late *Mr.* John Booth.

Place this opposite to Page 240.

the Zodiac. Sometimes their Motion appears *Retrograde*, or in a contrary Order of the Signs, and ſometimes they appear to be *Stationary*, or without any Motion at all, for ſome Days together. All which is occaſioned by the Earth and theſe Planets moving in concentric Orbits, one within another, but with different Velocities.

Fig. 98. Let the leſſer Circle about the Sun repreſent the Orbit of Mercury, and the larger the Orbit of the Earth. Now becauſe the Earth moves through only one Quarter of it's Orbit, in about the ſame Time that *Mercury* makes one entire Revolution round us; or that one Quarter of the Earths Orbit which is run through in 12 Weeks, may anſwer or be equal to the Time of *Mercury's* Period; let us divide one Quarter of the Earths Orbit into 12 equal Parts, and the entire Orbit of Mercury into the like Number of equal Parts, as in the Scheme; then it is plain that when the Earth is at o in it's, and Mercury at o in his Orbit, he appears at o in the Zodiac. About a Week after, when the Earth is in 1 in it's and *Mercury* is at 1 in his Orbit, he will appear to be at 1 in the Zodiac. In the Like Manner when the Earth is at 2, 3, 4, 5 *&c.* in it's Orbit, and if at the ſame time *Mercury* be at 2, 3, 4, 5, *&c.* in his, Mercury will be ſeen to be in 2, 3, 4, 5, *&c.* in the Zodiac. So that from the Time the Earth leaves o, and Mercury leaves o, till the Time that the Earth arrives to 4 and Mercury to 4, the Planet appears to move *Direct*, and it's Motion becomes ſlower. About the Time the Earth is at 4, and Mercury is at 4 he will appear *Statio-*

nary; for though the Tangent Line 444 can touch the Orbit of *Mercury* but in one Point, yet a little before *Mercury* arrives at that Point, and a little after he has quitted it, he will be found to appear very nearly in one and the ſame Point. At 555 he appears to move *Retrograde*, alſo at 666 when he is in his Inferior Conjunction, and at 777 till about 888, he is again *Stationary*; after which at 999 and 10 10 10, he becomes again *Direct*; and more ſwiftly at 11 11 11 and 12 12 12. The Caſe of *Venus* is the ſame.

The Superior Planets *Mars*, *Jupiter*, and *Saturn*, are by Turns Morning and Evening Stars, as well as the inferior ones are; and they alſo appear *Direct*, *Stationary* and *Retrograde*.

Fig. 99. Let the leſſer Circle about the Sun repreſent the Orbit of the Earth, and the larger that of *Jupiter*, who moves through, about a 12th Part of his Orbit, while the Earth compleats it's Revolution round the Sun. When the Earth is at 0 in it's, and *Jupiter* at 0 in his Orbit, he is ſeen at 0 in the Zodiac, about a Month after at 111 he appears *Direct*; and near his Conjunction with the Sun; at 222 and 333 he continues *Direct* though more ſlow in his Motion; about 444 he is *Stationry*; at 555 he appears *Retrograde*, as alſo at 666 when he is in Oppoſition, and at 777, till about 888; and then he is again *Stationary*; after which at 999 and 10 10 10, he becomes again *Direct*, and more ſwiftly at 11 11 11 and 12 12 12. The Caſe of *Saturn* and *Mars* are much the ſame.

Seeing the *ſuperior Planets* appear *Direct*, *Stationary*, and *Retrograde*, the Earth muſt have it's annual

annual Motion round the Sun; for if it had no ſuch Motion, they could never appear otherwiſe than *Direct*.

Aſtrologers aſcribe to the *Planets* a certain Influence they conceit they have upon us, according to their different *Aſpects* *, and by which they pretend to foretell Events. But whoever conſiders the vaſt Diſtance they are from us, and the probability of their being habitable Worlds, will not eaſily be induced to believe ſo great an Abſurdity.

Of Comets.

Comets, or Blazing-Stars were antiently ſuppoſed to be Meteors, or Exhalations, ſet on Fire in the Atmoſphere; but the modern Aſtronomers have found that they are not only above the Earth's

* *Aſpects* of the heavenly Bodies, ſignify their Situation in the Zodiac, with reſpect to one another, of their Diſtance from one another in Longitude. The Name and Characters of the different Aſpects are.

1. ⚹ *Sextile*, when they are two Signs, or 60 Degrees aſſunder.
2. □ *Quartile*, when they are three Signs, or 90 Degrees diſtant.
3. △ *Trine*, when they are four Signs, or 120 Degrees from each other.
4. ☍ *Oppoſition*, when they are ſix Signs, or 180 Degrees aſunder.
5. ☌ *Conjunction*, when they are in the ſame Sign and Degree.

Atmoſphere, but that they are even beyond the Moon's Orbit. It is probable that they are very excentrical Planets, which move periodically round the Sun, or that their Orbits are very long *Ellipſes*, having the Sun in one of their *Foci*.

The Motion of *Comets* is very variable, for ſome go from *Weſt* to *Eaſt*, others from *Eaſt* to *Weſt*; ſome from *North* to *South*, and again others from *South* to *North*; in ſhort they move in all Directions, ſo that they have no Zodiac to contain them.

There have not been many more than twenty Planets, which have been hitherto obſerved, ſo as their Paths in the Heavens have been particularly traced and deſcribed; and the periodic Times of only two or three of them are yet known.

When the *Comets* deſcend near to the Sun, they become viſible, and continue ſo for ſome Time, 'till they aſcend again, and leave him; and as they remove by Degrees from the Sun, we looſe Sight of them, and at length they diſappear, and are not again ſeen for a long Time.

When a *Comet* deſcends near the Sun, it becomes greatly heated, and it's Tail ſeems to be a long and lucid Train of Vapours, which iſſue from the Body, in a contrary Direction to the Sun.

Comets are divided into three Kinds, *viz. Caudati*, or *Tailed*, *Barbati* or *Bearded*, and *Criniti* or *Hairy*. This Diviſion does not ariſe from any real Difference there is in the Comets themſelves,

but

but from different Circumſtances of the ſame Comet. Thus,

When a *Comet* is moving toward the Sun, the Train of Vapours follows it, like a *Tail.*

When the *Comet* is moving from the Sun, or when it has left it's Perihelion, the luminous Vapour precedes or goes before it, in the Manner of a *Beard.*

When the Vapour is projected directly behind the *Comet* with reſpect to us, it is almoſt from our View; for we then ſee only a little of it appearing round the *Comet*, like a Border of *Hair*. This Appearance is owing partly to the Expanſion of the Train, which widens as it recedes from the Head of the *Comet*, by which Means we ſee ſome of the remote Vapours about it; and partly, becauſe what is raiſed by the Heat of the Sun, is thrown off by the Nature of Gravitation, the contrary Way. For as in the Atmoſphere, the Smoke of all heated Bodies, aſcends from the Earth towards which the Body gravitates; ſo in the Heavens, where all Bodies gravitate towards the Sun, Smoke and Vapours muſt aſcend from the Sun; therefore the Vapours which are raiſed from that Side of the *Comet* which is towards the Sun, is turned backwards, and thrown the contrary Way. Conſequently when the *Comet* is oppoſite to the Sun, and the heated Side is turned towards us on the Earth, the Vapours which muſt be in an oppoſite Direction to us, in returning back, are ſeen round the Edge of the *Comets* Diſk; which occaſions us to compare it to *Hair*, becauſe it bears ſome Reſemblance thereto.

The

The *Tail* or *Beards* of a *Comet* appear longer or ſhorter, not only as it is projected to a greater or leſs Diſtance from it, but becauſe it appears to us under a greater or leſſer Angle. When the Tail is ſeen at a right Angle, it then appears longeſt, after which, as the Angle under which it is ſeen, becomes more and more acute, it will appear ſtill to be the ſhorter.

Sir ISAAC NEWTON has computed, that the great *Comet*, which appeared in 1680 and in 1681, was on account of it's unuſual proximity to the Sun, heated to ſo extraordinary a Degree, that it was 2000 Times hotter than red hot Iron. This *Comet* goes at leaſt 11200 Millions of Miles from the Sun, and yet it does not arrive within a 40th Part of the Diſtance to the fixed *Stars*.

Bodies that are capable of bearing ſo intenſe a Heat, without being entirely diſſipated and deſtroyed, muſt needs be very hard and ſolid; ſuch therefore no doubt the *Comets* are.

Hevelius, found the Diameter of the *Comet* that appeared in 1665, to be three Times greater than the Earth's Diameter; and conſequently it's Solidity, to be 27 Times greater than the Earth's. Spheres being to one another, as the Cubes of their Diameters.

The *Comet* that appeared in 1682, is ſuppoſed to be the ſame that appeared in 1607, and before in 1531; therefore it's Period muſt be 75 or 76 Years, and its Return may be expected in 1758. It's greateſt Diſtance from the Sun, is to it's leaſt, as 60 to 1; and it's greateſt Light and Heat, is to it's leaſt, as 3600 to 1.

The *Comet* that appeared in 1661, is ſuppoſed to be the ſame that appeared in 1532: and conſequently it's Period is about 126 Years, and it's Return may be expected in 1789. It's greateſt Diſtance is to it's leaſt, as 100 to 1; and it's greateſt Light and Heat is to it's leaſt as 10,000 to 1

The great *Comet* that appeared in 1680 and in 1681 is ſuppoſed to be the ſame that appeared in the 44th Year of the Chriſtian Æra, and again in the Year of our Lord 531 or 532, again in 1106, and laſtly in 1680; therefore it's Period muſt be 576 Years, and it's Return may be expected in the Year 2256. It's greateſt Diſtance is to it's leaſt, as 20,000 is to 1, and it's greateſt Light and Heat is to it's leaſt as 400,000,000 to 1.

We know little or nothing of the *Uſe of Comets*. They ſeem to be very unfit for the Habitation of Animals, becauſe of their intenſe Heat, when they are near the Sun, and of their extream Cold, when they are fartheſt from it; yet we have no room to doubt, but they are made for much nobler Purpoſes, than to preſage approaching Calamities; which ſeveral are idle enough to imagine they do.

Of the Tides.

The whole Globe of the Earth is every where preſſed by Gravitation towards it's Center.

If the Surface of the Globe of the Earth were covered with a Fluid, and if ſome Parts of it's Surface were more preſſed than others, the Parts which were moſt preſſed, would be loweſt, or neareſt to the Center; and thoſe that were leaſt preſſed, would be higheſt or moſt diſtant from the Center.

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The Sun and Moon attract and are attracted by the Earth, and the Force of their Attraction pervades the whole Globe. But the Moon's Attraction is ſtronger than that of the Sun, becauſe ſhe is much nearer to the Earth than the Sun is.

The Effects of the Moon's Attraction upon the Fluids of the Earth, to alter their natural ſpherical Form, muſt be as follow.

The Middle Point of that Hemiſphere of the Earth, which is next to the Moon, being more attracted by the Moon than any other Part of that Hemiſphere, will by that Means be leaſt preſſed upon by it's own central Gravitation; and therefore the Waters will riſe higheſt in that Point. The Point which is diametrically oppoſite to the aforéſaid Point in the other Hemiſphere, or that Point of the Earth, which is fartheſt from the Moon, being leſs attracted by the Moon than all it's other Parts, will therefore be left behind them; from whence it will follow, that the Surface of the Water at the Middle of that Hemiſphere will be higher, or more remote from the Center, than in any other Part. Theſe two middle Points will therefore be higheſt in their reſpective Hemiſpheres; the one being really *more elevated*, and the other being *leſs depreſſed* by the Moon's Attraction, than the adjacent Parts, and conſequently the Earth may be looked upon to be of a ſpheriodical or oval Figure, whoſe longeſt Axis if produced, would paſs through the Moon. Now by the Earth's Rotation, theſe higheſt Points will be continually ſhifting their Surface; from whence there will follow two *Flood Tides* and two *Ebb Tides*

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in the Space of 25 Hours; in which Time the Moon removes from the Meridian of any Place, to the ſame Meridian again.

When the Sun and Moon are in Conjunction with, or in Oppoſition to each other, that is at New or Full Moon; the Attraction of theſe two Bodies, acting upon the Earth in the ſame Right Line, their Force becomes united and ſo raiſes the Waters. And thus *Spring Tides* are produced.

When the Moon is in her Quadratures, her Attraction acts in one Direction, and the Sun in a quite contrary one; by this Means they correct or counteract one another, the Moon raiſing the Waters, where the Sun depreſſes them, and the Sun raiſing the Waters where the Moon depreſſes them. And thus Neap-Tides are produced.

It is plain, that if the two Protuberances, or Summits of Water, were always exactly at the Poles of the Earth, there would be no riſing and falling of Waters, by means of the Earths Rotation, or no Tides at all; for it would conſtantly be high Water at the Poles, and low Water all round the Equator. And were the two Summits of Waters upon the Equator, or at their greateſt Diſtance from the Poles; the Riſe and Fall of the Waters, by means of the Earths Rotation, would then be greateſt: Therefore the nearer theſe Summits are to the Poles, the Riſe and Fall of the Waters are leſs, than when they are nearer the Equator. Conſequently when the Sun and Moon are in Conjunction or Oppoſition, in or near the Equinoctial, as in *March* or *September*, the *Spring Tides* muſt riſe higher, the Summits being then upon the Equator, than when they are in Conjunction or Opposition in the Tropics as in *June* and *December*. And the Moon being in the Tropics at her Quadratures in *March* and *September*, and in the Equinoctial at her Quadratures in *June* and *December*, the *Neap Tides* will be less vigorous in the former Months, than in the latter. And besides when the Moon is in the Tropics at her Quadratures the Sun is in the Equinoctial; therefore the Rise and Fall of the Waters by his Influence, counteracting that of the Moon, is then greatest, though still less than that of the Moon; and consequently the Neap Tides and will then be weakest. But when the Moon is in the Equinoctial at her Quadratures, the Sun is in the Tropic, whose Influence in counteracting the Moon, is then least; therefore the *Neap-Tides* will then be strongest. so that the Difference between the *Spring* and the *Neap-Tides* is much less considerable at the *Solsticial*, than at the *Equinoctial* Seasons.

Yet the highest Tides of the Year are observed to be sometime before the Vernal, and sometime after the autumnal Equinox, *viz.* in *February* and *October*; which is owing to the Sun's being nearer the Earth in the Winter Months, when consequently the Force of his Attraction on the Waters, is greater, than in the Summer Months.

It has also been observed, that in this Part of the World, the Tides rise higher when the Moon is in the Northern Signs, at the Time of her coming to the Meridian above our Horizon, and when she is in the Southern Signs at the Time of her

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coming to the Meridian below the Horizon, than when ſhe is in the Southern Signs above our Horizon, and in the Northern Signs below it. The Reaſon of which will evidently appear upon the Globe, *viz.* That in the former Caſes, the Moon is nearer to our Zenith and Nadir, when ſhe is upon our Meridian, or at the Time of high Water, and conſequently we are then nearer to the Summits of Water, than in the two latter Caſes. Though the Force, by which the Tides are raiſed is continually increaſing, from the Time of the Moon's Quadrature to her Conjunction or Oppoſition, after which it gradually decreaſes until the next Quadrature; yet the higheſt Spring-Tide is not juſt at the New or Full-Moon, but a Day or two after; which is thus accounted for.

If we conceive every Tide to be raiſed by a double Force, *viz.* Some Part of the Force by which the laſt Tide was raiſed ſtill remaining, and the Force of a new Impulſe. When both theſe together amount to more than the whole Force, which raiſed the laſt Tide, the preſent Tide muſt riſe higher than the laſt did. Suppoſe the remaining Force to be always half the whole Force of the laſt Tide, and that the new Impulſe, juſt at New or Full-Moon be 15, and the whole Force with which that Tide is raiſed be 22.

Let the new Impulſe of the next Tide be but 14; then 14 and 11, (half of 22) will be equal to 25: This Tide will therefore be higher than the laſt. Let the new Impulſe of the next Tide be but 13; then 13 and 12½, (half of 25) will be equal to $25\frac{1}{2}$. Consequently this Tide will rise still higher than the last did; though the Force of the Action of the two Luminaries, by which the Tides are raised, is now considerably abated.

For the same Reason, the deadest or lowest Neap-Tides will fall out, not prescisely at the Moon's Quarters, but sometime after.

CHAP.

CHAP. X.

THE DOCTRINE, AND USE *of the* GLOBES.

A GLOBE or Sphere is a round Body, whoſe Surface is every where equally diſtant from it's Center. It may be conceived to be formed by the Rotation of a Semi-circle about it's Diameter.

The two Globes of which we here mean to treat, are artificial ſpherical Bodies: The one is called the *Terreſtrial* or the *Terraqueous* Globe; becauſe it's Surface comprehends a juſt Repreſentation of the Globe of the Earth as it conſiſts of Land, and Water: And the other upon which the *Starry Firmament* is deſcribed, is called the *Celeſtial Globe.*

We will therefore proceed to give a Deſcription of ſuch Things as are common to both Globes, and of thoſe which are peculiar to the Terreſtrial Globe, and ſo to it's Uſe; and then, after ſhewing the Parts which are peculiar to the Celeſtial Globe, we will proceed to ſhew it's Uſe.

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There are Things as well without, as upon the Surface of each Globe, which are common to both Globes, *viz.*

1. The two *Poles*, are the Ends of the Spindle or *Axis*, upon which the artificial Globe turns; or they are the Ends of the imaginary *Axis* of the Earth. One of these is called the *North*, or the *Artic Pole*, from two *Bears* that are near it; and the other the *South*, or the *Antartic Pole*, being opposite to the former*.

2. The large graduated Brass Circle, which circumscribes the Globe, and which passes through the Poles is called the *Brazen Meridian.* It divides the Globe, into two equal Parts called the Eastern and Western *Hemispheres*, and it is divided into four Quadrants of 90 Degrees each, two of which are numbered from it's Middle to each Pole, and the other two are numbered from each Pole till they meet in it's Middle. The graduated Edge of this Meridian represents the Meridian of any Place, when, by turning the Globe, the Place is brought just under it.

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* It will be here necessary to observe, that the Circles which are either about or upon the Surface of the Globe are distinguished into *Greater* and *Lesser*: the *greater* Circles divide the Globe into two equal Parts called *Hemispheres*, and the *lesser* Circles divide the Globe into two unequal Parts: Also, that every Circle whether great or small, is, or at least is supposed to be divided into 360 equal Parts called Degrees, and every of these into 60 equal Parts called Minutes: But a Degree in a great Circle, will be in the same Proportion to one, in a small Circle, just as the Circumference of one Circle is to the other; a Semicircle therefore contains 180 Degrees, and a Quadrant 90 Degrees.

3. The *Rational Horizon* is the upper Edge of the wooden Circle, in which the Globe ſtands; it divides the Globe into an upper and a lower Hemiſphere: It is ſo called to diſtinguiſh it from the *Senſible Horizon*, which limits our Proſpect quite round us.

When the Sun or a Star gets above the Rational Horizon, it is then ſaid to riſe; and when they ſink beneath it, they are then ſaid to ſet. Now though the rational and ſenſible Horizons differ by the Semidiameter of the Earth, yet becauſe the Heavenly Bodies are of a vaſt Diſtance from us, they may be conſidered as one and the ſame. For the whole Earth is but as a Point in compariſon of the Sun.

Upon the upper Surface of the wooden Frame or Horizon are exhibited. (Counting from the out Side.) 1. The 32 *Rumbs* or Points of the Mariners Compaſs, of which the *Eaſt*, *Weſt*, *North*, and *South* are called the *Cardinal Points*, dividing the Horizon into four equal Parts; and Lines drawn from any Point upon the Surface of the Globe towards the ſeveral Rumbs, are called *Rumb-Lines*.

2. The Days of every Month according to the Gregorian Account.

3. The like according to the Julian Account, and 4. The twelve Signs of the Zodiac are next diſtinguiſhed by their Names, Characters, and Symbols; each Sign being divided into 30 Degrees.

4. The *Quadrant of Altitude* is a narrow thin Plate of pliable Braſs, whoſe Edge is divided into

90

90 Degrees, and is exactly equal to one fourth Part of the Brazen Meridian. To the Top or upper Part or *Zenith* of this Meridian, it is screwed when it is used; which Part is every where 90 Degrees distant from the Horizon.

5 The *Horary Circle* is a small Circle of Brass, which is divided into twice 12 Hours: It is so fixed to the Brazen Meridian, that the Pole carries round the Hand which shews the Hour, and is the Center of the Circle: The Hours upon the East or graduated Side of the Meridian, are the Morning Hours, and these on the West Side are the Evening Hours.

6. A *Mariner's Compass* is sometimes placed on the Pedestal or Frame, in order that the North, South, East and West Points on the wooden Horizon, may point to those Parts of the Heavens.

7. The *Semicircle of Position* is a narrow thin Plate of pliable Brass, divided into 180 Degrees, and is exactly equal to half the Brazen Meridian, or it may be termed a double Quadrant of Altitude. It's Extremities are fixed to the North and South, so that it may be moved freely from the Horizon to the Meridian to any Position.

These Things we have described are without the Surface of each Globe. But on the Surfaces are the following Particulars delineated.

1. The *Equator* or *Equinoctial* Circle, or as Sailors term it, *the Line*, is that great Circle which lies in the Middle between the Poles. From this Line the Degrees of Latitude are counted towards each Pole. It divides the Globe into the Northern

and

and Southern Hemifpheres, and it is divided into 360 Degrees from ♈.

2 The Semicircles which extend from Pole to Pole, and cut the Equator at Right Angles are called *Meridians*. If 360 fuch Semicircles were drawn at equal Diftances quite round the Globe, they would mark out the Degrees, which are numbered upon the Equator, and are counted from the firft Meridian that ufually paffes through ♈.

The *Ecliptic* is a great Circle that cuts the Equator obliquely in the two oppofite Points ♈ and ♎, making with it an Angle of $23\frac{1}{2}$ Degrees; it is divided into 12 Signs each of 30 Degrees, in all 360. Thefe 12 Portions are called by 12 different Names, *viz.*

1. ♈ Aries, the *Ram*. 2. ♉ Taurus, the *Bull*. 3 ♊ Gemini, the *Twins*. 4. ♋ Cancer, the *Crab*. 5. ♌ Leo, the *Lion*. 6. ♍ Virgo, the *Virgin* 7. ♎ Libra, the *Ballance*, 8 ♏. Scorpio the *Scorpion*. 9. ♐ Sagittarius, *the Archer*. 10. ♑ Capricornus, *the Goat*. 11. ♒ Aquarius, *the Waterer*. 12. ♓ Pifces, *the Fifhes*.

On the Noon of every Day the Sun is on the Ecliptic, and paffes quite through it in a Year; therefore if the refpective Places of the Sun every Day at Noon, were united by Lines, the Whole would form the Ecliptic.

The apparent Motion of the Sun through the Ecliptic in a Year, is to be thus underftood. If at Noon one Day the Sun be in a certain Sign and

Degree of the Ecliptic; he from that Time till the Noon of the next Day, moves nearly parallel to the Equator, and then is found to have advanced about a Degree farther in the Ecliptic: When he quits this, he moves on nearly parallel to the Equator, and by the Noon of the next Day he is found ſtill to advance in the Ecliptic about a Degree farther, and ſo on every Day; conſtantly moving nearly but never exactly Parallel to the Equator; like a Screw that riſes or falls as it's Circumference is carried round.

4 The *Leſſer Circles are the* Tropics, and the *Polar Circles.* The two *Tropics* are each $23\frac{1}{2}$ Degrees diſtant on either Side of the Equator, and are parallel thereto. That on the North Side is called *the Tropic of Cancer*, to which the Sun is vertical at the Summer Solſtice, and paſſes through the Sign ♋ *Cancer.* That on the South Side is called the *Tropic of Capricorn*, towhich the Sun is vertical in our Winter Solſtice, and paſſes through the Sign ♑ *Capricornus.*

5. The two *Polar Circles* are parallel to the Tropics, each at $23\frac{1}{2}$ Diſtance from it's Pole. The Northern Polar Circle is called the *Artic Circle*, and the Southern one, the *Antartic Circle.*

The Parts we have thus far deſcribed are common to both Globes, and the following are peculiar to the Terreſtrial Globe only.

1. The Degrees upon the Brazen Meridian, which are numbered from the Equator 0, 10, 20, 30, &c. to 90 or to each Pole, are of uſe to determine the *Latitude of any Place*, or it's neareſt Diſtance from the Equator. And the Degrees

which

which are numbered from each Pole 0, 10, 20, 30, &c. to 90 or to the Equator, are of uſe to elevate the Pole to any Degree of Latitude. Hence it is plain that thoſe who live under the Equator only, have no Latitude. Thoſe that are neareſt to it have their Latitude leſs than thoſe that are farther off; and that no Place can have its Latitude more than 90 Degrees, as the Latitude of the Poles themſelves are but 90.

2. The 360 Degrees upon the Equator, which are uſually numbered from the Meridian which paſſes through ♈, and which is thence called the *Primary or the firſt Meridian*, are of uſe to determine the *Longitude of any Place*, or how many Degrees of the Equator, the Meridian of any Place is removed from the Primary Meridian. But this is the *old Method* of counting the Longitude.

The *new Method* is, to draw a Meridian through the Metropolis of the Kingdom, wherein the Globes are made; and from the Point where this interſects the Equator, the Equator is to be divided on either Side, or to the Eaſt and Weſt, to 180 Degrees, 'till the two 180's meet. On *Senex's* Globes, the Longitude is expreſſed according to the old Method, and it is alſo ſet out from a Meridian which paſſes through *London*, according to the new Method.

Hence 'tis plain, that all places which are under the Meridian from whence Longitude is reckoned, have no Longitude. That according to the old Way of counting, the Longitude is numbered with the Sun and never exceeds 360 Degrees.

That according to the new Way, if the Primary Meridian be ſet under the graduated Edge of the Brazen Meridian, that the Globe is then divided into two Hemiſpheres, termed the Eaſtern and Weſtern ones; in which Caſe the Longitudes of all Places are to be conſidered to be Eaſt or Weſt, as they lie on the one or on the other Side of this Meridian, and that the greateſt Longitude cannot exceed 180 Degrees.

If 360 the Degrees which go quite round the Equator, be divided by 24, the Hours in a Day and a Night, the Quotient 15 will ſhew, that the 24 Meridians called alſo *Hour Circles* which are uſually drawn on Globes, are to be at 15 Degrees aſunder; becauſe the Places through which each of them paſs, have Noon an Hour earlier than at 15 Degrees more Weſtward, and later at 15 Degrees more Eaſtward; and theſe 24 Meridians exactly correſpond with the 24 Hours on the Horary Circle.

Hence it is plain, that if we have the Longitudes of two places given, we may tell how much ſooner, or later, the one has the Sun upon it's Meridian than the other. Or if we have the Longitude of one Place and the Difference of Time between that and another Place, which is the *Difference of Longitude*, we may know the Longitude of the laſt Place.

3. *Parallels of Latitude* are all Circles on the Globe which run parallel to the Equator.

Becauſe the Meridians are wideſt aſunder at the Equinoctial, and that their Diſtance diminiſhes the more, as the Parallel is nearer to the Pole; it therefore

fore follows a Degree or any Number of Degrees of the Equator, muſt be leſs than a Degree or any like Number of Degrees in any parallel.

Of the Diviſions *of the* Earth.

The Surface of the Terreſtrial Globe admits of ſeveral Diviſions.

1. It is divided into five *Zones*, or Belts, which encompaſs it; and they bear their Names from their different Degrees of Heat. *viz.* One *Torrid Zone*, two *Temperate Zones*, and two *Frigid Zones*.

The *Torrid Zone* is contained between the two Tropics.

The *Temperate Zones* are contained between the Tropics and the Polar Circles, and the *Frigid Zones* are contained within the Polar Circles.

2. The Earth is divided into ſeveral Parts by *Climates*.

Climates are contained between Parallels of Latitude, drawn at ſuch a Diſtance from each other as that the longeſt Day at the leſſer Parallel, may exceed that at the next greateſt Parallel by half an Hour.

There are 24 *Climates* between the Equator and each Polar Circle, which become narrower as they approach the poles. And there are ſix other *Climates* from each Polar Circle to it's Pole, which exceed one another by a Month.

A TABLE *of the* CLIMATES.

Climates	From the Equator to the Polar Circles.		Climates	From the Equator to the Polar Circles.	
	Ends in Latitud.	*Where the longest D. is.*		*Ends in Latitud.*	*Where the longest D. is.*
	D M.	D. M.		M. D.	D. M.
1	08.25	12.30	17	64.06	20.30
2	16.25	13.00	18	64.49	21.00
3	23.50	13.30	19	65.21	21.30
4	30.20	14.00	20	65.47	22.00
5	36.28	14.30	21	66.06	22.30
6	41.22	15.00	22	66.20	23.00
7	45.29	15.30	23	66.28	23.30
8	49 01	16.00	24	66.31	24.00
9	51.58	16.30		From the Polar Circles to the Poles.	
10	54.27	17.00			Months.
11	56.37	17.30	1	67.30	1
12	58.29	18.00	2	69.30	2
13	59.58	18.30	3	73.20	3
14	61.18	19.00	4	78.20	4
15	62.25	19.30	5	84.00	5
16	63.22	20.00	6	90.00	6

3 With reſpect to the Horizon; ſome have the Poles in the Horizon, others have their Poles in the Zenith and Nadir; and again others have their Poles between the Horizon and the Zenith and Nadir.

Such

Such as have their Poles in the Horizon, are ſaid to be in a *Right Sphere*, becauſe the Equator and all the Parallels are perpendicular to the Horizon, or cut it at Right Angles. The Inhabitants under the Equator are thoſe to whom this Sphere or Poſition of the Globe, is only peculiar, where the Sun and Stars always riſe and ſet perpendicularly, and where they have equal Day and Night throughout the whole Year.

Such as have their Poles in the Zenith and Nadir, are ſaid to be in a *Parallel Sphere*, becauſe the Equator and all the Parallels are then parallel to the Horizon. The Inhabitants (if any) who are under the Poles, this Sphere is only peculiar to; where they have but one Day and one Night in a Year.

Such as have their Poles obliquely ſituated, or whoſe Poles lie between the Horizon and the Zenith and Nadir, are ſaid to be in an *Oblique Sphere*, becauſe the Equator and the Parallels cut the Horizon obliquely. The Inhabitants of this Sphere are they who live on all Parts of the Earth, except under the Equator, or Poles; and their Pole muſt neceſſarily be elevated as much above the Horizon, as is the Latitude of the Place, in order that the Place may be in the Zenith, and that it's Inhabitants may have the Horizon quite round them; as the Inhabitants at every Place on the Earth have.

4. The Inhabitants of the Earth are divided with reſpect of one another into *Antœci*, *Periæci*, and *Antipodes*.

Thoſe

Thoſe who live on contrary Sides of the Equator, having their Latitudes equal, and who are under the ſame Meridian, or who have the ſame Degree of Longitude are called *Antæci*. The Hour is conſtantly the ſame in both, but the Seaſons of the Year are contrary.

Thoſe who are in the ſame Latitude, but in oppoſite Meridians or whoſe Longitudes differ 180 Degrees, are called *Periæci*. Their Seaſons of the Year are the ſame, but their Days and Nights are contrary.

Thoſe who live in oppoſite Parallels and Meridians are called *Antipodes*. Their Days, Nights, and Seaſons, are all contrary to one another.

5. The *Natural Diviſion* of the Earth, is that which Nature has made by Land and Water; The Land being divided into *Continents*, *Iſlands*, *Peninſulas*, *Iſthmus's*, *Promontories*, *Mountains*, &c. and the Water is diſtinguiſhed into *Oceans*, *Seas*, *Gulphs*, *Straits*, *Lakes*, *Rivers*, &c.

A *Continent* is a large Tract of Land containing ſeveral Countries, Kingdoms, and States, without having any of it's Parts ſeperated by Water.

An *Iſland* is a Tract of Land every where ſurrounded with Water.

A *Peninſula* is a Tract of Land which extends itſelf into the Sea, and is every where ſurrounded with Water, but in a narrow Neck, which joins it to the Continent. And that narrow Neck is called an *Iſthmus*.

A *Promontory* is a *Cape* or *Head-Land* which ſhoots it ſelf into the Sea.

A *Moun-*

A *Mountain* is a high riſing Ground or Eminence, which overlooks the adjacent Country.

The *Ocean* is properly that general Collection of Water, which waſhes the ſeveral Parts of the Land and Continent.

A *Sea* is a Part of the Ocean interrupted by divers Iſlands, and nearly environed with Land.

A *Gulph* is nearly the ſame Portion of the Sea, as a *Peninſula* is of Land.

A *Strait* called ſometimes a *Channel*, is an open narrow Paſſage between any two Shores.

A *Lake* is a Collection of Waters ſurrounded with Land, which has no viſible Communication with the Sea.

A *Creek* is a narrow Part, or Arm of the Sea running a little Way into the Land.

A *Bay* is a much larger Inlet, and more ſafe and capacious for Ships to Anchor in.

A *River* is a conſiderable Stream of freſh Water iſſuing from one or many Fountains, which uniting with what tricles from the Sides of Hills, forms it ſelf into one or more Channels through which it paſſes, till it is diſcharged into the Sea.

There is another Diviſion of the Earth called the *Political Diviſion* which is made by Men, who have diſtinguiſhed it into four Parts or *Quarters*; and thoſe again into *Empires*, *Kingdoms*, *States*, *Republics*, *Principalities*, *Provinces*, *Pariſhes*, &c. for a particular Deſcription of which we refer to Mr. *Gordon*'s, or to Mr. *Salmon*'s Geographical Grammers, or to larger Syſtems.

The Use of the

Terrestrial GLOBE.

PROBLEM I.

To find the Latitude and Longitude of any given Place upon the Globe.

BRING the given Place to the graduated Edge of the Brazen Meridian; then the Degree of the Meridian that is over the given Place, will ſhew it's Latitude; and the Degree of the Equator which is at that Time under the Meridian, will be the Longitude of the Place.

PROB. II.

The Latitude aud Longitude of a Place given, to find that Place upon the Globe.

Bring the given Longitude to the Brazen Meridian, and holding the Globe ſteady, find the given Degree of Latitude upon the Meridian; and the Place which lies under it, is that required.

PROB. III.

The Latitude of a Place being given, to find all Places on the Globe that are in the ſame Latitude.

With

With a Chalk, mark the Degree of Latitude upon the Brazen Meridian; and turning the Globe quite round, obſerve what Places paſs under the Chalk; for thoſe are they which have the ſame Latitude with the given Place.

PROB. IV.

To find the Diſtance between any two Places on the Globe.

Lay the Quadrant of Altitude on both Places; or take their Diſtance with a pair of Compaſſes and apply it to the Equator. The Number of Degrees between them counted on the Quadrant, or that is between the Feet of the Compaſſes on the Equator, will be the required Diſtance in Degrees, which multiplied by 70, the Miles in a Degree, ſhews their Diſtance in Miles.

PROB. V.

To find the Antæci, Periæci, *and* Antipodes, *of any given Place on the Globe.*

Bring the given Place to the Brazen Meridian; and having found it's Latitude, count the ſame Latitude on the Meridian towards the contrary Pole, and the Place under that Latitude will be that of the *Antæci*.

Keep the given Place to the Brazen Meridian, and ſet the Hour Index at the upper 12 or at Noon; and marking with Chalk the Latitude on the Meridian, turn the Globe about, till the Hour Index points to 12 at Night; then the Place under the chalked Mark, will be that of the *Periœci*.

Keep the Globe now ſtayed, and count the ſame Latitude or that at the Chalk, to the contrary Pole; the Place under that Latitude, will be that of the *Antipodes*.

PROB. VI.

A Place and the Hour being given at that Place; to find thoſe Places of the Globe, where it is then either Noon, or Midnight.

Bring the Place to the graduated Side of the Brazen Meridian; fix the Hour Index to the given Hour, and turn the Globe about till the Index points at the upper 12, or to 12 at Noon: Then all thoſe Places which are under that Semicircle of the Meridian to which the Index points, have the Sun in their Meridian, or have their Noon at that particular Time; and thoſe who are under the oppoſite Semicircle of the Meridian, have then Midnight.

PROB. VII.

A Place, and the Hour at that Place being given; to find what Hour it then is at any other given Place.

Bring the firſt Place to the graduated Side of the Brazen Meridian, and ſet the Hour Index to the

the given Hour; then turn the Globe till the other Place comes to the Meridian, and the Index will point to the Hour required.

PROB. VIII.

Any Place being given, to move the Globe, ſo as that Place may be in the Zenith, or that the wooden Horizon ſhall be an Horizon to the ſame,

Bring the given Place to the Brazen Meridian; and having found it's Latitude, elevate the Pole, or count from it the ſame towards the Equator, and fix that Degree to the Notch of the wooden Horizon: The given Place will then be in the Zenith, and the wooden Horizon will be an Horizon to it.

PROB. IX.

The Latitude of a Place being given, to find the Hour of the Day by the Globe when the Sun ſhines.

With a Mariners Compaſs, ſet the Brazen Meridian due North and South, which is done by cauſing the North Part of the Meridian to point about 19 Degrees to the Eaſt of the *Flower de Luce*; for ſo much now the Needle varies from pointing truly North and South.

This being done, and Care being taken to have the Globe ſet on a due Horizontal Plane.

In

In the Summer half Year, or from the 20th of *March* to the 23d of *September*, elevate the Pole to the Latitude.

But in the Winter half Year, or from the 23d of *September* to the 20th Day of *March*, depress the same Pole as much below the opposite Part of the Horizon; and then the Shadow of the Axis of the Globe on the Hour Circle, will shew the Hour of the Day.

PROB. X.

The Month and Day being given, to find the Sun's Place on the Ecliptic,

Upon the wooden Horizon find the Month and Day, in the *Julian* or *Gregorian* Kalender, as Occasion requires; opposite to which in the inward Circle you have the Sign and Degree of the Sun's Place. Then find that Sign and Degree on the Ecliptic; and a Mark of Chalk being there made, or a very small Bit of Paper being wet and stuck thereon, will shew the Place of the Sun for the given Time.

PROB. XI.

To find how one Place beareth from another.

By Prob 8. Move the Globe so as that one Place may be in the Zenith: Screw the Quadrant of Altitude on the Meridian over that Place, and staying the Globe, move the said Quadrant till it's it's graduated Edge be brought to paſs over the other Place, then that Point of the Compaſs on the wooden Horizon which is oppoſite to that Edge, will be the Point that the ſecond Place beareth from the firſt.

PROB. XII.

The Day of the Month in any Place whoſe Latitude is leſs than 66½ Degrees, being given, to find the Time of the Sun's riſing and ſetting, and the Length of the Day and Night.

Elevate the Globe to the given Latitude; and having found the Sun's Place in the Ecliptic for the given Day, bring it to the Meridian, and ſet the Hour Index to the upper 12. Then bring the Sun's Place to the Eaſt Side of the Horizon, and the Hour Index will point to the Time the Sun riſes; and if it be brought to the Weſt Side of the Horizon, the Index will point to the Time of ſetting.

The Sun's ſetting being doubled, will give the Length of the Day; and the Sun's riſing being doubled, will give the Length of the Night.

Hence it is eaſy to find the Length of the longeſt and ſhorteſt Day in any Place, whoſe Latitude is leſs than 66½ Degrees. For if in the firſt Caſe a Mark for the Sun be put on ♋ *Cancer*, and in the ſecond on ♑ *Capricornus*; ſince in theſe Places the Sun is, on the longeſt and ſhorteſt Days: The riſing and ſetting of the Sun, may be eaſily had as above

above, as well as the Length of the Day and Night.

PROB. XIII.

The Day and Hour at any Place being given to find where the Sun is vertical, or in the Zenith *at that Hour.*

Bring the Sun's Place to the Meridian, over which, mark the Degree with Chalk. Then bring the given Place to the Meridian, and ſet the Index to the given Hour, and turn the Globe till the Index points to 12 at Noon: The Place which is then under the chalked Mark, will be that to which the Sun will be then in the Zenith.

PROB. XIV.

A Place being given in the Torrid Zone, *to find thoſe two Days of the Year, in which the Sun ſhall be* vertical *to the ſame, at* 12 *at Noon.*

Bring the given Place to the Meridian, and with Chalk mark the Degree of Latitude that is above it. Move the Globe till two Points in different Parts of the Ecliptic paſs directly under the Mark; and having noted theſe Points, and found the Sign and Degree of each; then upon the wooden Horizon, find the Days of the Month, which are oppoſite to each Sign and Degree reſpectively; and thoſe will be the Days required.

PROB.

PROB. XV.

The Day and Hour being given to find all those Places of the Earth, where the Sun is rising, setting, *or* culminating; *and also where it is* Day-light, Twilight, *or* Dark-night.

By Prob. XIII. Find the Place where the Sun is vertical at the given Hour; elevate the Globe to the Latitude of that Place, and bring it to the Meridian. Then all Places that are in the West Semicircle of the Horizon, have the Sun *rising*; those in the East Semicircle have it *setting*; those under the Meridian, above the Horizon, have it culminating; and all Places above the Horizon have the Sun so many Degrees above the Horizon as the Places themselves are. Those Places that are below the Horizon, but within 18 Degrees of it, have *Twilight*; and those lower than 18 Degrees have *Dark-Night.*

PROB. XVI.

A Place, Day and Hour being given, to find the Sun's Height at that Hour

Elevate the Globe to the Latitude of the Place, screw the Quadrant to said Latitude on the Meridian, bring the Sun's Place on the Ecliptic to the Meridian, and set the Index of the Hour-Circle to 12 at Noon; then turn the Globe about untill the Index points to the given Hour, and staying it there, bring the Edge of the Quadrant to the Sun, and it will point out it's Height which was required.

PROB. XVII.

A Place, Day of the Month, and Sun's Height being given, to find the Hour of the Day.

Elevate the Globe, ſcrew the Quadrant to the Latitude, bring the Sun's Place to the Meridian, and ſet the Hour Index to 12 at Noon; then move the Globe and Quadrant together, ſo that the Sun's Place on the Ecliptic may correſpond with the given Height on the Quadrant; the Hour then pointed to by the Index, will be that required.

PROB. XVIII.

To find the Time when the Sun begins to appear above the Horizon, and when it begins to diſappear, and alſo the Length of the longeſt Day or Night, in any Place within the Polar Circles, or whoſe Latitude is more than 66½ Degrees.

Subtract the Latitude of the given Place from 90, and with a Chalk mark upon the Meridian the remaining Degrees both above and below the Equator: Then move the Globe till two Points of the Ecliptic come directly under the upper Chalk Mark, and having noted theſe Points, and found the Sign and Degree of each in the Order of the Signs, find the Days of the Month correſ-

ponding

ponding with thofe Places of the Sun upon the wooden Horizon; the firft of thefe will be the Day the Sun begins to appear above the Horizon, and the other the Day it begins to difappear, and confequently the Length of their longeft Day will be the Time intercepted between the firft and the laft of thefe Days.

The Length of the longeft Night is every where equal to the Length of the longeft Day, and the Beginning and End of the longeft Night may be found in the fame Manner that the Beginning and End of the Day was by ufing the lower Chalk Mark inftead of the upper.

PROB. XIX.

A Place, and the Day of the Month being given, to find the Beginning, End, and Duration of Twilight, and of dark Night.

Elevate the Globe to the given Latitude, and fcrew the Quadrant of Altitude to that Latitude on the Meridian, bring the Sun's Place to the Meridian, and fet the Index of the Hour Circle to 12 at Noon; then bring the Point which is oppofite to the Suns Place to cut 18 Degrees of the Quadrant on the Weftern and Eaftern Sides of the Meridian, and the Index will fhew when the Twilight begins or ends.

The Time of the Beginning of Twilight being taken from the Time of the Sun's rifing, leaves the Duration of Twilight, and the Time when

Twilight begins being doubled, gives the Length of dark Night.

PROB. XX.

The Diſtance between two Places lying under the ſame Meridian being given, as alſo their reſpective bearing from a third Place, to find thereby that Place with it's due Diſtance from the other two.

Mark the Latitudes of the given Places on the Meridian with Chalk, and keeping them under the ſaid Marks, elevate the Globe to the Latitude of the upper Mark, and fixing the Quadrant of Altitude on ſaid Mark, move it to that Point of the Compaſs, upon which the third Place bears from it, and make a ſmall Track with Chalk upon the Globe by the Edge of the Quadrant. Then elevate the Globe to the Latitude of the lower Mark, and ſcrew the Quadrant of Altitude to that Latitude, and turn the ſaid Quadrant to that Point of the Compaſs upon which the third Place bears from it, and obſerve where the Quadrants Edge interſects the Tract of Chalk, and that will be the third Place required.

Concerning the

Celeſtial GLOBE.

THE Celeſtial Globe is ſuppoſed to comprehend the Terreſtrial one in it's Center. If we imagine the Surface of the Celeſtial Globe were made of Glaſs, and that the Stars were drawn upon it, then a Spectator from the Terreſtial Globe would ſee the Stars form in a Concave Surface, juſt as that in the Heavens. The Circles and Points which are peculiar to the Celeſtial Globe are theſe.

1. The *Zodiac* is a Hoop or Belt round the Heavens of about 16 Degrees broad, through the Middle of which the Ecliptic or the Sun's annual Path paſſes.

The *Signs of the Zodiac* are the fixed Stars, which are contained in this Belt, and which for Diſtiction ſake are thrown into 12 Conſtellations or Aſteriſms, and are called *Aries*, *Taurus*, &c.

2. The Meridians which paſs through *Aries* and *Libra*, and through *Cancer* and *Capricorn*, form two great Circles called *Colures*; the firſt of which is called the *Equinoctial Colure*, and the other the *Solſticial Colure*.

3 The Points *Aries* and *Libra* are called the *Equinoctial Points*, becauſe when the Sun is in either of them, the Day and Night is every where equal.

4. The

4. The Points *Cancer* and *Capricorn* are called the *Solsticial Points*, becauſe when the Sun is in either of them, he ſeems to ſtand ſtill for ſeveral Days. When he is in the Solſticial Point *Cancer* he then makes the longeſt Day, and when in the other, the ſhorteſt, to all the Inhabitants of the Northern Hemiſphere.

5. That Point in the Heavens which is juſt over our Head is called the *Zenith*, and the Point oppoſite to it is called the *Nadir*, and theſe are the Poles of the Horizon.

Imaginary Circles paſſing through the *Zenith*, and *Nadir*, and cutting the Horizon at right Angles, are called *Vertical* or *Azimuth Circles.* And the *Azimuth* of the Sun, or a Star is an Arch of the Horizon intercepted between the Meridian, or South Point of the Heavens, and an Azimuth Circle paſſing through either: Sometimes the Azimuth is reckoned from any other of the Cardinal Points.

When the Azimuth is counted from the Eaſt or Weſt to the Sun or a Star at the Time of its riſing or ſetting, it is then called it's *Amplitude.*

6. The *Meridian Altitude* of the Sun, is it's Height above the Horizon at Noon, and when he arrives to that Height, he is ſaid to *Culminate.*

Almicantars, or *Parallels of Altitude*, are imaginary Circles drawn parallel to the Horizon, through every Degree of the vertical Circles.

7. The Poles of the Ecliptic are two Points of the Solſticial Colure, which are 23½ Degrees from the Poles of the World.

8 Great

8. Great Circles paſſing through the Poles of the Ecliptic and cutting it at right Angles, are called Circles of Longitude; and if we imagine other Circles to be drawn parallel to the Ecliptic through every Degree of the Circles of Longitude, theſe will be *Parallels of Latitude* on the Celeſtial Globe; for Longitude and Latitude on the Celeſtial Globe, bear juſt the ſame Relation to the Ecliptic, as they do on the Terreſtrial Globe to the Equator. Thus, as the Longitude of Places on the Earth, is meaſured from the firſt Meridian upon the Equator; ſo the Longitude of the Heavenly Bodies is meaſured upon the Ecliptic from the firſt Circle of Longitude, which paſſes through Aries. And as Latitude on the Earth is counted from the Equator upon the Meridian, ſo the Latitude of the Heavenly Bodies is meaſured by Degrees upon a Circle of Longitude counting either North or South from the Ecliptic.

9. The Diſtance of any Heavenly Body from the Equinoctial meaſured upon the Meridian, is called it's Declination; therefore all Parallels of Declination on the Celeſtial Globe are the very ſame as Parallels of Latitude on the Terreſtrial. What is called Longitude on the Terreſtrial Globe, is called *Right Aſcenſion* on the Celeſtial. *viz.* The Sun or a Star's Diſtance from the firſt Meridian, or that paſſing through Aries counted upon the Equinoctial.

Oblique Aſcenſion and *Deſcenſion* is the Diſtance of that Point of the Equinoctial from the firſt of Aries, which in an oblique Sphere riſes or ſets at the ſame Time that the Sun or Star riſes or ſets.

Aſcenſional

Ascensional Difference is the Difference between right and oblique Ascension; and this turned into Time, by allowing fifteen Degrees for every Hour will shew how much the Heavenly Body rises before or after six o'Clock.

The visible Hemisphere of Stars, is continually changing in a right or oblique Sphere, by Reason of the Suns apparent Motion round the Ecliptic in a Year.

When the Sun gets so near a Star as to hide it in his Beams, it is said to set *Heliacally*, and when after it's Conjunction with the Sun, it becomes again visible, it is said to rise *Heliacally*.

A Star that rises or sets when the Sun rises or sets, is said to rise or set *Cosmically*.

A Star that rises or sets in the Evening when the Sun sets, is said to rise or set *Achronically*.

Of the Divisions of the Heavens, and the Constellations.

Astronomers have divided the Stars into six Classes or Magnitudes, and the Stars of each Magnitude are distinguished by different Marks on the Celestial Globe.

They have also distinguished the Stars into several *Constellations* or *Asterisms*, to which they have given Names; Some have the Names of Men, and others the Names of Beasts, Birds, and several other Things. The Images of those Animals and other Things, from whence the Names of the Constellations are taken, are drawn upon the Celestial

leſtial Globe over the ſeveral Parcels of Stars which are called by thoſe reſpective Names.

The Conſtellations are divided into *Northern* and *Southern*, beſides the twelve Signs of the *Zodiac* which lie in the Middle between them.

The Antients formed the Northern Regions into twenty one Conſtellations *viz.* *Urſa Minor* or the little Bear; *Urſa Major*, the great Bear; *Draco*, the Dragon; *Cepheus*; *Caſſiopeia*; *Andromeda*; *Triangulum*, the Triangle; *Perſeus*, with *Meduſa*'s Head; *Auriga*; *Bootes*; *Corona Septentrionalis*, the Northern Crown; *Hercules*; *Lyra*, the Harp; *Cygnus*, the Swan; *Pegaſus* the flying Horſe; *Equiculus* the littleHorſe's Head ;*Delphinus* the Dolphini; *Sagitta*, the Arrow; *Aquila*, the Eagle or Vultur; *Serpens*, the Serpent; and *Serpentarius*, the Man who holds it.

To theſe the Moderns have added *Antonius* near the Eagle; *Coma Berenices*, or Berenice's Hair, near the Lion's Tail; *Leo Minor*, the little Lion, between the great Bear and the Lion, *&c.*

The Antients formed the Southern Regions into 15 Conſtellations, *viz.* *Cetus*, the Whale; the River *Eridanus*; *Lepus*, the Hare; *Orion*, the moſt glorious Conſtellation of all; *Canis major*, the great Dog; *Canicula*, the little Dog: *Argo Navis*, the Ship Argo; *Hydra*, the Water Serpent; *Crater*, the Cup; *Corvus* the Crow; *Centaurus*, the Centaur; *Lupus*, the Wolf; *Corona Auſtralis*, the Southern Crown; *Ara*, the Altar; and *Piſcis Auſtralis*, the Southern Fiſh.

To theſe the Moderns have added twelve Conſtellations more, which lie ſo near the South Pole that they cannot be ſeen by us.

The odd Stars, which are ſcattered here and there between the Conſtellations, are called *unformed Stars.*

Some remarkable Parcels of Stars have obtained Names beſides thoſe given to the Conſtellations which contain them, as the *Pleiades* or ſeven Stars in the Conſtellation *Taurus*; *Charles*'s *Wain* or *Waggon* conſiſts of ſeven large bright Stars in the hinder part of the *great Bear*: The three in the Tail are ſuppoſed to repreſent the Horſes and the other four the Wain. The two hindermoſt Stars in the Wain are called the *Pointers*, becauſe they point to the North Star, which is in the Tip of the Tail of the little Bear, that is, a Line drawn through the Pointers if continued, will nearly touch the Pole Star. Several ſingle Stars of the firſt or ſecond Magnitude have Names given them; as *Sirius*, in the great Dog; *Aldebaran*, or the Bull's Eye; *Procyon*, in the little Dog; *Arcturus*, in Bootes; *Regel*, in Orion; *the Lion*'s *Heart*; and *Deneb*, in his Tail; *Spica Virginis*, or the Ear of Corn in the Virgin's Hand; *Caſtor and Pollux*, in the Conſtellation *Gemini*; and many others.

The *Galaxy*, *Via Lactea* or milky Way, is a broad irregular whitiſh Tract in ſome Places double but for the moſt Part ſingle, ſurrounding the whole Heavens. It's bright Appearance is owing to an innumerable Multitude of Stars, which lie quite through it, whoſe united Rays of Light occaſion the ſhining Whiteneſs. The modern Aſtronomers ſince the Invention of Teleſcopes, have diſcovered an innumerable Multitude of Stars, in thoſe Parts which appear only white to the naked

Eye

Eye; and to the ſame Cauſe may be aſcribed other bright Spots, which lie here and there in the Heavens, as the *Præſepe* or Aſſes and Manger in the Conſtellation *Cancer*.

A Connection between the ſeveral Parcels of Stars, which form the Conſtellations, and the Figures after which they are named, can hardly be diſcovered in the Conſtellations themſelves, except in a very few of them, as *Charles*'s *Wain* may be ſuppoſed to reſemble a Waggon and three Horſes; but a very ſtrong Imagination would find it difficult to diſcover any ſuch natural Reſemblance between the Bulk of the Conſtellations, and the Figures they are named by.

The Author of *Spectacle de la Nature* Vol. I. conceives it probable that the Conſtellations in the Zodiac, were formed and named by the *Egyptians*, who dealt in Hieroglyphics or myſtic Figures by which they expreſſed the Doctrines and Secrets of their Religion, Philoſophy and Politics. Thus, a *Lion* was the Hieroglyphic of Strength and Fortitude; a *Horſe* of Liberty, a *Circle* of Eternity, *&c.* now this Author imagines that the 12 Signs of the Zodiac were ſuch Egyptian Hieroglyphics, by which they deſigned to expreſs or repreſent ſome remarkable natural Occurrence in each Month of the Year, as the Sun was paſſing through the reſpective Conſtellations.

The firſt three Months, beginning from the vernal Equinox were remarkable for the Production of thoſe Animals, which they moſt uſed and valued, *viz. Sheep*, *Kine* and *Goats*. The *Lambs* which come firſt are repreſented by their Parent the *Ram*;

the *Calves* which come next are repreſented by the *Bull*; and then the *Kids*, which commonly come in Pairs, therefore gave a Name to the third Conſtellation. But inſtead of the *twin Kids*, the *Greeks* have ſubſtituted the *twin Brothers Caſtor and Pollux*.

In the fourth Month, the Sun having arrived at the Summer Solſtice, diſcontinues his Progreſs towards the North, begins now to go back again to the South, this retrograde Motion the *Egyptians* expreſſed by the *Crab*, which is ſaid to go backward.

The exceſſive Heat that uſually attends the fifth Month is expreſſed by the *Lion*, an Animal remarkable for his Strength and Fierceneſs.

The ſixth or the Harveſt Month is repreſented by the *Virgin Reaper*, *or Gleanor* with an Ear of Corn in her Hand.

The ſeventh Month, their Sun arrives at the autumnal Equinox, when the Days and Nights are every where equal, and is therefore expreſſed by the *Ballance*, or Scales in Equilibrio.

October is repreſented by the *Scorpion*, with a Sting in his Tail, becauſe it is often a ſickly Seaſon, occaſioned by the Surfeits got in the hot Summer Months.

November being the hunting Seaſon, is repreſented by the *Sagittary* or *Archer*.

As the *Crab* repreſents the backward Motion of the Sun after the Summer Solſtice, ſo in *December*, the *Goat* which delights to browſe up Hill, repreſents the Winter Solſtice, becauſe after it, the Sun begins then to aſcend or to ſtretch to the Northward.

January

January is reprefented by *Aquarius* or the *Waterer*, fignifying the Rains and Snows of the Winter Seafons; and *February* is reprefented by the *two Fifhes in a Band*, becaufe this is the prime fifhing Seafon in the Year.

As for the reft of the Conftellations which are out of the Zodiac, the Bulk of them were formed by the *Grecians*, who imitated the *Egyptians* in giving the Names of Men, Animals and other Things, to Parcels of Stars; but without any fuch particular Reafons as the Egyptians had, for naming the 12 Signs of the Zodiac.

The

The Use of the

Celestial GLOBE.

PROBLEM I.

To find the right Ascension and Declination of any Star.

BRING the Star to the graduated Edge of the Brazen Meridian, and the Degree over it will be it's Declination; then observe the Degree of the Equinoctial that is at the same Time under the graduated Edge of the Meridian, and that will be its right Ascension.

PROB. II.

To find the Latitude and Longitude of any Star.

Bring the Pole of the Ecliptic to the graduated Edge of the Meridian, over which screw the Quadrant of Altitude and elevate the Globe to 66½ Degrees or to the Distance of the Polar Circles from the Equator, and then the Ecliptic will coincide with the Horizon: Stay the Globe in this Position and turn the Edge of the Quadrant of Altitude to the Star; then the Degree on the Quadrant which meets the Star, will be it's Latitude, and the

the Degree on the Ecliptic which is cut by the Edge of the Quadrant is the Degree of it's Longitude.

PROB. III.

To find the rising and setting of any Star for any given Time and Place.

Elevate the Globe to the Latitude of the Place, find the Sun's Place for the given Day on the Ecliptic, and bring it to the graduated Edge of the Brazen Meridian, and put the Index of the Hour Circle to 12 at Noon: Then bring the Star to the East Part of the Horizon and the Index will shew the Time of it's Rising and it will tell the Setting, if the Star be brought to the West Part of the Horizon.

N. B. In like Manner the Rising and Setting of any Planet may be found, by putting a small Bit of Paper to represent it's Place in the Ecliptic, which may be known at any Time by an *Ephemeris*.

PROB. IV.

How to distinguish one Star from another, and to know the Situation of the Heavens for any given Time.

Elevate the Globe to the Latitude of the Place you are in, and having marked the Sun, Moon, and Planets on small Bits of Paper, stick them in their respective Places on the Ecliptic; bring the

Sun

Sun to the Meridian and ſet the Index of the Hour Circle to 12 at Noon, and ſet the Meridian of the Globe due North and South by the Compaſs.

Then turn the Globe till the Index Points to the Hour of the Night, at which you make your Obſervation, and every Star and Planet, which is then above the Horizon, will coincide with it's Original in the Heavens: For if Lines drawn from the Center of the Globe to every Star on it's Surface, were continued to the Heavens, each would paſs through it's Original; or if the Globe were tranſparent, and the Obſerver's Eye in it's Center, every Star on the Globe would cover it's real Star in the Heavens. So that by learning the Names given them on the Globe, you may by Degrees become ſo well acquainted with the Heavens, as to be able to tell at any Time, what Stars they are that lie here or there.

PROB. V.

The Place and Day being given, to find the Sun or Stars Eaſtern or Weſtern Amplitude, oblique Aſcenſion and Deſcenſion, aſcenſional Difference, and Semidiurnal Arch.

Elevate for the Latitude, and bring the Sun's Place or the Star to the Eaſt or Weſt Part of the Horizon; then the Arch between it, and the Eaſt or Weſt Point of the Horizon ſhews it's Eaſtern and Weſtern *Amplitude.* The Degree of the Equinoctial, where it cuts the Horizon ſhews the *oblique Aſcenſion* or *Deſcenſion*; and the Difference between the

the right and oblique Aſcenſion (or if it be of the Sun, the Difference between the Hour which the Index points to,and Six) is the aſcenſionalDifference, which being converted into Time, and added to Six, when the Sun or Star declines towards the elevated Pole, *i. e.* in Northern Latitude, when it is North Declination, or ſubtracted from Six when it declines towards the depreſſed Pole, gives half the Time of its Stay above the Horizon; which when we ſpeak of the Sun, is called the *ſemidiurnal Arch.* The Conpliment of the ſemidiurnal Arch to 12, gives the *ſeminocturnal Arch* or half the Time of it's Stay below the Horizon. The Sun's ſemidiurnal Arch computed from Noon, gives the Time of it's ſetting, and his ſeminocturnal Arch computed from Midnight, gives the Time of his riſing.

PROB. VI.

The Latitude and Sun's Place being known, and if either the Hour of the Day, or the Altitude, or Azimuth of the Sun or Star be given, to find the other two.

Elevate for the Latitude, bring the Sun's Place to the Meridian, fix the Index of the Hour Circle to 12 at Noon, and ſcrew the Quadrant of Altitude to the Latitude; then,

1ſt. If the *Hour* be given, turn the Globe till the Index points to it, and bring the Quadrant of Altitude to the Place of the Sun or Star; then will its graduated Edge ſhew the Degree of Altitude, and the Degree of the Horizon where the Quadrant cuts it, ſhews the Sun's Azimuth or Bearing.

2d. If the *Altitude* be given, bring the Sun or Stars Place to meet with the Quadrant at the given Altitude, then the Index will Point to the Hour, and the Interſection of the Quadrant and Horizon will ſhew the Azimuth.

3. If the *Azimuth* be given, bring the Quadrant to interſect the Horizon at the given Azimuth; then by turning the Globe, bring the Sun's Place or Star to the graduated Edge of the Quadrant, and the Degree of the Quadrant where they meet ſhews the Altitude, and the Index points to the Hour.

Hence if the Altitude and Azimuth of any Star be found by Obſervation, it will be eaſy to find that Star on the Globe; and by taking the Altitude and Azimuth of any Star on the Globe at a given Hour, the Star may be found in the Heavens.

PROB. VII.

The Latitude of a Place being given, to find the Coſmical riſing and ſetting of any given Star.

For the Riſing.

Elevate for the Latitude, and bring the Star to the Eaſtern Part of the Horizon: See what Degree of the Ecliptic is then riſing, and anſwering to that Degree in the Kalendar on the Horizon, you will find the Day required.

For

For the Setting.

Elevate as before, bring the given Star to the Weſtern Part of the Horizon, then obſerve what Degree of the Ecliptic is riſing to the Eaſt, and over againſt it as before, the Day may be found. Thus, Latitude $53\frac{1}{2}$ N *Sirius* riſes Coſmically; the 13th of *Auguſt*, and ſets Coſmically the 12th of *November*.

PROB. VIII.

The Latitude of a Place being given to find the Archronical Riſing or Setting of any Star.

For the Riſing

Elevate for the Latitude, bring the given Star to the Eaſtern Part of the Horizon; then ſee what Degree of the Ecliptic is cut by the Weſtern Part of the Horizon, the Day anſwering to that Degree will be the Day required.

For the Setting.

Elevate as before, bring the Star to the Weſtern Part of the Horizon, and ſee what Degree of the Ecliptic is then ſetting, and oppoſite to it in the Kalendar, you will have the Day required. Thus, *Sirius* riſes Achronically the 9th of *February*, and ſets the 11th of *May*.

PROB. IX.

The Day of the Month being given, to find when any Star will come to the Meridian.

Elevate for the Latitude, bring the Sun's Place to the Meridian, and put the Hour Index to 12 at Noon, then turn the Globe till the given Star come to the Meridian, and the Index will point to the Time required.

PROB. X.

To find when a given Star will come to the Meridian at any given Hour of the Night.

Bring the given Star to the Meridian, ſet the Index at 12 at Noon, then turn the Globe Eaſtward till the Index points to an Hour, that is far before 12 in the Forenoon, as the given Hour is after 12 in the Afternoon; obſerve the Degree of the Ecliptic then at the Meridian, over againſt which in the Kalendar is the Day of the Month when the given Star will be upon the Meridian at the given Hour.

Many more Problems might be inſerted upon this Head, but theſe will be found to be ſo far ſufficient, that if a Perſon is Maſter of them, he will readily be able to work any he may meet with in other Authors.

FINIS.

Remember thy Creator in the Days of
thy youth

Georgina Maria

Teresa Catherine

Mary Martha

Remember or

Remember

Teem thou ash

Zaharia — Ivan
Georgeni

Eliza Butler
Catherine Butler
Jane Butler
Anna Butler
Maria Butler
George Butler
James Butler
Margret Butler

Catherine Wheeler

Eliz [illegible]

[illegible]